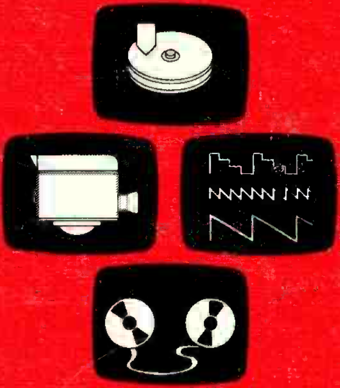
TELEVISION BROADCASTING

Tape and Disc Recording Systems

by Harold E. Ennes



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Preface

Since the first television tape recorder was introduced in 1956, there has been phenomenal growth in the use of video magnetic tape by telecasters and independent production centers. It is difficult for the "old-timer" to realize that many of his fellow workers do not remember the days before tape, when practically two-thirds of the nation watched tv programs at odd hours or from "hot kines" that had little resemblance to modern recordings. Video tape, from the very start, provided superior picture quality, giving a presence that cannot be matched by film. In addition, this medium provided the telecaster, for the first time, with a capability for local spot-commercial and program production well within the means of a modest budget.

In spite of (or because of) the rapid growth, students and practicing engineers have been faced with a scarcity of information relative to basic recording systems. Having been privileged to attend training seminars at both Ampex and RCA, as well as having had considerable practical experience with each system, the author has undertaken to fill this need. The primary purpose of this book is to provide fundamental knowledge for the practicing engineer who feels the need for a beter understanding of his equipment; this information may also serve as an introduction to the subject for the beginner.

Specific circuitry will undoubtedly change in the future as it has in the past. Therefore, this coverage is general in nature, pointing up the primary functions of video-tape equipment. The scope of coverage is from basic theory to testing and maintenance of complete systems.

This text assumes a background in basic electronics theory. The reader should also have a fundamental grasp of semiconductor logic circuitry, at least of the same level as that presented in Chapter 3 of *Television Broadcasting: Systems Maintenance* by Harold E. Ennes (Indianapolis, Howard W. Sams & Co., Inc., 1972). For the serious reader or student of broadcasting, the following texts (by the same author and publisher) should be considered prerequisites to this book: *Workshop in Solid State, Television*

Broadcasting: Equipment, Systems, and Operating Fundamentals, and *Television Broadcasting: Camera Chains.*

The complete cooperation of the two major suppliers of television tape recorders in the United States, Ampex and RCA, has made this book possible. Liberal use has been made of material supplied in factory training programs of both manufacturers—in particular, descriptions of specific circuit functions in a given system which have been integrated into the text—as well as material gathered by the writer from various specialized departments.

Credits to Ampex: For the "early days" of the VR-1000 and the VR-1200, much credit is hereby extended to Larry Weiland for making plant facilities available to the author, to Eldon Brown for his painstaking training seminar, to Tom Merson and Frank Gonzalez for their efficient scheduling of plant facilities tours, and to Joe Roizen for supplying much of the requested material and photographs. For recent times (the VR-2000B and the AVR-1), thanks are expressed to Frank B. Thompson, product manager for the Ampex Audio-Video Systems Division, for supplying photographs and requested technical material, including the coverage of the ACR-25 video cassette system.

Credits to RCA: For the "early days" of the TRT-1A and TRT-1B, appreciation is expressed to John P. Taylor for supplying requested photographs and other material, to H. G. Wright for photos of the SMPTE tape response, to Norman Hobson and Roy Marian for their answers to questions which confronted the writer in practical applications, to Ed Hill for his most thorough scheduling of plant facilities inspection, and to John Wentworth for his inimitable training sessions. For recent times (the TR-70 series), the thorough training sessions conducted by Bill Martin were of highest value. Much credit is also due Dana Pratt, manager of Southern broadcast sales for RCA, for supplying photographs and technical coverage of the TCR-100 video cartridge system.

The author also extends his appreciation to the SMPTE and the *Journal of the SMPTE* for permission to use material from SMPTE Recommended Practice RP10 and to reproduce the paper "Electronic Editing of Magnetic Television Tape Recording," by Norman F. Bounsall of Ampex, which appeared in the February, 1962, issue of the *Journal.*

Also invaluable was the contribution of the Electronic Engineering Company of California (EECO) to the coverage of the latest electronic editing systems.

HAROLD E. ENNES

Contents

CHAPTER 1

CHAPTER 2

CHAPTER 3

CHAPTER 4

CHAPTER 5

CHAPTER 6

CHAPTER 7

CHAPTER 8

CHAPTER 9

CHAPTER 10

CHAPTER 11

CHAPTER 12

CHAPTER 13

CHAPTER 14

APPENDIX A

APPENDIX B

CHAPTER 1

Basic Concepts in Quadruplex Video Tape Systems

Television tape recording requires a magnetic-field manipulation that can adequately handle an 18-octave signal range at a satisfactory signal-to-noise ratio. This chapter states the basic problems and the approaches to their solutions.

1-1. THE TIME-SPACE RELATIONSHIP

Although the time-space relationship is important to all communication theory, television tape techniques tend to exaggerate the interdependence of these quantities. The familiar frequency-to-wavelength conversion, which is a fundamental time-space relationship, is given in Fig. 1-1.

For any given medium, time and space have a fixed relationship. A *given medium* indicates a fixed velocity, which is determined by the medium or system in question. On waveform A of Fig. 1-1, point 1 of a passing wave is at reference point t1. One second later (waveform B), point 1 of the passing wave has advanced to t2, and point 2 is at the reference point. The unit distance between t1 and t2 is the wavelength, which also defines one cycle of the waveform. One cycle per second is one hertz (Hz).

The velocity of sound waves, although influenced by temperature, humidity, and height above sea level, may be taken as approximately 1088 feet per second. Since the wavelength is equal to the velocity divided by the frequency in cycles per second, a 1000-Hz tone will have a wavelength (in air) of 1088 ÷ 1000, or 1.09 feet. Doubling the frequency to 2000 Hz results in a wavelength just one-half as long. Increasing the velocity, however, increases the wavelength for a given frequency.

The tape velocity of broadcast-type audio tape recorders is either 7½ or 15 inches per second (in/s). At 7½ in/s, the recorded wavelength of a 1000-Hz tone is 7.5/1000, or 0.0075 inch (7.5 mils, since one mil is 0.001

inch). At a tape speed of 15 in/s, the recorded wavelength of a 1000-Hz tone is 15/1000, or 0.015 inch (15 mils).

The magnetic head gap must have a certain minimum physical size to lay down adequate field strength on the tape. The relationship of head-gap size to frequency is illustrated in Fig. 1-2. As the frequency is increased with the tape speed held constant, the recorded wavelength approaches the physical size of the head gap. This results in zero output because of north-south field cancellation of the signal. Therefore, the high-frequency limit of the system is fixed by head-gap size and tape speed. Response can be expanded into higher frequency regions by either or both of two methods: (1) increased tape speed to produce a longer wavelength for a given high frequency, (2) decreased gap size. See Fig. 1-3.

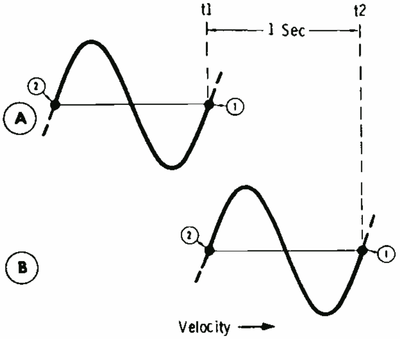


Fig. 1-1. Fundamental time-space relationship.

Note that the higher tape speed extends the upper frequency response, but, since the wavelength for a given low frequency is longer, the low-

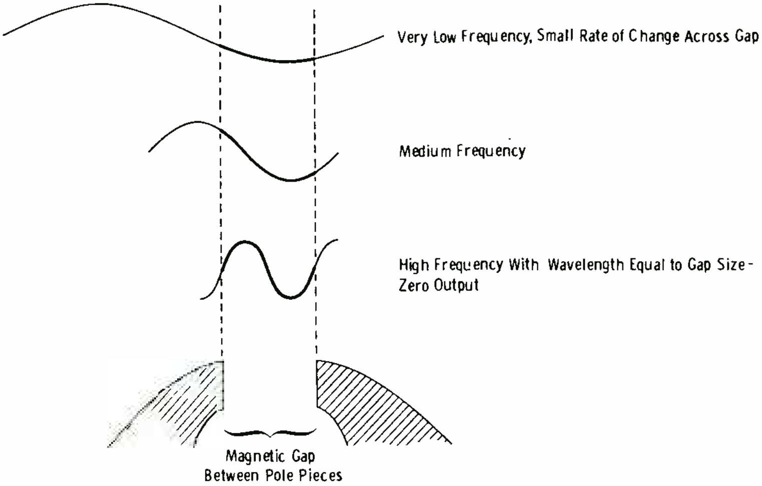
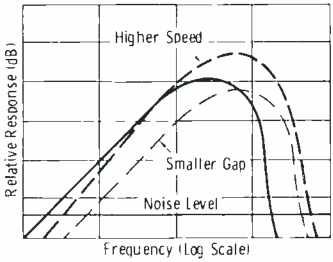


Fig. 1-2. Relationship between head-gap size and frequency.

Fig. 1-3. Effects of head gap and speed on frequency response.

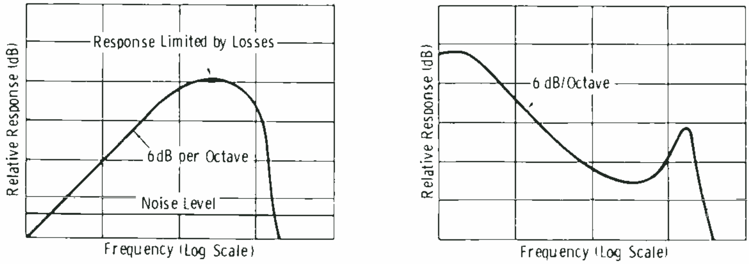


frequency response suffers. (There is a very small rate of change across the gap; hence there is very small induced magnetic field energy.) Reducing the gap size means that less energy is available at the lowest frequencies, so the low-frequency response again suffers.

The strength of the magnetic field is determined by the amplitude of the signal fed to the head and the rate of change of the magnetic field. For a given signal amplitude, as the frequency is increased (increased rate of change) the magnetic-field intensity is increased. As the frequency is doubled (increased by one octave), the voltage is doubled. This voltage increase, measured in decibels, is 6 dB. Therefore, a 6-dB-per-octave rise with increasing frequency occurs in magnetic recording. Fig. 1-4A shows the typical response (6 dB/octave) up to the high-frequency limitations, where the response falls quite rapidly. Note that near the noise level and below, the response cannot be called usable. The noise levels are tape noise, modulation noise, and noise level of input amplifiers.

Conversely, as the frequency decreases from a given frequency limit, a 6-dB-per-octave falloff in response occurs. At a certain low-frequency limit, the change rate of the magnetic recording is so low, compared to the gap size, that very little output exists. When the signal output falls to an objectionable signal-to-noise ratio, the lower frequency limitations of the system have been exceeded.

Fig. 1-4B shows the typical equalization curve for correction of the magnetic recording characteristic of Fig. 1-4A. The rising response at the end is



(*A*) *Uncompensated response.* (*B*) *Typical equalization curve.*

Fig. 1-4. Frequency response in tape recording.

to correct for the rolloff at highest frequencies in the passband due to gap size and tape magnetic-coating factors.

The frequency limitation of direct magnetic recording is about nine octaves, or 30 to 15,000 Hz in the audio range. If it is desired to increase the upper frequency limit to 30,000 Hz, the lower frequency limit must also be doubled to maintain an adequate signal-to-noise ratio. The result is still a nine-octave range, 60 to 30,000 Hz.

1-2. REQUIRED FREQUENCY RANGE FOR TELEVISION TAPE

The range of frequencies required in a video signal extends to very low frequencies for good picture shading and to comparatively high frequencies for satisfactory fine detail in the picture. System requirements at the extreme low-frequency end (approaching zero frequency, or dc) are aided by line-to-line clampers and dc restorers; however, the low-frequency ac response must also be very good. As a reference for this discussion, it will be stated arbitrarily that 10 Hz is the low-frequency ac-response requirement. Response in this region is directly related to the proper operation of clamps and dc restorers when these circuits are employed.

There are two resolution factors for a television picture—vertical resolution, which is independent of system bandwidth, and horizontal resolution, which is directly related to system bandwidth.

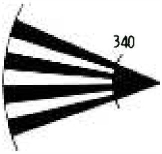


Fig. 1-5. Wedges for interpreting vertical resolution.

The vertical resolution determines how well the horizontal lines in a picture are resolved. The maximum vertical resolution is fixed by the number of active scanning lines. The United States standards call for a total of 525 lines per frame. Vertical-blanking time is approximately 7.5 percent of the total frame time; therefore, the number of lines blanked out is 525 × 0.075 = 40 (approx). Since approximately 40 lines of the picture are blanked out, approximately 485 active picture lines remain. This would appear to indicate that 485 vertically spaced horizontal lines would be resolved, but in practice this is not true. The slight spacing between the scanning lines and the fact that the scanning spot straddles some of the lines both tend to reduce the utilization of the maximum number of active lines. The reduction factor is usually considered to be 0.7 times the total active lines. Thus, there are 485 × 0.7, or approximately 340 usable lines.

Fig. 1-5 shows the horizontal wedges of a test pattern. Here, the lines merge at a point that represents 340 black and white horizontal lines in the total image height. This is a typical value of vertical resolution at both the studio and transmitter outputs; hence, the television tape system should not limit it.

Horizontal resolution is the ability to define vertical lines in the image. The essentially round shape of the scanning spot and the fact that it is not infinitely small place an immediate limitation on the ability to reproduce rapid picture transitions. Thus, when the beam suddenly encounters the sharp vertical line representing a transition from black to white (Fig. 1-6), the resulting signal is not a square wave, but more nearly a sine wave.

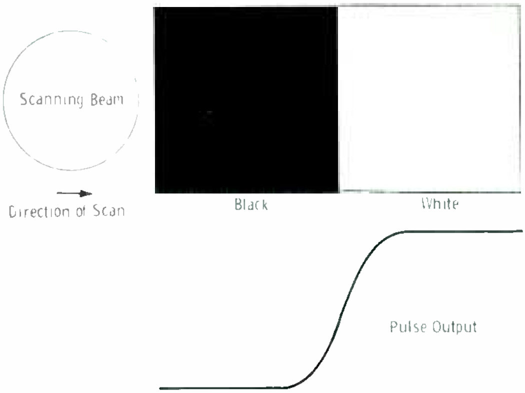


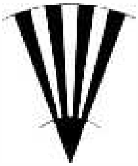
Fig. 1-6. Scanning beam encountering sharp vertical line.

Another factor contributing to the sine wave is the fact that a straight vertical line represents an infinitely short rise time, which would require infinite bandwidth. Such a bandwidth, of course, is impossible in practice; the rise time of the signal representing the instantaneous transition is limited by the available bandwidth of the system.

When the total of the rise and decay time equals the spacing between lines, the lines are not visible as separate picture elements and are not resolved. Rather, they appear as a solid area (Fig. 1-7). Assuming that the scanning beam is properly focused, the limitation on horizontal resolution is the system bandwidth. The pulse rise time representing an instantaneous transition in the picture is directly related to the system bandwidth. As a "rule of thumb," resolution of 80 tv lines requires a 1-MHz bandwidth.

The gain-bandwidth product defines the relationship between a practical amount of gain and the necessary bandwidth:

Fig. 1-7. Wedges for interpreting horizontal resolution.



$$f_u = \text{Gain} \times \text{Bandwidth}$$

where,

f_u is the upper frequency limit for a gain of unity.

For example, for a given circuit with gain reduced to unity at 35 MHz:

$$\text{Gain} \times \text{Bandwidth} = 35 \text{ MHz}$$

Then for an uncompensated amplifier, the bandwidth for a gain of 10 is:

$$\text{Bandwidth} = \frac{35 \text{ MHz}}{10}$$

$$= 3.5 \text{ MHz}$$

The relationship of bandwidth and rise time is of equal importance. The product of bandwidth and rise time gives a factor, k, which depends on type and magnitude of high-frequency compensation. If leading-edge overshoot is limited to less than 3 percent, factor k can be given a value of 0.35, and the relationship between bandwidth and rise time can be expressed in any of these three forms:

$$BW \times RT = 0.35$$

$$BW = \frac{0.35}{RT}$$

$$RT = \frac{0.35}{BW}$$

Thus, the greater the bandwidth, the shorter is the rise time that can be passed. For a bandwidth of 10 MHz:

$$RT = \frac{0.35}{10}$$

$$= 0.035\ \mu s$$

Table 1-1 relates bandwidth to rise time and horizontal-resolving power in terms of TV lines.

The normal bandwidth of modern studio equipment is at least 8 MHz. The picture transmitter, however, is limited to approximately 4 MHz by Federal Communications Commission (FCC) channel assignments and engineering regulations. Therefore, the horizontal resolution is restricted to about 320 lines in the home receiver. The complexity of the problem encountered in recording pictures on magnetic tape warranted a compromise in this particular studio gear. Specifications for modern television tape recorders include a bandwidth of at least 4 MHz (320 lines horizontal resolution) with a signal-to-noise ratio of at least 35 dB. This meets the minimum requirements for network-signal distribution as specified by AT&T. These specifications are exceeded in high-band recording systems.

Table 1-1. Relationship of Bandwidth, Rise Time, and Horizontal-Resolving Power

Bandwidth (MHz)	Rise Time (μs)	TV Lines
1	0.35	80
2	0.175	160
3	0.1166	240
4	0.0875	320
5	0.07	400
6	0.058	480
7	0.05	560
8	0.0437	640
9	0.039	720
10	0.035	800

The video-signal frequency range for television tape extends from very low frequencies (actually dc) to an upper frequency of at least 4 MHz. If the range is considered to be 10 Hz to 4 MHz, a gamut of more than 18 octaves is required, which, as discussed earlier, is not possible in direct magnetic-recording techniques.

1-3. SOLVING THE LOW-FREQUENCY PROBLEM

The dc component in a standard video signal is *inserted* by means of line-to-line clampers. Essentially, the clamper charges or discharges a coupling capacitor to a dc reference, which usually represents the signal-blanking level. This reference level assures that each active line starts from the same reference immediately following horizontal blanking.

The extreme low-frequency requirements are met by employing an rf carrier which is frequency-modulated by the video signal. (Frequency modulation was chosen over amplitude modulation to allow amplitude limiting to be employed for attenuation of extraneous noise.) The carrier frequency represents the dc component (either sync tip or blanking, depending on the system clamp reference). Fig. 1-8 shows the modulation characteristic with a carrier frequency of 5 MHz clamped to the signal-blanking level. The conventional assumption that the carrier frequency must be at least ten times the highest modulating frequency is discarded in television-tape applications.

> IMPORTANT NOTE: The frequencies and deviation shown in Fig. 1-8 apply only to low-band monochrome standards. The discussion in this section and following Section 1-4 apply to the same standard. Section 1-5 will introduce the remaining standards now in use for quadruplex recording systems.

With the carrier frequency clamped at the video-blanking level, it is standard monochrome practice to adjust the picture-signal gain so that peak white deviates 1.8 MHz upward in frequency; the peak-white signal occurs at 6.8 MHz in Fig. 1-8. With a standard video input, 0.3-volt sync to 0.7-volt video, sync tips deviate the carrier 0.7 MHz lower in frequency, to 4.3 MHz. The total deviation of 2.5 MHz is used currently as the 100-percent modulation reference for monochrome signals, in low-band video tape systems.

When the modulation index is less than 0.5 (frequency deviation less than one-half the modulation frequency), sideband energies beyond a single pair are practically nonexistent, and the modulated signal approaches a-m characteristics in this respect.[1] Sidebands occur at the carrier frequency plus and minus the instantaneous video frequency. The maximum video frequency in the system passband determines the sideband limits. For a 4-MHz bandwidth, the lowest sideband occurs at 5 − 4, or 1 MHz. The upper sideband extends just far enough to provide a shelf for the upper frequency deviation. Sidebands beyond this limit are not used in low-band recording.

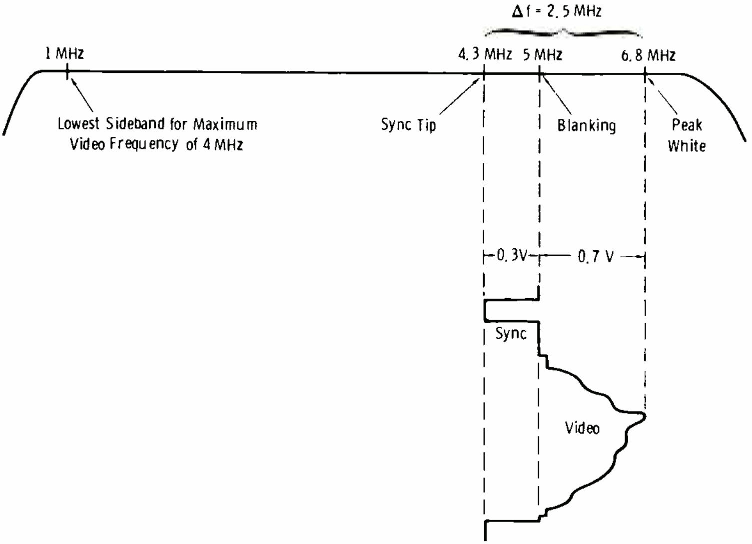


Fig. 1-8. Frequency modulation of carrier for low-band monochrome recording.

The only practical result of these compromises is a slight zig-zagging of vertical lines apparent at a resolution of 300 lines and above.

The total frequency range now becomes 1 MHz to approximately 7 MHz; thus, the modulation process has reduced the original 18-octave video range to less than three octaves. A practical solution to magnetically recording

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[1] Charles E. Anderson, "Signal Translation Through the Ampex Videotape Recorder," *Journal of the SMPTE,* November 1958.

the video signal has been found if the problem of handling a 7-MHz signal can be met.

1-4. SOLVING THE HIGH-FREQUENCY PROBLEM

A good audio tape recorder may have a head-gap size as small as 0.25 mil (0.00025 inch). Then, for an upper audio limit of 15,000 Hz and a tape speed of 7.5 in/s, the recorded wavelength is equal to:

$$\begin{aligned}\text{Recorded wavelength} &= \frac{7.5}{15{,}000}\\ &= 0.0005 \text{ inch}\\ &= 0.5 \text{ mil}\end{aligned}$$

The recorded wavelength is twice as long as the gap width. This wavelength/gap-size ratio is the lowest practical limit which can be adequately pre-emphasized for good reproduction and signal-to-noise ratio. (Losses in the magnetic core structure cause the signal to begin to decrease before this point, and pre-emphasis is required.)

The smallest practical magnetic gap on the original video heads was approximately 100 microinches, or 0.1 mil. Therefore, the minimum wavelength for 7 MHz must be twice as long as 100 microinches, or 200 microinches.

The required tape velocity can be calculated if the gap size and the minimum required recorded wavelength at the upper frequency limit are known. Since:

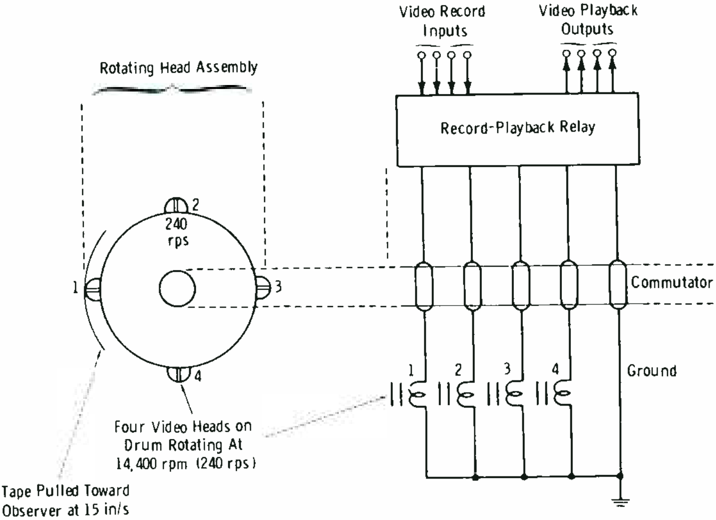
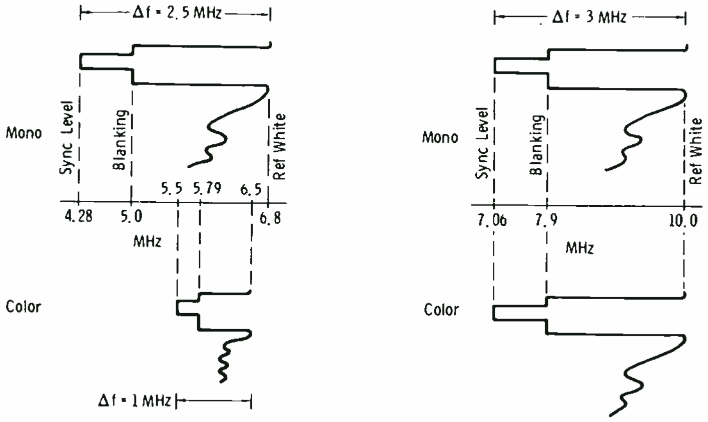


Fig. 1-9. Parallel feed of four rotating heads (simplified diagram).



(*A*) *Low-band.* (*B*) *High-band.*

Fig. 1-10. Frequency modulation in vtr systems.

$$\text{Wavelength} = \frac{\text{Velocity}}{\text{Frequency}}$$

then,

$$\begin{aligned}\text{Velocity} &= \text{Wavelength} \times \text{Frequency}\\ &= 0.0002 \times 7{,}000{,}000\\ &= 1400 \text{ inches per second}\end{aligned}$$

If the tape were actually pulled across the head at a speed of 1400 in/s, 420,000 feet of tape on a reel over 80 feet in diameter would be required

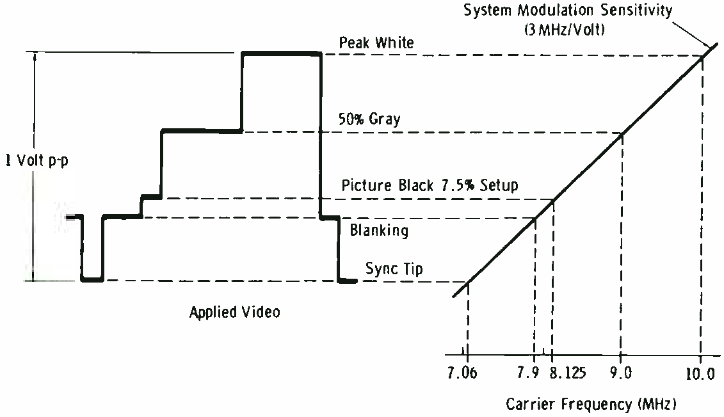


Fig. 1-11. High-band recording standard for monochrome and color signals.

to record one hour of material. Try to visualize the required tape-transport mechanism; obviously, this is an impractical solution.

The problem is solved by pulling the tape at a practical speed of 15 in/s past a rotating video head. Insofar as the video signal is concerned, the resultant velocity is more accurately termed head-to-tape velocity. The rotating-head principle, illustrated in Fig. 1-9, gives an effective head-to-tape velocity of slightly over 1500 in/s. The fm video signal is fed to the individual heads (quadruplex system) on the rotating drum and brush assembly. Video tracks approximately 10 mils wide are laid down transversely across the 2-inch-wide magnetic tape. Audio is recorded longitudinally along the top of the tape at the conventional 15-in/s rate. A 240-Hz control signal, which indicates the precise position of the rotating head drum relative to the recorded video information, is recorded longitudinally along the bottom of the tape. (NOTE: Details of connections between the heads and the commutator are given in Chapter 2.)

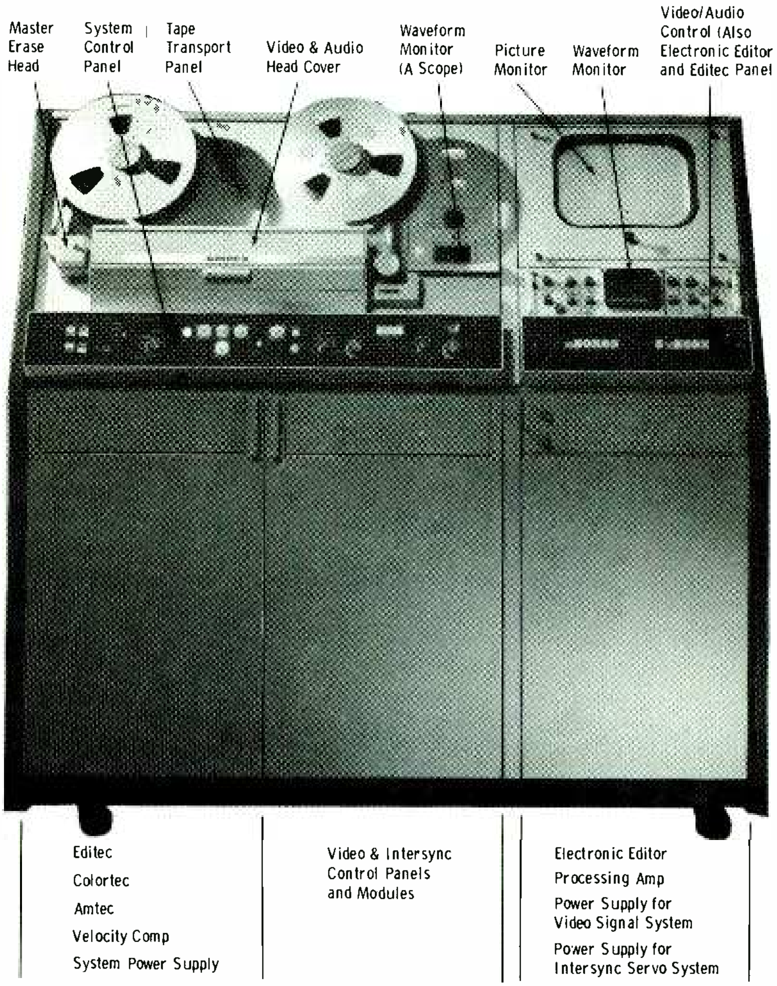
1-5. RECORDING STANDARDS FOR QUADRUPLEX TAPE SYSTEM

The standard monochrome deviation for low-band systems shown in Fig. 1-8 is repeated at the top of Fig. 1-10A. The sync-tip level is actually at 4.28 MHz, generally rounded off to 4.3 MHz. For low-band *color* recordings, the deviation is reduced as shown in the bottom portion of Fig. 1-10A.

Because of the strong color subcarrier component in the video signal, interference and moire patterns result if standard monochrome deviation is used for a color signal. Also, an excessive amount of differential phase and gain of the color subcarrier results. Therefore, for low-band color recording, the standard deviation is reduced to 1 MHz for 100-percent modulation (Fig. 1-10A). Blanking is clamped at 5.79 MHz, the sync tip occurs at 5.5 MHz, and picture white peaks occur at 6.5 MHz. The main characteristic that suffers here is a reduced signal-to-noise ratio.

Fig. 1-10B shows the standard deviation for high-band recording systems, and Fig. 1-11 is a graph of the high-band recording standard. Note that the deviation is the same for monochrome and color signals. Blanking level is clamped at 7.9 MHz. Sync tip occurs at 7.06 MHz, and peak picture white occurs at 10 MHz. The deviation for 100-percent modulation is then approximately 10 − 7, or 3 MHz. NOTE: All tape recorders capable of high-band operation are also capable of recording and playing back low-band monochrome and color tapes.

Before recent advances, the head-gap size in video headwheels was 90 microinches. The gap size now has been reduced to 50 microinches. This allows a higher frequency response as required for high-band recorders. Improved design has resulted in as much sensitivity as existed with the former (wider) gap. Also, due to more sophisticated design of filters and pre-emphasis, de-emphasis circuitry, low-band performance is greatly improved over the former low-band (only) recorder system. The performance of modern high-band quadruplex recording systems can be made so good that one is hard-pressed to judge whether the picture is from a live or taped show. Where the high-band standard is used, even second- and third-generation dubs can be made with almost negligible degradation from the original performance. Almost all tape recording today is done on the high-band standard.



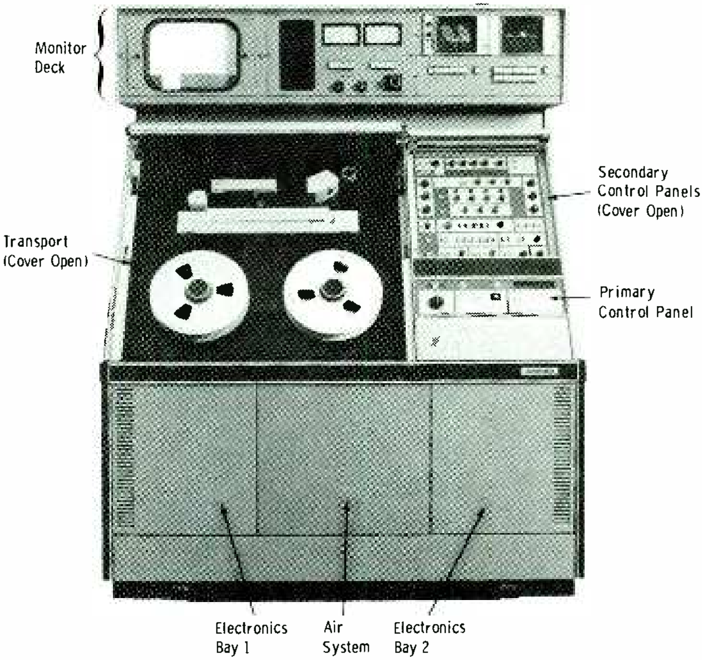
Courtesy Ampex Corp.

Fig. 1-12. Ampex VR-2000 video tape recorder.

1-6. TAPE SYSTEMS

Modern television tape recorders of both Ampex and RCA design are housed in a single console requiring no external rack space. External racks normally house video and audio signal-source selection panels, color monitors, and vectorscopes.

A typical tape "system" is the Ampex VR-2000 video tape recorder shown in Fig. 1-12. The rotating video head drum and all audio heads are under the protective head cover. The front of the lower section houses all system modules, and the rear of the lower section contains the required air systems and intermodule wiring harness.



Courtesy Ampex Corp.

Fig. 1-13. Ampex AVR-1 tape system.

Normal system inputs are ac power, selected video and audio signal sources, composite sync, and 3.58-MHz subcarrier.

Fig. 1-13 illustrates the Ampex AVR-1 tape system. This is a complete and automatic system itself, or it may be used on a "shared electronics" basis for the Ampex ACR-25 video cassette system (Chapter 13).

EXERCISES

Q1-1. From your studies thus far, and your understanding of Figs. 1-3 and 1-4, would you conclude that the low video frequencies need to be brought up in amplitude relative to higher video frequencies?

Q1-2. If you have an amplifier with unity gain at 50 MHz, what is the usable bandwidth at a gain of 5 (uncompensated)?

Q1-3. Assume that the head-to-tape velocity is 1560 inches per second. What is the recorded wavelength of a 10-MHz signal?

Q1-4. What is the shortest usable wavelength on the tape for a head gap of 50 microinches?

Q1-5. What frequency corresponds to your answer for Q1-4, assuming the same velocity as in Q1-3?

Q1-6. What is the term applied to the sideband above the highest deviation frequency in video tape recording?

Q1-7. In the drawing of Fig. 1-8, a standard 1-volt p-p composite signal input is assumed. Give the sync-tip frequency and peak-white frequency resulting from an input which overshoots to 1.5 volts p-p (video-to-sync ratio maintained and no video clipping or limiting used in recorder).

CHAPTER 2

The Quadruplex Head: the Basic Time Base

You will now learn the precision of the four-head (quadruplex) assembly. By acquiring the time-base concept, you will more clearly understand the relationship of the recording system to the television signal itself.

You will learn later that as precise as the rotating head assembly is, more than one-half of all the rest of the system function is concerned with *correcting* for deficiencies of this assembly. This is the reason why the time-base concept is so important.

The circular mounting which contains the four video heads is termed the *headwheel* by RCA, and the *drum* by Ampex.

2-1. ORIENTATION OF RECORDED SIGNALS

A rotating head contacts the tape for an arc of approximately 120°. Since the head rotates at 240 rps, it takes 1/240 second for 360°, and one-third of this time (1/720 second) to traverse the 2-inch tape (120°).

Inasmuch as the tape travels at a rate of 15 inches per second, it will go 15/720, or 0.02, inch (20 mils) while the head describes its arc across the tape. Therefore the bottom of each video track is ended 20 mils later than the start, resulting in an angle of 0.54° (Fig. 2-1).

The orientation of recorded information on a vertical tape transport is shown in Fig. 2-2A. The video heads contact the entire 2-inch surface of the tape; however, a 70-mil-wide area across the top is erased for audio information, which is recorded on a track parallel to the edge of the tape. The video tracks along the bottom of the tape, containing the control and cue track, are not actually erased; however, only that portion used as video information is shown in Fig. 2-2A.

Tapes recorded on horizontal and vertical transports are entirely compatible and may be played back on either type of transport. The track

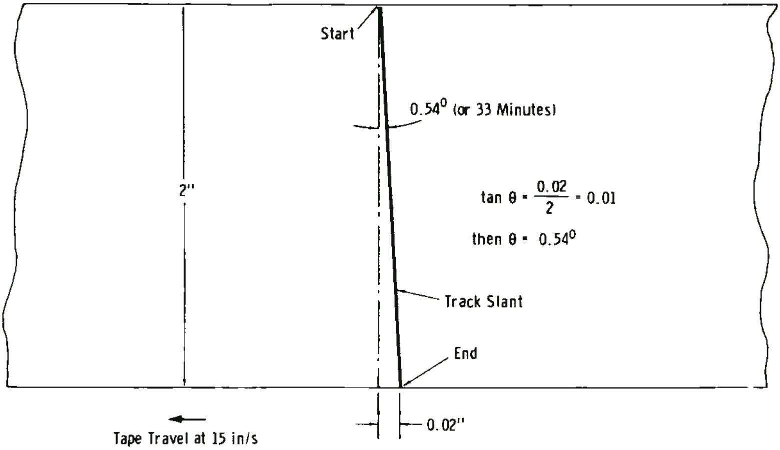
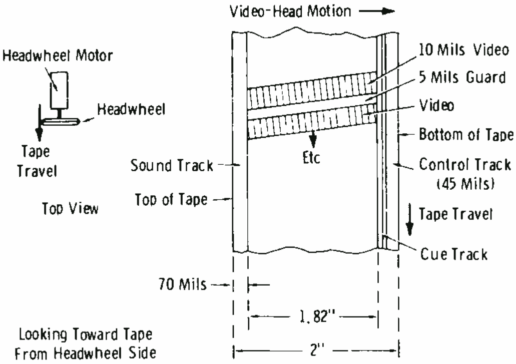
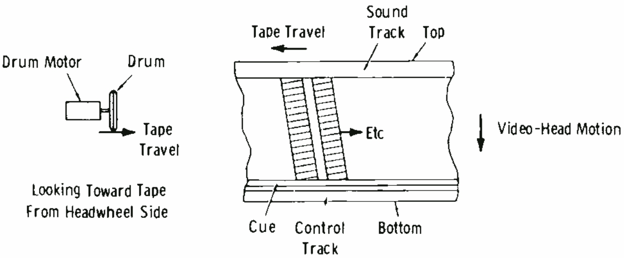


Fig. 2-1. Track slant on tape.

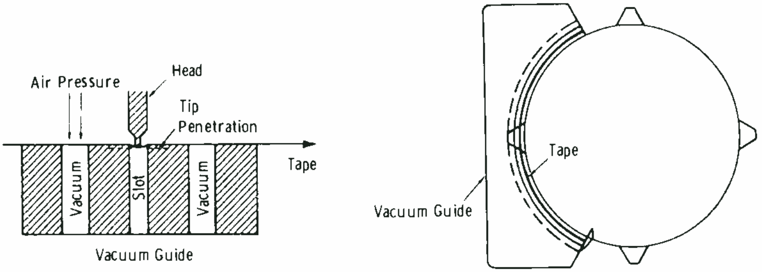


(*A*) *Vertical transport.*



(*B*) *Horizontal transport.*

Fig. 2-2. Track orientation.



(*A*) *Top view.* (*B*) *Side view.*

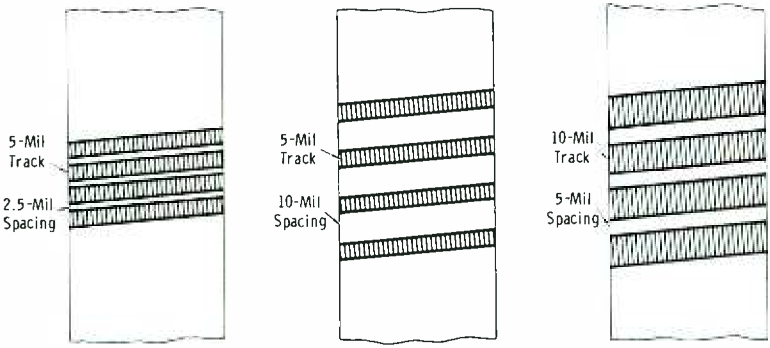
Fig. 2-3. Cross-sectional view of vacuum guide.

orientation on the tape is that which is viewed looking toward the coated side from the rotating heads. The track dimensions on the horizontal version shown in Fig. 2-2B are exactly the same as for the vertical arrangement in Fig. 2-2A.

The method of holding the tape concentric with the rotating heads is shown in Fig. 2-3A. The vacuum guide holds the tape in place, and the center slot provides clearance for tape *stretch* under head penetration. Fig. 2-3B is a side view of the vacuum guide and the rotating headwheel.

Most modern tape systems provide for a dual-speed tape transport (7½ or 15 in/s). Dual-speed operation employs standard quadruplex recording techniques, using standard two-inch recording tape. All the advantages of quadruplex recording are retained, and the cue track, audio track, and control track are untouched. Only the method by which video tracks are laid down is modified.

The headwheel employs four video heads which record a track only 5 mils wide, as compared with 10 mils for conventional recording. Fig. 2-4A shows how the 5-mil tracks at half speed are spaced with respect to the



(*A*) *Half-track, 7½ in/s.* (*B*) *Half-track, 15 in/s.* (*C*) *Full-track, 15 in/s.*

Fig. 2-4. Dual-speed recording tracks.

video portion of the tape (5-mil track with 2½-mil spacing). The capstan motor pulls the tape at 7½ in/s; thus, twice as much video information is packed into each foot of tape. Because the speed of the headwheel rotation is the same as in normal operation, each recorded track contains the same number of tv lines, approximately 16.5.

During operation at 15 in/s, video tracks are recorded by the half-track heads as shown in Fig. 2-4B. In this case, the track width remains at 5 mils, but the spacing between tracks becomes approximately 10 mils. The tracks in Fig. 2-4B correspond to every other track in Fig. 2-4A.

Standard video-headwheel panels recording 10-mile tracks with approximately 5-mil spacing between them (Fig. 2-4C) are oriented in the same manner as in Fig. 2-4B. Comparison of Figs. 2-4B and 2-4C will show how interchangeability is achieved.

If a 10-mil head traces a 5-mil track, the head is in contact with the signal included on the track, and, in addition, it traces over 5 mils of blank tape. It encounters the next track after a 5-mil spacing interval which brings the head into position to read all the information on the next track.

In the case of a half-track (5-mil) head reading a fully recorded (10-mil) track, the principle is reversed. Here, the half-track head reads enough of the video information (5 mils) on the fully recorded track to produce high-quality pictures.

2-2. HEAD-TO-TAPE VELOCITY

The wheel which contains the four video heads has a reference diameter of 2.064 inches. The tip projection of a new head is about 3.6 mils, and for a worn head it is about 1.0 mil (Fig. 2-5).

The maximum recording diameter (tip projection of 3.6 mils) is:

$$\begin{aligned} A + B + C = {} & 0.0036 \\ & 2.0640 \\ & \underline{0.0036} \\ & 2.0712 \text{ inches} \end{aligned}$$

The recording circumference is:

$$\begin{aligned} \text{Circumference} &= \pi d \\ &= 3.1416 \times 2.0712 \\ &= 6.507 \text{ inches} \end{aligned}$$

Since the head revolves at 240 rps, the head-to-tape velocity at the maximum tip projection is:

$$\begin{aligned} \text{Head-to-tape velocity} &= 6.507 \times 240 \\ &= 1561 \text{ in/s} \end{aligned}$$

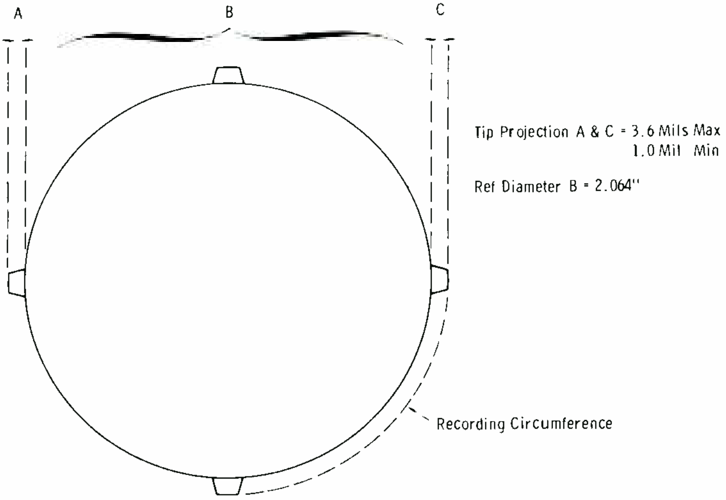


Fig. 2-5. Headwheel reference diameter and tip projection.

The recording diameter at the minimum tip projection of 1.0 mil is:

$$\begin{array}{r} A+B+C = 0.001 \\ 2.064 \\ \underline{0.001} \\ 2.066 \text{ inches} \end{array}$$

The recording circumference is:

$$\begin{aligned} \text{Circumference} &= \pi d \\ &= 3.1416 \times 2.066 \\ &= 6.490 \text{ inches} \end{aligned}$$

The head-to-tape velocity is:

$$6.490 \times 240 = 1557 \text{ in/s}$$

at minimum tip projection of 1.0 mil.

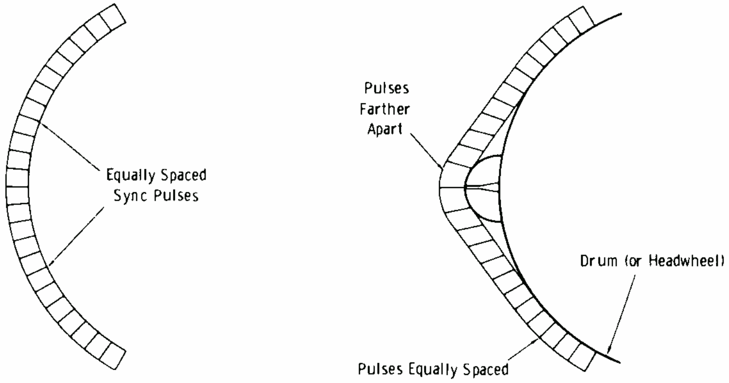
HEAD-TO-TAPE VELOCITY AT 3.6-mil TIP PROJECTION = 1561 in/s.
HEAD-TO-TAPE VELOCITY AT 1.0-mil TIP PROJECTION = 1557 in/s.

The foregoing relationship of tip velocities has a direct bearing on proper timing to avoid space errors in television-tape playback.

The *angular velocity* remains the same regardless of tip projection. The spacing of the horizontal-sync pulses across the entire video track must also remain the same to avoid time-space errors in the reproduced picture.

That is, the space occupied by a tv line must be the same at the middle and end of the video track as it is at the beginning of the track.

Fig. 2-6A shows the tape without the head engaged. As the vacuum guide is moved toward the head, the pole pieces contact the tape and a stretch occurs as shown in Fig. 2-6B. The greater the tip penetration, the greater is the stretch and the wider is the space between sync pulses. The effective spacing in time between pulses is determined by the tip velocity. A recording made with a 3-mil penetration can be played back with a worn head having a tip penetration of only 1 mil. This is because the reduced tip velocity of the worn head means a longer time is required to scan a given length of the video track; therefore *less tape stretch* is required to maintain the correct space-time relationship between pulses.



(*A*) *Tape without head engaged.* (*B*) *Tape with head engaged.*

Fig. 2-6. Pole-tip stretch of tape.

From this analysis, it is evident that reduced velocity due to worn tips is complementary to the resulting reduction in tape stretch. Therefore, assuming that the video-tape stock neither shrinks nor stretches during its life, the vacuum-guide position relative to the headwheel remains the same as tip projection decreases with head wear.

To emphasize this point, see Fig. 2-7. A new head with a 3.6-mil tip stretches the tape considerably more than when this same head is worn down to a 1-mil tip. But note that the head-to-tape velocity is 4 in/s greater for a 3.6-mil projection than when the head is worn to a 1-mil projection.

This is not a geometric (space-in-time) error if the vacuum guide has not been moved, since the standard radius of rotation is maintained. In Fig. 2-7B, the arrow corresponding to maximum tape stretch represents the length of the pole-tip contact with the tape, which is about 16 video lines. The other arrow indicates the shorter length of the same 16 lines under minimum stretch, but the *time* taken to scan the same *space* is longer; hence there is no geometric error.

Keep the time-space concept. Errors in timing (velocity errors) result in horizontal displacement of vertical lines in the picture (Section 2-5). Velocity errors result when the time to scan a given space (such as the space occupied by 16 lines) differs from the time elapsed in recording that space on the tape.

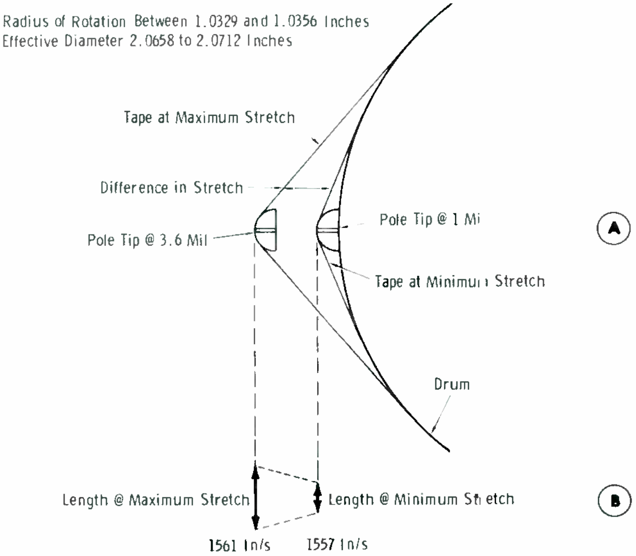


Fig. 2-7. Change in tip projection does not cause geometric error.

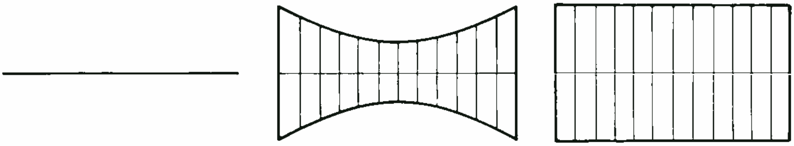
A nonstandard recording radius can be used to make a recording on a tape. If the tape is played back on the same head with the same adjustment, no geometric error results. This simply means that the playback space-in-time velocity is the same as the recorded signal space-in-time velocity.

For interchangeability of tapes and to facilitate splicing of sections from different types, it is necessary to adhere to a standard pole-tip arc radius, within very narrow limits. Even when this standard tolerance is maintained, velocity errors can result from slightly different guide-height adjustments, tolerances in tape tensions between machines, slightly different positions of tape-transport fixtures, and tape stretch resulting from use. (These problems are expanded in Section 2-5.)

2-3. TIP-PENETRATION EFFECT ON RF LEVEL

The position of the vacuum guide, which cups the tape around the rotating heads, determines the amount of pole-tip penetration into the tape. When the guide is sufficiently far away from the pole tips, a positive clearance between tape and heads occurs, and no contact exists. Under this condition, no recording would be laid down on the tape, and no playback of recorded information can occur (Fig. 2-8A).

Radio-frequency output from recorded information begins to occur as the vacuum guide is brought closer to the head. There is now a negative clearance between the pole tips and the tape in the slotted guide. The amount of this negative clearance is the tip penetration. When the penetration is extremely light, concentricity between the tape and head does not exist (discussed further in Section 2-5). Under this condition, tip penetration is less at the center of the tape than at either edge, resulting in a dip (Fig. 2-8B) in the rf envelope of the head output. As the tip penetration is further increased, intimate contact is gained with full concentricity, and an even rf output (Fig. 2-8C) is obtained from the head.



(A) No contact, zero output from tape.

(B) Penetration too light, dip in center of envelope.

(C) Full contact, even rf output.

Fig. 2-8. Relationship of rf output and pole-tip contact with tape.

An adequate magnetic contact must prevail at the low values of tip penetration which exist near the end of head life. Therefore, since the guide position relative to the head is a constant value (Section 2-2), new heads with high tip projection will exhibit relatively high values of tip penetration.

High values of tip penetration increase head and tape wear and the load on the head-motor drive amplifiers. If excessive loading occurs, head-servo instability can occur. This is particularly true when marginal tubes are in service in the older tube-type recorders.

A tip penetration of less than 1 mil aggravates dropouts and possible head clogging. *Dropouts* are white flashes in the reproduced picture; they are caused by microscopic irregularities in the magnetic coating of the tape. Head clogging results when iron-oxide particles, loosened from the tape coating, become lodged in the head gap. (See Chapter 8 for tape-dropout compensation systems.)

2-4. TIMING

The headwheel (or drum) rotates at 240 rps, or four times the tv-field frequency of 60 Hz. Thus, one revolution (360°) of the wheel lays down four tracks (four heads spaced 90° and fed simultaneously) which are equal to one-fourth of a field. Since there are 262.5 lines per field, there are 65.625 lines in four tracks on the tape, and each track contains 16.4 lines.

> NOTE: A tv line is designated as H, where H is the interval from the leading edge of one horizontal-sync pulse to the leading edge of the next horizontal-sync pulse. (The standard interval is 63.5 microseconds.) Therefore, a recorded track equals 16.4H.

The preceding is the average number of picture lines used in reproducing the signal; actually, each track contains more than this number of lines. The guard bands and control, cue, and audio tracks (Fig. 2-2) leave approximately 102° of the tip pass for picture information. The number of lines per degree of rotation can be calculated as follows. First, find the time for 90° of rotation:

$$\text{Time per revolution} = \frac{1}{240}\text{ second}$$

$$= 4167\text{ microseconds}$$

$$\text{Time for }90^\circ = \frac{4167}{4} = 1042\text{ microseconds}$$

Since the duration of one line is 63.5 microseconds, the number of lines in 90° of rotation is:

$$\frac{1042}{63.5} = 16.4\text{ lines}$$

Then the number of degrees per line is:

$$\frac{90}{16.4} = 5.48^\circ$$

and the number of lines per degree is:

$$\frac{1}{5.48} = 0.182\text{ line}$$

The heads are 90° apart and lay down 16.4 tv lines in 90° of rotation. Since the heads are spaced 90°, the remaining time that both heads are in contact with the tape is $102^\circ - 90^\circ$, or 12°. This leaves an overlap of 0.182×12, or 2.2 lines (Fig. 2-9). In recording, the same information is duplicated in these 2.2 lines. During playback, electronic switching is used to disconnect the head nearing the end of a track and to connect the head beginning the next track. The switching is done during horizontal retrace to avoid visible switching transients.

During 240 revolutions of the headwheel, the tape travels 15 inches. One revolution of the headwheel (four tracks) is equal to one-fourth of

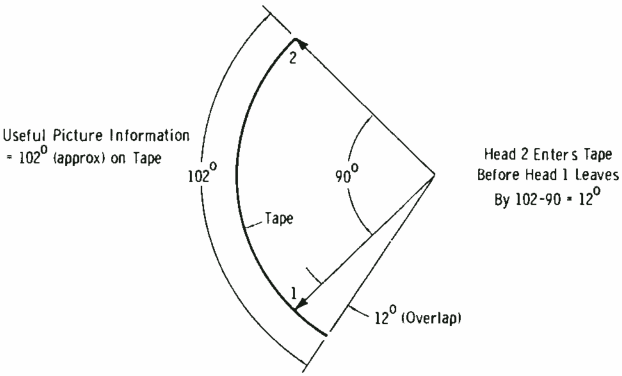


Fig. 2-9. Active picture information and overlap on tape.

Table 2-1. Significant Head Timing

Subject	Relative Frequency (Hz)	Microseconds (μs)	Vertical (V = 1/60 sec = 16,667 μs)	TV Lines (H = 63.5 μs)	Headwheel Degrees 360° = 1/240 sec = 4166.6 μs
TV Field	60	16,667	1	262.5	1440
TV Line	15,750	63.5	1/262.5	1	5.48
1 Revolution of Headwheel	240	4166.6	1/4	65.625	360
½ Revolution of Headwheel	480	2083.3	1/8	32.8	180
¼ Revolution of Headwheel	960	1041.6	1/16	16.4	90
Playback Switching Rate (and Sweeps Across Tape per Sec)	960	1041.6	1/16	16.4	90
1° of Rotation		11.58		0.182	

Additional Significant Measurements

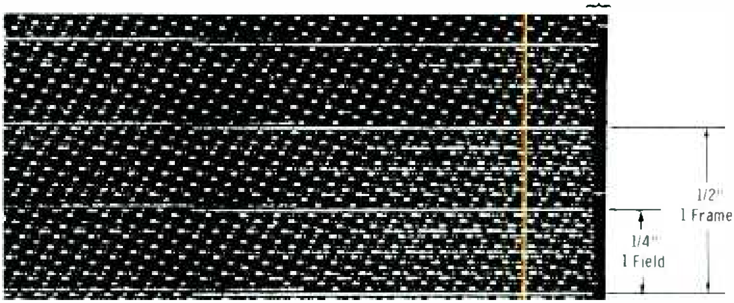
Width of video-head magnetic gap	0.05 mil
Video-head tip speed	1561 in/s
Length of one tv line on video track	98 mils (approx)
Head-to-head spacing around circumference	1.626 inches (approx)
Length of video track across tape	1.82 inches
Space along tape between fields	0.25 inch
Space along tape between frames	0.50 inch

a field. Therefore, there are 60 fields (240 ÷ 4) recorded on 15 inches of tape. Thus one field equals 0.25 inch (15 ÷ 60), and a frame (2 fields) equals 0.5 inch of tape.

The foregoing timing relationships and other significant factors are summarized in Table 2-1.

> NOTE: The tracks on video tape can be made visible by coating the tape with a suspension of carbonyl iron and diluent (Fig. 2-10). Horizontal-sync pulses show as white dots between the long white lines of vertical blanking. Fig. 2-11 shows how the picture raster is made up of consecutive bands of 16 to 17 lines contained in each head pass across the tape.
>
> Visible tracks such as those in Fig. 2-10 are used only for mechanical splicing. This method has largely been replaced by electronic splicing and editing systems (Chapter 10).

White marks in this control-track area are frame edit pulses.



Courtesy Ampex Corp.

Fig. 2-10. Visible tracks on tape for mechanical splicing.

2-5. TIME-SPACE ERRORS

Errors in spacing, as a function of time, in a video-tape reproduction occur as horizontal displacements of vertical lines in the picture. We will now study the space errors caused in the reproduced picture by time-base discontinuities.

A headwheel assembly consists of the rotating headwheel and the vacuum guide (details and illustrations in Section 2-6). For a given headwheel assembly, the vacuum guide has a radius of from 1.0329 inches minimum to 1.0334 inches maximum. The rotating headwheel has a pole-tip arc radius of 1.0329 inches minimum to 1.0356 inches maximum (Fig. 2-12). A nominal tape thickness of 1.4 mils is assumed.

See Fig. 2-13A. If the guide position is adjusted so that the center of curvature of the guide and the center of rotation of the headwheel exactly coincide, then precise concentricity is achieved. This means that the head-to-tape pressure remains exactly the same across the entire arc of head-to-tape contact. Under the condition of Fig. 2-13A, playback of a properly

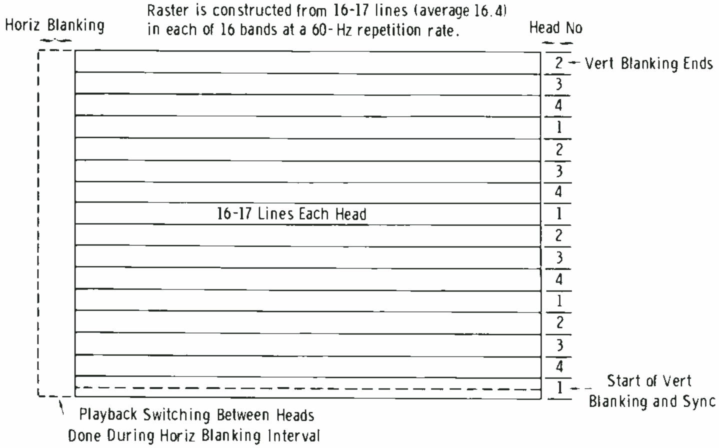
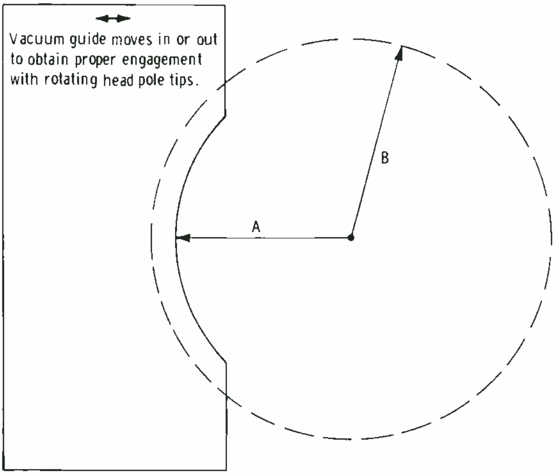


Fig. 2-11. Raster makeup, with vertical sync on head 1.

recorded standard tape will yield a picture that, when viewed without any automatic time correction (ATC) or other time-base correction (Chapter 6), is free of geometric errors.

If the guide is now moved away from the headwheel as in Fig. 2-13B, we have the condition already discussed relative to Fig. 2-8B. A high head-to-tape pressure occurs at the top and bottom of the head pass, and a low

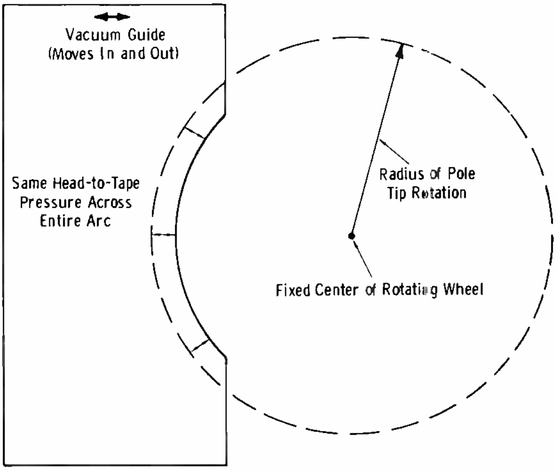


A Vacuum Guide Radius: 1.0329 Inches Minimum
1.0334 Inches Maximum

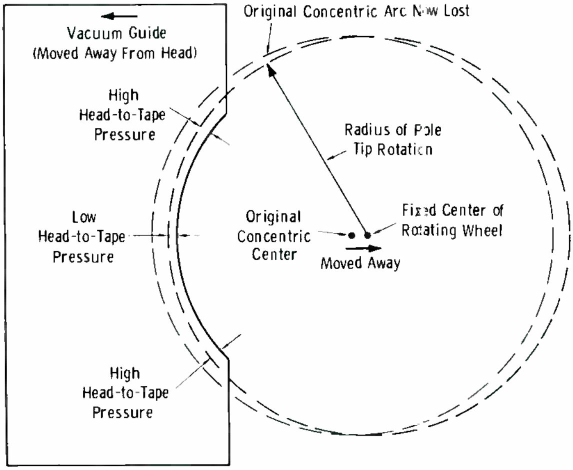
B Radius of Pole-Tip Arc: 1.0329 Inches Minimum
1.0356 Inches Maximum

Reference: SMPTE RP11

Fig. 2-12. Guide and pole-tip radii.



(A) Guide and headwheel precisely concentric.



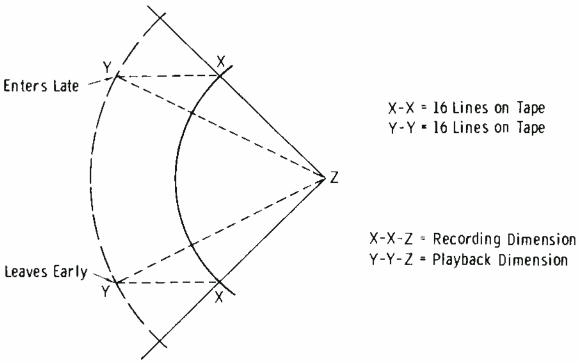
(B) Guide moved away from headwheel.

Fig. 2-13. Relative positions of guide and headwheel.

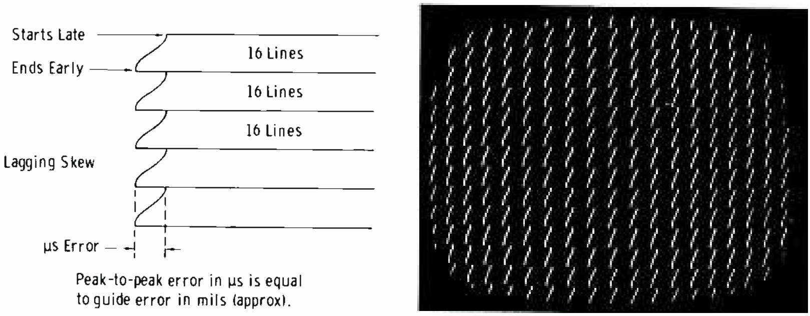
pressure occurs at the center. Note that a measure of actual tip projection of the headwheel is that obtained when the contact at the center of the tape is lost under nonconcentric (eccentric) operation. We may now study the various forms of geometric distortion, starting with the example just cited, the vacuum guide adjusted too far from the headwheel.

Tape Vacuum Guide Too Far From Head

Point Z in Fig. 2-14A represents the center of the drum, or headwheel. Assume that the recording is made with arc X-X representing 16 lines.



(*A*) *Recording and playback dimensions.*



(*B*) *Bands of lines.* (*C*) *Effect on vertical lines.*

Fig. 2-14. Space distortion, vacuum guide too far from head.

Arc Y-Y is the playback position, if the guide is too far from the heads, and contains the same 16 lines of information. The pole tip enters this information late and leaves early compared to the recorded time base.

Space errors resulting from the condition in the preceding paragraph are depicted in Fig. 2-14B. Each band of lines representing a head pass across the tape starts late and ends early, producing the *skew* effect, also called the *venetian-blind* effect.

Fig. 2-14C shows the effect on a series of vertical lines (viewed on a video monitor) when time-base distortion, as a result of having the vacuum guide too far from the head, is present.

> NOTE: The horizontal position of the vacuum guide (which determines the distance of the tape from the heads) is controlled by a servo amplifier. This servo (in the playback mode) may be placed either in the manual or automatic sense position.

In practice, mechanical adjustments are made on the head assembly with the electrical controls centered. After the initial mechanical alignment of a given head assembly, only the electrical control need be used to eliminate skew in the manual mode of operation (Chapter 11). Details of the guide servo in the manual and automatic modes are found in Chapter 7.

Interchange S-Distortion

Note from Figs. 2-14B and 2-14C that the skewed lines are not straight diagonal lines, but that each segment is a 90° section of a sinusoid. A single head scan across the tape is 90° of the headwheel rotation rather than the full 360°, so only 90° of the sinusoid occurs on each band of 16 to 17 lines.

Note also from Fig. 2-14B that the number of microseconds of error (peak-to-peak) on vertical lines in the picture is approximately in direct ratio to the guide error (tip-projection error) in mils. Thus if the guide is misadjusted by 0.5 mil, a timing error of approximately 0.5 μs occurs. If the guide is misadjusted 1 mil, an error of approximately 1 μs results. This error is approximate because a 1-mil misadjustment of the guide results in exactly 0.92 μs of timing error rather than 1 μs, but the rule of thumb is to use a direct microsecond-to-mil relationship. This information is useful in judging the amount of tips remaining on a headwheel, as outlined in Chapter 11.

Note from Fig. 2-12 that the tolerance on the guide radius is from 1.0334 inches maximum to 1.0329 inches minimum. Thus the tolerance is 1.0334 − 1.0329, or 0.0005 inch (0.5 mil). Let us see what this seemingly tight tolerance actually means in practice.

Assume that a "standard recording" (precisely concentric guide and pole-tip arc) has been made on a headwheel assembly with the maximum guide radius. Further assume that this same tape is now played back on a headwheel assembly which has the minimum guide radius (0.5 mil smaller). The panel is adjusted for exact concentricity. Fig. 2-15A shows the result. When precisely concentric operation is carried out, the smaller guide radius gives a geometric error (timing error) which is 0.5 μs in the skew direction, indicating that the guide to *too close* to the headwheel. Note, however, that this skew error consists of lines that are perfectly straight.

Now if this guide is backed away from the headwheel assembly 0.5 mil, concentric operation is lost (Fig. 2-13B). If the recording had been made with this same headwheel panel, the result would be as in Fig. 2-15B, which is the same as was indicated in Fig. 2-14B. In this case, however, the guide is actually being adjusted to obtain *minimum skewing* of the recorded signal. Since the recorded signal was made with a guide radius 0.5 mil larger, the playback guide radius will be made 0.5 mil larger (0.5 mil lighter pressure) by backing the guide away 0.5 mil from precisely concentric operation.

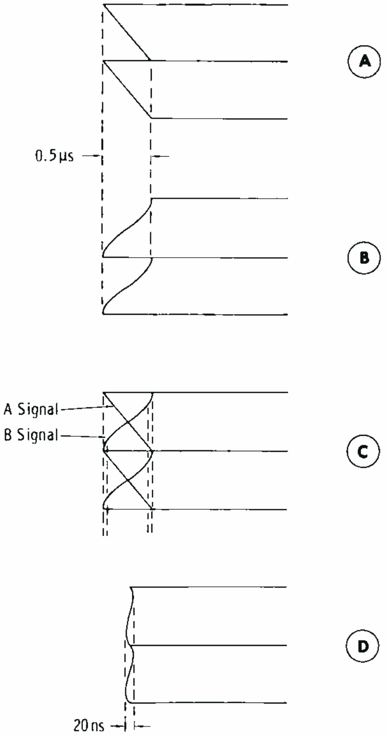
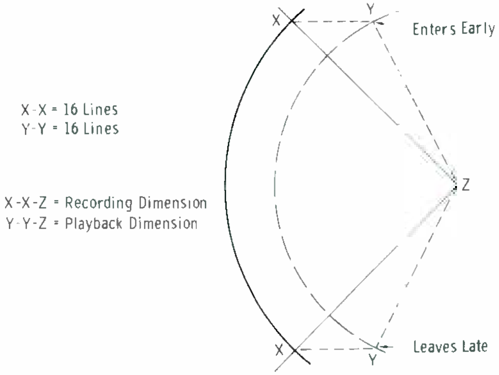


Fig. 2-15. Interchange S-distortion.

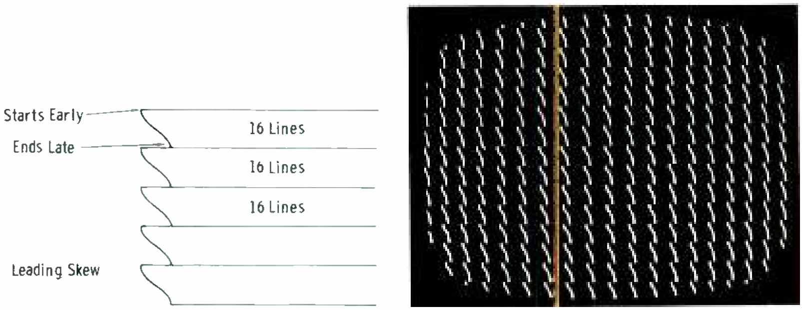
See Fig. 2-15C. Note that the cancellation of timing error is not perfect, due to the curvature caused by nonconcentric operation of the panel. As shown by Fig. 2-15D, the resultant "interchange S-distortion" is about 20 nanoseconds peak-to-peak at the tolerance extremes. Although the stated guide dimensions are reasonable manufacturing tolerances (0.5 mil, or 500 microinches, is about 1/6 the thickness of this page), manufacturers are holding even closer tolerances. Furthermore, such errors are readily reduced to practically zero by automatic time correction circuitry, as discussed in Chapter 6.

Tape Vacuum Guide Too Close to Head

1. In Fig. 2-16A, X-X-Z represents the recording dimension with a given number of pulses in arc X-X. The playback dimension when the guide is too close to the head is represented by Y-Y-Z. Here, arc Y-Y contains the same number of pulses as X-X. The pole tip now enters early and leaves late compared to the recording time base.
2. Each band of lines starts early and ends late, producing leading skew (Fig. 2-16B), which is opposite to that of Fig. 2-14B.



(*A*) *Recording and playback dimensions.*



(*B*) *Bands of lines.* (*C*) *Effect on vertical lines.*

Fig. 2-16. Space distortion, vacuum guide too close to head.

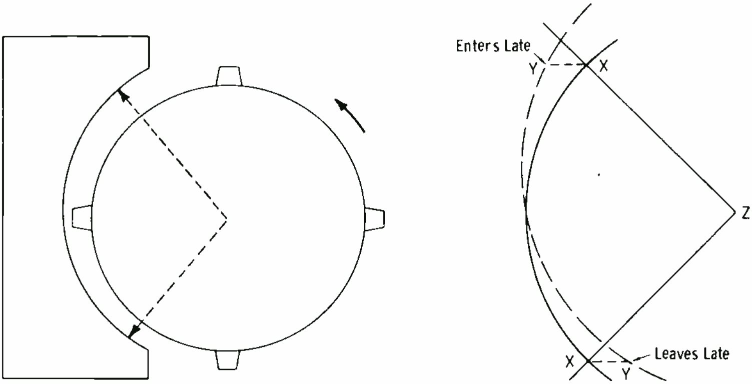
3. The effect on reproduced vertical lines of space distortion caused when the vacuum guide is too close to the head is shown in Fig. 2-16C.

Tape Vacuum Guide Too High

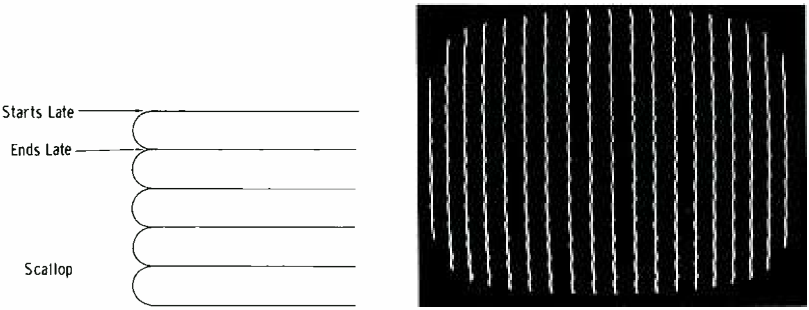
Vertical alignment of the guide constitutes a mechanical adjustment only. The correct alignment is that which allows maximum concentricity of the tape with the pole-tip circumference. A major problem in the interchangeability and interspliceability of the tape is maintaining the same *stretch* of tape at top and bottom of the pole-tip arc.

1. With the guide too high (Fig. 2-17A), less stretch occurs at the top than at the bottom; hence, there is lack of concentricity.
2. Assuming the tape was recorded with correct concentricity, the pole tip enters late and leaves late compared to the recording time base (Fig. 2-17B).
3. The start and end of each band of lines is late, producing a scallop, as shown in Fig. 2-17C.
4. Vertical lines on a video monitor appear as shown in Fig. 2-17D when the guide is too high.

If a recording is made with the guide positioned as shown in Fig. 2-17A, it can be played back on the same head without distortion. However, if



(*A*) *Guide position too high.* (*B*) *Recording and playback dimensions.*



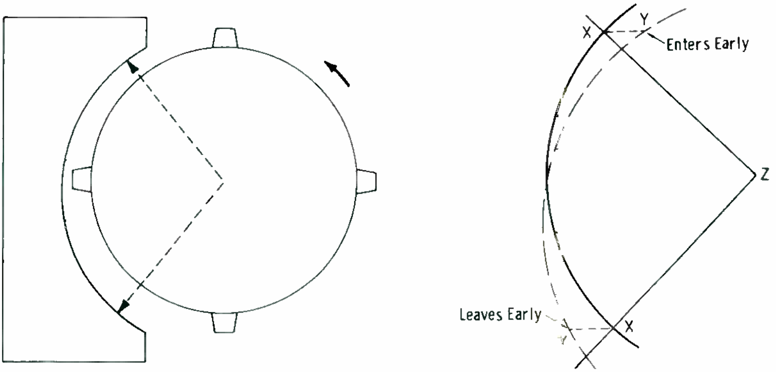
(*C*) *Bands of lines.* (*D*) *Effect on vertical lines.*

Fig. 2-17. Space distortion, vacuum guide too high.

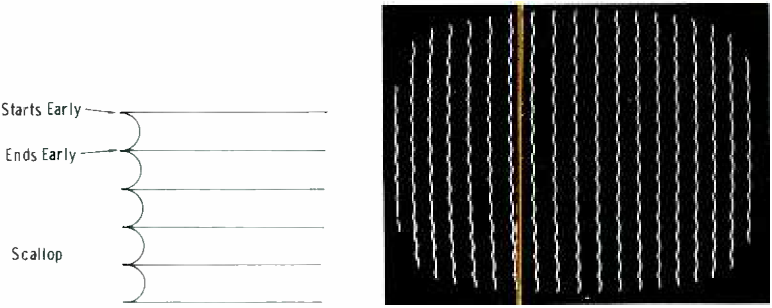
this tape is played back on a correctly adjusted head assembly, the guide must be misadjusted vertically to eliminate scalloping in the picture. A misadjustment such as that in Fig. 2-17A produces excessive wear on the bottom half of the tape.

Tape Vacuum Guide Too Low

1. When the guide is positioned too low (Fig. 2-18A), more stretch occurs at the top than at the bottom of the tape.



(*A*) *Guide position too low.* (*B*) *Recording and playback dimensions.*



(*C*) *Bands of lines.* (*D*) *Effect on vertical lines.*

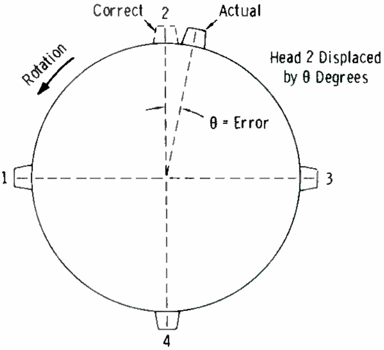
Fig. 2-18. Space distortion, vacuum guide too low.

2. Assuming that the recording is made at the correct vertical alignment, the pole tip enters early and leaves early compared to the recording time base (Fig. 2-18B).
3. Each band of lines starts and leaves early (Fig. 2-18C), producing a scallop which is opposite to that of Fig. 2-17C.

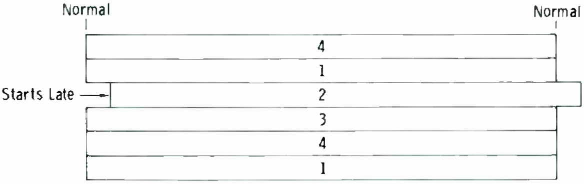
4. Vertical lines on a video monitor appear as shown in Fig. 2-18D when the tape guide is adjusted too low.

Quadrature Error

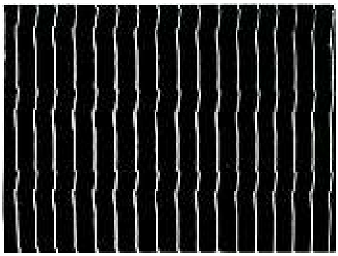
In the rotary-head tv-tape system, the ideal head spacing is exactly 90 degrees plus or minus zero seconds of arc. Manufacturing problems understandably place considerable strain on this "perfect" situation. For example, since there are 60 minutes in a degree and 60 seconds in a minute, there are 90 × 60 × 60 = 324,000 seconds in 90 degrees. Table 2-1 states that 90° of head rotation occurs in 1041.6 μs. Therefore the time required for one second of rotation is 1041.6/324,000, or 0.00321 microsecond. If the head is off quadrature by just 30 seconds of arc, the error is equal to 30 × 0.00321, or 0.0963 microsecond—close to 0.1 microsecond.



(A) *Head.*



(B) *Effect on lines.*



(C) *Appearance on monitor.*

Fig. 2-19. Space distortion, head-quadrature error.

If a recording is made with +30 seconds of quadrature error and played back on a different head with −30 seconds of error, the accumulated error is 60 seconds (1 minute). This equals an approximately 0.2-microsecond error in quadrature—a noticeable displacement of a complete band of lines. In practice, quadrature error must be held under approximately ±0.02 microsecond to be invisible on vertical picture lines.

Space distortion caused by head quadrature error is shown in Fig. 2-19. The position of the heads on the rotating drum is shown in Fig. 2-19A. Notice that head 2 lags the correct position by θ degrees. Assuming that a tape is recorded with correct quadrature, the band of lines from head 2 is displaced on playback as shown in Fig. 2-19B. Displacement is to the right, since the head enters the recorded information late. Fig. 2-19C shows the effect on a series of vertical lines viewed on a video monitor.

If a recording were made with the error shown in Fig. 2-19A and played back with correctly spaced leads, head 2 would be advanced in time relative to the recorded information. This deletes a portion of the duplicated overlap interval (Fig. 2-9) and starts the lines of head 2 slightly early, displacing the band of lines to the left.

The "reading" of quadrature error is complicated by certain misleading factors, such as possible overmodulation, overcompensation of high-frequency response, gap tilt, and horizontal flywheel in the monitor.

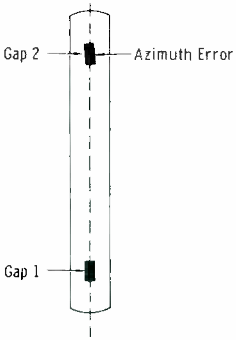


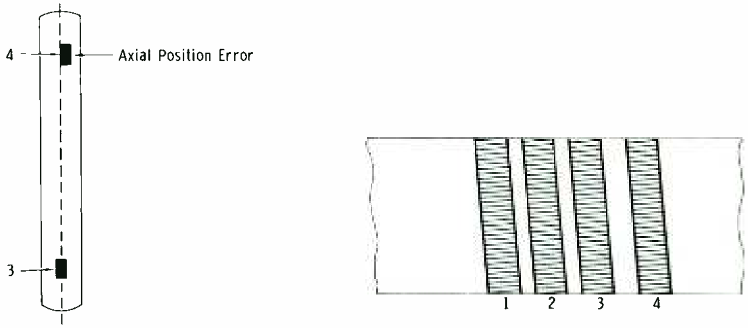
Fig. 2-20. Azimuth error.

Other Time-Space Error Sources

Azimuth error, a manufacturing problem not subject to the control of the user, occurs when the gap is not perpendicular to the transverse magnetic track made on a tape by a head with zero azimuth error. In Fig. 2-20, gap 2 is in azimuth error. If a properly recorded tape is played back with this error present, banding of the number 2 channel from loss of higher frequencies and reduction of signal-to-noise ratio results. A pseudoquadrature effect can also occur.

Axial-position error is another manufacturing defect. In Fig. 2-21A, head 4 is positioned to the right of its correct location. The effect of axial-position error on a recording is shown in Fig. 2-21B. Banding of one channel occurs because of irregular spacing between head tracks 3 and 4. This effect often occurs as *half-banding* on a single channel.

Techniques for checking possible head errors are outlined in Chapters 11 and 12. However, such techniques are full of pitfalls unless a good background in theory and practice is acquired.



(*A*) *Head location.* (*B*) *Tracks on tape.*

Fig. 2-21. Axial-position error.

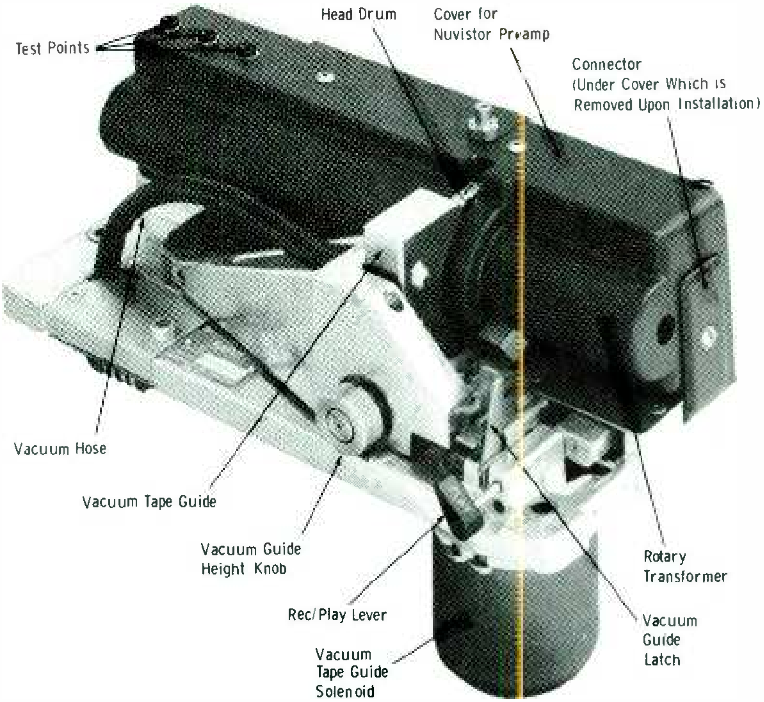
2-6. THE HEADWHEEL ASSEMBLY

Fig. 2-22 illustrates the Ampex Mark Ten head assembly. The complete assembly is built on a rigid base plate, and the base plate is fastened to the top plate of the transport by one knurled and two hex-head screws. Two integral connectors on the underside of the base plate engage mating connectors integral with the top plate.

The servo-controlled, hysteresis-synchronous, air-bearing drum motor is driven by square-wave (instead of sine-wave) ac power, generated by the Intersync servo system, which also controls its instantaneous frequency. The nominal frequency is 240 Hz.

The drum-motor armature assembly is supported by air bearings which cause it to float in a nearly frictionless condition on a thin layer of air. The air used is furnished at 55 psi (nominal) through an opening (on the underside of the base plate) which mates with an air line from the bearing air supply. *Due to the dependence of the armature upon air under pressure for its support, it is imperative that it never be turned or rotated in the absence of the bearing air pressure. To do so may seriously damage the air-bearing surfaces.*

The video head drum is supported by and mounted on the armature shaft of the drum motor. The four video heads are mounted on the head drum in precise quadrature. The drum motor turns the video head drum at 14,400 rpm.



Courtesy Ampex Corp.

Fig. 2-22. Ampex Mark Ten video head assembly.

The drum tachometer (described later) is located at the "upstream" end of the drum-motor shaft. It includes a transducer which derives a continuous signal that indicates the precise instantaneous phase position of the video head drum. This signal is fundamental to the actions of the Intersync servo.

The rotary transformer is placed adjacent to and "downstream" from the video head drum. Its primary windings numbers 1, 4, 2, and 3 are electrically connected to video heads numbers 1, 4, 2, and 3, respectively, and their core structure is supported by the drum-motor shaft. Hence the primary windings rotate with the video head drum. The core structure of the associated secondary windings is supported by the base plate of the video head assembly. The outputs of secondary windings 1, 4, 2, and 3 are routed directly to the nuvistor preamplifiers in video channels 1, 4, 2, and 3, respectively.

See Fig. 2-23 for the method of Ampex head identification. Note that the head-numbering sequence is 1-4-2-3. We will see later that head 4 is gated on immediately following head 1 on playback so that the fm from the heads is passed in sequence just as head 4 physically contacts the tape immediately after head 1. Similarly, fm from head 2 is gated on immediately following fm from head 4, etc. The heads are numbered not according to actual physical sequence, but according to gated channels. This arrangement minimizes cross talk between heads. The Ampex head-numbering sequence differs from that of RCA, but this is of no consequence in practical operations.

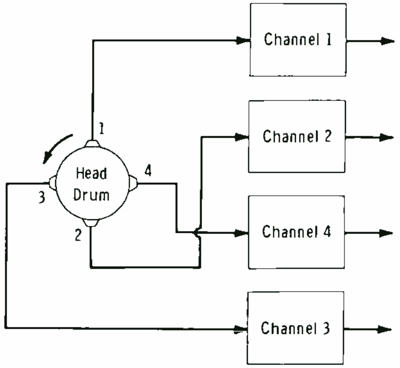


Fig. 2-23. Ampex head-identification method.

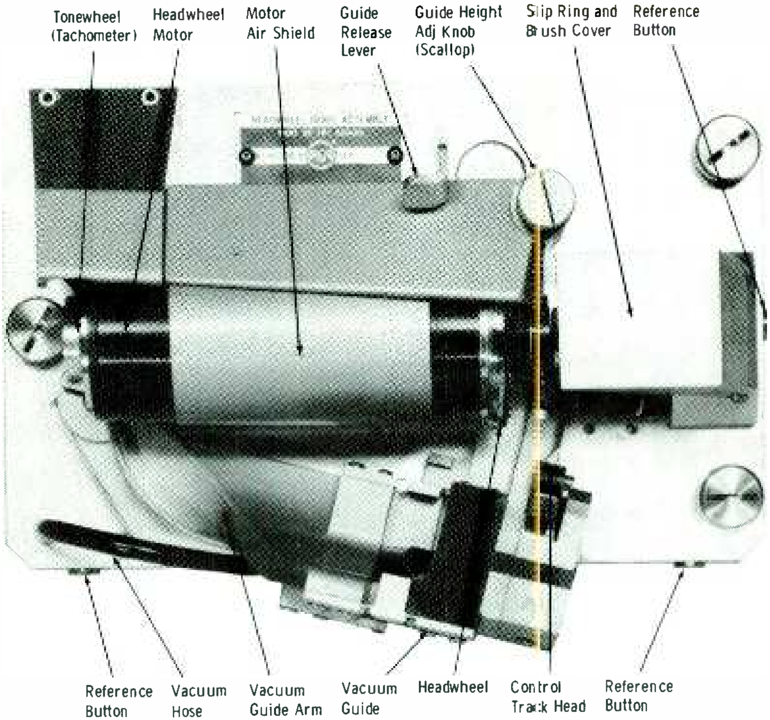
The nuvistor plug-in preamplifiers are built on one etched board adjacent to the rotary transformer. Each is a one-stage amplifier which functions during the system play mode and is biased off during the system record mode.

The connector at the right end of the video head assembly (Fig. 2-22) carries the outputs of the individual nuvistor preamplifiers, as well as their incoming power. This connector mates with another at the end of a cable, which routes the preamplifier outputs to their associated preamplifiers in the head channel housing, and also connects the power required by the nuvistors.

The surfaces of the vacuum tape guide which face the video head drum are curved to the circular path described by the rotating video head tips. Vacuum is applied to a narrow cavity between these surfaces to hold and cup the tape on this curve. A shoulder on the lower end of both curved surfaces stabilizes the position of the lower edge of the magnetic tape.

The vacuum tape guide is hinged to allow it to swing away from or toward the rotating headwheel. Fig. 2-24 shows the vacuum guide swung back from the head on the RCA headwheel panel. When the guide is closest to the head drum (Fig. 2-22), the guide latch acts to hold it there; when it is desired to open the guide to gain access to the video heads, the guide latch is actuated to unlock the guide from the closed position.

On the Ampex assembly, there are two factory-set controls of the position of the vacuum tape guide. The first is the guide-height knob; the second is the REC/PLAY lever. When the guide is closed and the REC/PLAY lever is set at the record position, the vacuum tape guide accurately positions the tape for standard tip penetrations of the tape.



Courtesy RCA

Fig. 2-24. RCA headwheel panel assembly.

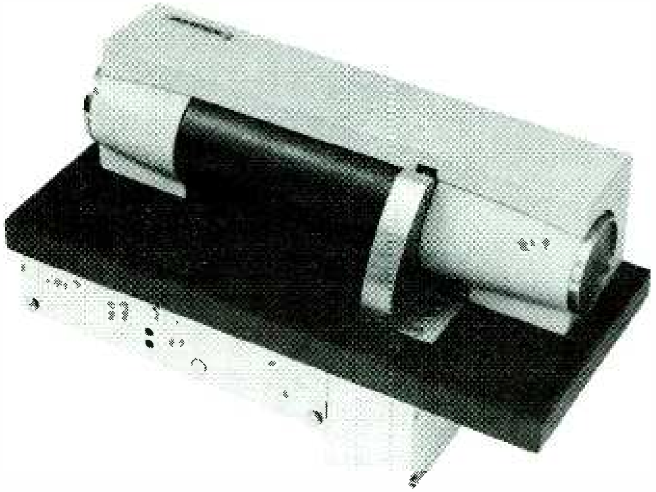
The guide solenoid advances or retracts the guide as a function of the system mode selected. It is energized to advance the guide and establish tip-to-tape engagement during the play and record modes, and it is de-energized during all other modes of tape movement (such as rewind and fast forward). Under the latter condition, a tension spring acts to retract the guide and disengage the tape from the video head tips.

The RCA headwheel panel Assembly (Fig. 2-24) plugs into receptacles on a recessed cast mounting on the tape-transport panel. Three captive thumbscrews secure the headwheel panel to the tape-transport panel and facilitate removal and replacement. The headwheel motor rotates on an air bearing to drive the video headwheel. A jumper wire connected to the headwheel panel activates the high-pressure air system when the headwheel panel is plugged into position on the tape-transport panel. Removal of the headwheel panel stops the high-pressure air system from operating.

NOTE: The headwheel panel is a precision instrument that requires special factory procedures using special tools and instruments for maintenance. Therefore it is strongly recommended that parts replacement be avoided and maintenance be limited to the procedures described in the instruction book. If operating difficulty is encountered that cannot be corrected with the cleaning and adjustment procedures presented, the headwheel panel should be replaced with a new or reconditioned headwheel panel from spare-parts stock.

The headwheel is a nonmagnetic wheel having four equally spaced video heads mounted on it. The headwheel diameter is approximately 2.0642 inches, and the video heads protrude beyond the wheel diameter by approximately 3.5 mils when the headwheel is new. The heads are mounted with high precision to obtain a precise quadrature of the four gaps around the wheel rim.

The video heads are 10 mils wide and consist of a coil on a trapezoidal ferrite core, a hard spacer for maintaining a precise gap length, and metal pole pieces of Alfecon. Resonance of the head with its load capacitance produces a "ledge" at the carrier frequency; this normally offsets a falling response due to head losses.



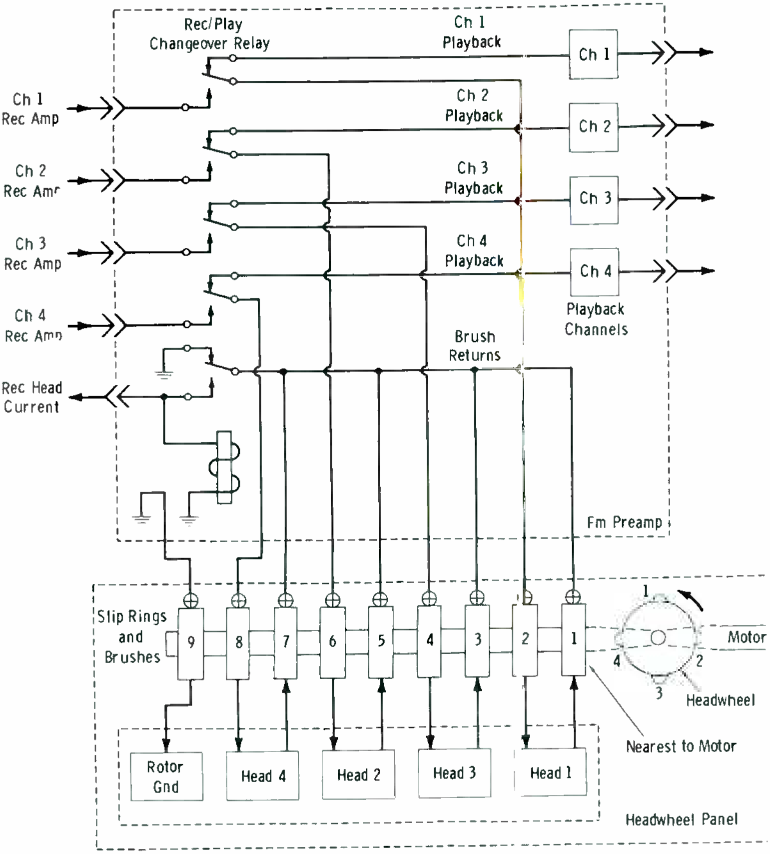
Courtesy Ampex Corp.

Fig. 2-25. Ampex Mark XX video head.

The headwheel motor, headwheel, slip rings, and brushes form a single assembly. The three-phase asynchronous motor rotates at 240 rps. It is driven by three power amplifiers (one for each phase) in the headwheel servo system. Fig. 2-25 shows the physical appearance of the Ampex Mark XX video head. This contains a special 6-phase motor winding instead of the conventional 3-phase type. It is used in the Ampex AVR-1 tape system, and the ACR-25 video cassette system (described in Chapter 13.)

The motor is surrounded by a metal shroud which serves both as a magnetic shield and an air duct. Cooling air is drawn in at the headwheel end of the motor, passes over the motor housing, and is exhausted to the headwheel blower through a hole in the headwheel mounting plate.

Fig. 2-26 illustrates the RCA method of identifying the video heads. Compare this to the Ampex method of Fig. 2-23. Nine silver slip rings mounted on the headwheel shaft serve to connect the video-head signals to associated brushes and output connector pins. Each of the four heads has separate input and return wires to isolate their respective signals and reduce cross talk. The rotor ground connection is made with a final connection to the ninth slip ring. Two carbon brushes associated with each slip ring are spring loaded in pairs to equalize forces and increase reliability. Note that the heads on the rotating wheel are numbered in sequence, 1-2-3-4. However, head 1 is connected to the first pair of brushes (1 and 2), while head 2 is connected to pair 5 and 6. Note that if the RCA method



Note: Changeover Relay Shown in Play Position

Fig. 2-26. RCA head-identification method.

of identification was in the manner of Ampex, the heads would be numbered 1-3-2-4 (as arranged on the slip-ring assembly) compared to the Ampex sequence of 1-4-2-3. Recordings made on either system are entirely compatible and interchangeable; the head-numbering method is immaterial in this respect. But the user must be familiar with the method used in his particular system. Table 2-2 correlates the slip-ring numbers and associated signals.

The tonewheel and associated tonewheel head are used to provide an indication of the speed and angular position of the headwheel. The tonewheel head is an electromagnet with a coaxial gap. As the tonewheel rotates, a notch in its rim varies the reluctance of the head and produces 240-Hz pulses in the pickup coil. The tonewheel is mounted so that the notch is located at a precisely determined position with respect to video head 1.

Table 2-2. RCA Slip Rings and Signals

Slip Ring	Signal
1 (nearest motor)	Head 1 return
2	Head 1 input
3	Head 3 return
4	Head 3 input
5	Head 2 return
6	Head 2 input
7	Head 4 return
8	Head 4 input
9	Rotor ground

The vacuum guide assembly consists of a solid piece of nonmagnetic material that is curved to a required inner radius. A slot at the center of the inner radius provides clearance for protrusion into the tape of the pole tips on the video heads. Two additional slots on each side of the center slot provide an orifice for the vacuum side of the low-pressure air system. Vacuum holds the video tape against the curved inner radius to form a precise cylindrical surface for penetration by the video heads during headwheel rotation.

The vacuum guide is mounted on a triangular-shaped arm which is pivoted near one end of the headwheel panel. The guide end of the vacuum guide is supported by ball-tipped assemblies that are positioned over an adjustable wedge-type assembly when the vacuum guide is closed. An associated thumb screw moves the wedge assembly in a perpendicular direction with respect to the ball-tipped assemblies, thereby making the guide arm (and video tape) perpendicular with respect to the headwheel panel. This provides the scallop adjustment required during setup procedures.

After the vacuum guide has been locked in the general operating area with the vacuum-guide release lever, tape-penetration pressure is provided by the guide-arm assembly. The guide-arm assembly is spring-loaded to press an eccentric bearing against the edge to the vacuum guide and move the guide and tape away from the rotating headwheel when air pressure is removed. This is a safety feature that prevents the headwheel from damaging the tape when the machine is stopped, or during other operations which require the tape to stop while the headwheel continues to rotate.

The guide-arm assembly consists of a round shaft with an arm clamped at one end and a bearing mounted eccentrically at the opposite end. A flat head at the upper end of the shaft contains an extension of the shaft near the end of the flat head. The bearing is mounted on this extension to provide an eccentric pressure to the edge of the vacuum guide. Since the vacuum-guide release mechanism provides a spring pressure pulling the vacuum guide closed, the eccentric gear holds the vacuum guide open to the required penetration depth.

Two additional bearings hold the guide-arm assembly to the headwheel panel. One is a bearing near the upper surface of the panel and is pressed into the panel and guide-arm shaft. A second bearing near the lower surface of the panel is pressed to the headwheel panel and spring loaded to the guide-arm shaft by means of a circular wedge on the shaft that is pressed to the lower bearing by a spring and spring-retaining clamp on the shaft.

When the tape is moving, air pressure is applied to the guide air cylinder (not part of the headwheel panel) which moves the guide-arm assembly with an attached circular spring until the arm attached to the eccentric shaft stops against the lead screw of the vacuum-guide positioner assembly (not part of the headwheel panel). The position of the lead screw on the vacuum-guide positioner assembly determines the amount of penetration of tape by the heads of the headwheel.

The control-track record/playback head is mounted on the triangular-shaped arm that holds the vacuum guide. In the record mode of operation, this head records a control track on the tape. In the play mode, the head picks up the control-track signal and feeds it to the servo system to provide proper tracking between the video heads and the recorded information on the tape.

Since the control-track record/playback head is mounted on the vacuum-guide arm, the head is constantly in contact with the tape (even in the stop mode). Consequently, there is a minimum of delay in reception of a control-track pulse by the servo system.

NOTE: Further details of headwheel assemblies as well as a study of the associated air systems are included in Chapter 4.

EXERCISES

Q2-1. Name the proper sequence of signal information as recorded from "top" to "bottom" of a video tape.

Q2-2. When the headwheel is mechanically aligned for minimum geometric errors, is the headwheel itself physically moved?

Q2-3. What is the head-to-tape velocity when the pole tips have a 2-mil projection?

Q2-4. (A) What is the length of a tv line (1H, or 63.5 μs) recorded with a head having a 2-mil tip projection? (B) What is the length of H recorded with a head having a 1-mil tip projection?

Q2-5. If a recording is made with a pole-tip projection of 3 mils, can it be played back on a head having only a 1-mil tip without readjustment to eliminate geometric errors?

Q2-6. If a recording is made with a head having a 0.8-mil tip projection, will it meet SMPTE standards?

Q2-7. What adjustment would be wrong in recording if there is a difference in spacing for a tv line between the top and bottom of the video track?

Q2-8. Convert 1.59 μs to nanoseconds.

Q2-9. If the raster width on a vtr picture monitor is 10 inches, what horizontal displacement will occur between "bands" of picture with a playback error of 1 μs?

Q2-10. Why would the 4.2-MHz portion of a multiburst signal break out first at the vertical center of the image when the vacuum guide is adjusted for lighter pressure (less tip penetration)?

CHAPTER 3

Basic Requirements: What the System Must Do

A brief tabulation of what the television tape system must do can be outlined as follows:

1. The composite video signal is presented to the four rotating heads simultaneously in the form of an fm signal.
2. One revolution of the headwheel lays down four video tracks. Since the tape is pulled past the headwheel at 15 in s, adjacent video tracks are spaced approximately 5 mils apart.
3. To recover the recorded information, the video-head outputs are first amplified, then fed to an electronic switcher which selects the signal from the head that is in contact with the tape. This selection occurs during horizontal-retrace intervals so that switching transients are invisible.
4. The electronic-switcher output is then demodulated to recover the video signal from the rf carrier. The recovered video is then processed to "clean up" the sync and blanking intervals for distribution to the television system.
5. For proper synchronization, the tape velocity (15 in/s) must be locked to the headwheel rotation (240 rps). During recording, stripped-off sync from the incoming video is utilized to obtain a 240-Hz signal (4 times a field pulse frequency of 60 Hz), which is amplified to obtain sufficient power to drive the headwheel. This 240-Hz signal is also converted to a sine wave, which is recorded on the control track of the tape.
6. Also during the record mode, a signal determined by the speed of the headwheel is obtained and divided to 60 Hz to supply power to the capstan motor. The speed of the capstan motor has absolute control over the velocity of the tape, which is a nominal 15 inches per second.
7. In the playback mode, the headwheel again rotates at 240 rps with

the initial reference being either the power-line frequency or local sync. The 240-Hz control-track signal is phase-compared to the playback speed of the headwheel, and any phase error slightly modifies the 60-Hz frequency applied to the capstan motor. Thus, the tape velocity is continuously maintained so that the rotating heads sweep directly across the video tracks originally laid down.

8. The audio signal is handled by conventional magnetic-recording techniques. (The audio portion of the recording system is outlined later in this chapter.)

3-1. THE TAPE TRANSPORT

The tape transport conveys the magnetic tape across the recording and pick-up heads at the correct velocity and tension. We will cover only the basic function and orientation in this chapter. Chapter 4 describes in detail the transport and associated equipment.

The basic transport, whether it is physically placed horizontally or vertically, is illustrated by Fig. 3-1. The following numbers refer to the identification numbers given in Fig. 3-1.

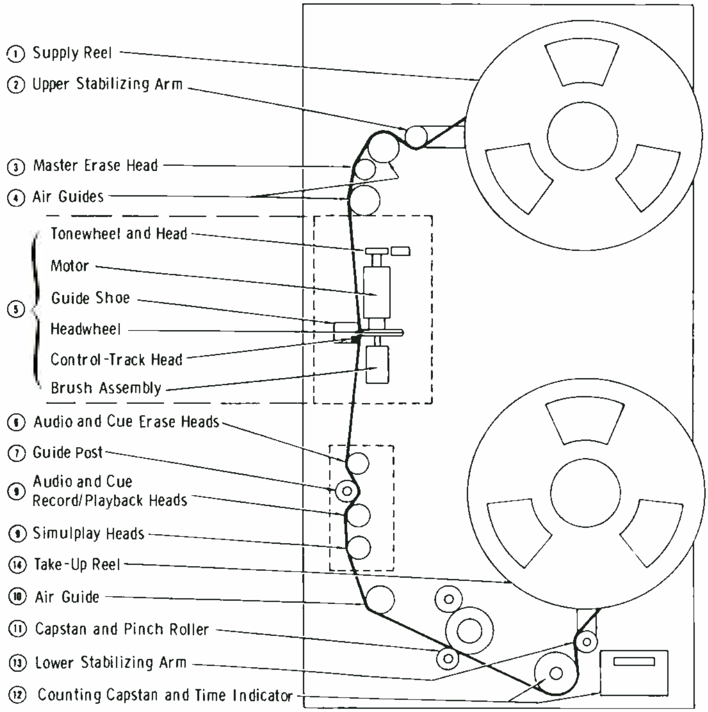


Fig. 3-1. The basic RCA tape transport.

Table 3-1. Tape-Reel Data

Feet	Minutes	Reel Diameter (Inches)
1200	16	6
2400	32	8
4800	64	12½
7200	96	14

1. The supply reel contains the tape on which a recording is to be made or from which a recording is to be played. The length and recording times for the various reel diameters are given in Table 3-1.
2. The upper (left in a horizontal tape transport) stabilizing arm provides a damping action and takes up excess tape in the event of erratic motion, as in starting. (See Item 13.)
3. The master erase head is energized (in the record mode only) to erase any previous signals.
4. Air guides preceding and following the master erase head position the tape for its approach to the headwheel. Air under pressure from the headwheel blower escapes through small pinholes in the guides across which the tape passes. This technique is sometimes referred to as air lubrication. (Not always used.)
5. Video and control signals are either written onto or read from the tape by the headwheel panel assembly.
6. The audio- and cue-erase heads (energized in the record mode only) clear their respective tracks of any previous information and remove the video from this portion of the tape.
7. This guide post serves to maintain tight tape contact with heads 6, 8, and 9.
8. Simulplay heads consist of an audio playback head at the top of the tape, which functions to ensure that an audio track is being recorded, and a control-track playback head at the bottom of the tape to ensure the control-track amplitude is maintained. The two heads are mounted on a single post.
9. The audio record/playback head is at the top of the post. The cue record/playback head is at the bottom of the post. The relative location of the sound and cue tracks is given in Fig. 2-2.
10. This air guide changes the direction of the tape for approach to the capstan and pinch rollers.
11. In the normal play and record modes, the pinch rollers, actuated by a rotary solenoid through a spring-loaded linkage, clamp the tape against the capstan, which controls the tape speed. The shaft of the capstan motor is sized to give a tape velocity of 15 in/s at a motor speed of 600 rpm. A hysteresis-synchronous two-phase motor with 11 inch-ounces rated running torque is employed. A flywheel is

mounted on the rear end of the capstan-motor shaft to smooth out speed fluctuations.

12. The counting-capstan diameter and spur gears are designed to give one count per 15 inches of tape. The counter indicates minutes and seconds of tape, with a maximum time of 99 minutes and 59 seconds.
13. The lower (or right) stabilizing arm provides the same control over the tape on starting the transport as does the upper arm (2). Both of these arms sometimes employ unidirectional air dampers (mounted on the rear of the support panel) for proper tape damping and stabilization.
14. The takeup reel provides storage of the tape after it passes through the machine.

The headwheel blower, mentioned under item 4, cleans and cools the headwheel. A permanently lubricated ball-bearing motor drives a multistage blower which draws the air from the headwheel panel over an oil-wetted wire filter. This filter traps dust, lint, and iron-oxide particles from the tape and headwheel.

In the normal play and record modes, the reel motors supply power to hold back or take up the tape; the capstan maintains full control over tape speed. During rewind, the upper reel motor is fully energized, and the lower motor is energized to rotate counterclockwise (although its direction of rotation is clockwise) to maintain tape tension and avoid spillage. During either rewind or fast forward, the pinch rollers are lifted to disengage the capstan.

Brakes are spring-actuated and solenoid-released for fail-safe operation. Braking is done by an asbestos-lined band on a brass drum. The linkage is arranged to give differential braking on approximately 240° of the drum. Differential braking is used to keep the tape tight during stop from high-speed wind or rewind.

The adjustment and maintenance of proper tensions on the tape transport are very important to overall system stability. The techniques are outlined in Chapter 12.

3-2. THE RECORDING MODE

Fig. 3-2 is a functional block diagram of the basic system when it is in the record mode of operation. Only the basic requirements not including later refinements are discussed at this time. The audio section is also disregarded at this time. Notice that the majority of circuits are involved in a time (synchronizing) function rather than in handling video. The following numbers correspond to the like-numbered points in Fig. 3-2.

1. The video signal is applied to a frequency modulator. The resulting fm signal is heterodyned with a fixed oscillator.

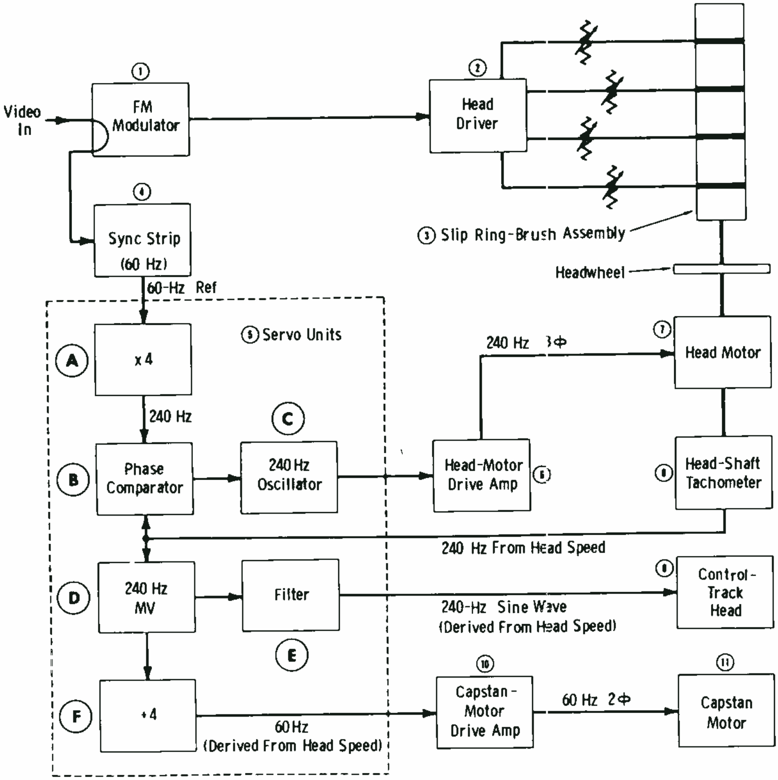


Fig. 3-2. Basic block diagram, recording mode.

2. The fm output from the modulator is amplified and split into four separate channels, one for each of the rotating video heads. This is necessary in the record mode because the video amplitude of each head must be adjusted individually to obtain optimum results. (NOTE: Whenever "video" is mentioned relative to the video heads, it must be understood that the signal is in the form of a frequency-modulated carrier.)
3. The individually adjusted fm outputs from the driver amplifier drive all four video heads in parallel. No head-channel switching occurs during the record mode of operation.

This completes the basic video function when recording. The remaining functions serve in the timing of the recorded signals.

4. Sync pulses are stripped from the video signal being recorded, and the field frequency (60 Hz) provides the initiating power source for the rotating-head motor. This is termed the reference pulse.
5. The 60-Hz pulses are multiplied to 240 Hz in frequency multiplier

A and fed into phase-comparison circuit B. The other side of this comparator receives a 240-Hz nominal frequency from the head-shaft tachometer, a device for measuring shaft speed. The resultant error signal is used to control the nominal frequency of 240-Hz oscillator C, which feeds the head-motor drive amplifier.

6. The head-motor drive amplifier is capable of supplying over 80 watts of 240-Hz, three-phase power to the head motor. Nominal power consumption is about 50 watts. The multiple-phase output is obtained through the use of Scott-connected transformers.
7. The head motor is a three-phase 240-Hz type.
8. The head-tachometer signal is used to generate the master-control signal recorded on the tape and to develop the initial power reference for the capstan motor. This signal indicates the relative position of the heads, controlled by the head motor, and the longitudinal position of the tape, controlled by the capstan motor.

The tachometer (Fig. 3-3) is simply a timing ring and a pickup head. For example, the RCA "tonewheel" is a metal wheel with a notch that breaks the magnetic path as it passes across the tonewheel pickup head, inducing a pulse of current. The pulse is used to form a symmetrical square wave of 240 Hz.

9. The control-track head records the signal (now a sine wave) which is derived from the head tachometer. Since this same initial reference from the head tachometer is also fed to the phase comparator (B of item 5), any tendency of the motor speed to "hunt" is compared to the original signal timing to indicate the magnitude of error. The corrective action of the servo controls the motor speed.
10. The capstan-motor drive amplifier receives 60-Hz information derived from the tachometer (through D and F of Fig. 3-2) and provides amplification to the two-phase power necessary for the capstan

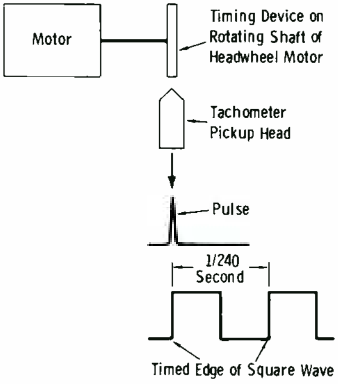


Fig. 3-3. The tachometer, or timer.

motor. Thus, the capstan is electronically coupled to the rotation of the video heads.

11. The capstan motor is a two-phase synchronous type. It has full control over the tape speed, which is phase-locked to the rotating heads in the manner described previously.

Some important relationships to remember concerning the basic recording mode are as follows:

1. The video to be recorded is converted to an fm carrier, which is split into four individual signals for feeding to the rotating heads through a slip-ring brush assembly. The carrier amplitude for each individual head is adjusted to obtain optimum playback of the recorded signal. Pre-emphasis is employed to compensate for various high-frequency losses in the head-to-tape response.
2. The speed of the rotating-head motor is made four times the vertical frequency of the signal being recorded ($60 \times 4 = 240$ rps). The vertical-scanning frequency in the incoming signal itself supplies the initial power for this motor so that any line-to-line or field-to-field phase drift is followed by the motor.
3. The speed of the head motor determines the absolute values of the deflection frequencies, control-track signal, and capstan speed; therefore, it must be tightly controlled. A three-phase winding permits tighter phase control with less power. The leading edge of the tachometer signal bears a direct relationship to the head in contact with the tape. This signal is continually compared with the initial reference pulse so that any tendency of the motor to hunt in speed is corrected by an error signal.
4. The action described in the preceding paragraph assures that each picture field occupies exactly 16 complete transverse tracks on the tape. (Each revolution produces four tracks. This is one-fourth field, so four revolutions equal one field, or 16 tracks.)
5. Since the speed of the head motor is the determining factor for all frequency components, the signal from the head tachometer is converted to a sine wave (nominal frequency of 240 Hz) and recorded as a control track to supply the playback circuits with proper timing information.
6. The head-tachometer signal is also divided down to 60 Hz to be amplified for power to drive the capstan motor.
7. The phase-stability requirements for the capstan motor are not as severe as for the head motor. Therefore a two-phase motor is practical.

NOTE: The foregoing discussion has omitted the audio function and the circuitry associated with the vacuum-guide control. Audio is covered later in this chapter, and the vacuum-guide circuitry is covered in Chapter 7.

It should be understood that the method of attack in system functions is, in some instances, quite different between Ampex and RCA practice. Except where noted, the discussions in this section are general in nature rather than specific. The first consideration is to become introduced to fundamental working requirements.

For a more complete diagram of the basic function of modern servos in the record mode, substitute the drawing of Fig. 3-4 for the dashed-in area of Fig. 3-2.

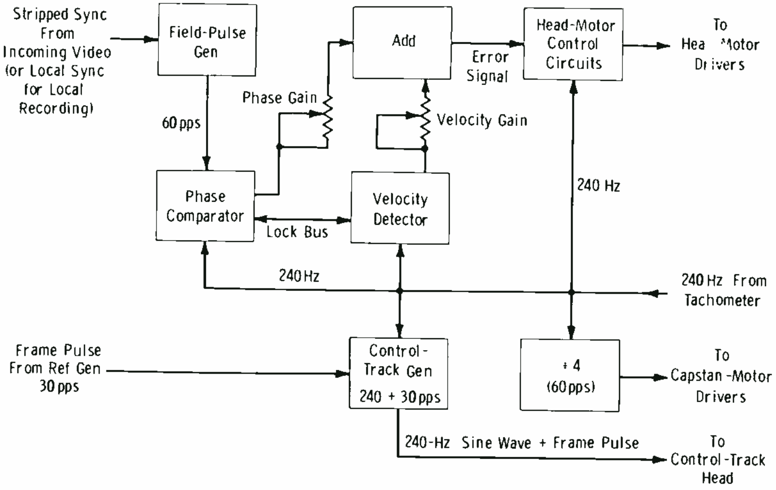


Fig. 3-4. Basic servo units (record mode).

Since the speed of the head motor (nominally 240 rps) determines absolute values of deflection frequencies (video scanning), control-track signal, and capstan speed, this reference (pulse from head tachometer) is made as "tight" as possible relative to the recorded video signal.

Follow Fig. 3-4. Pulses are formed from the stripped-off sync of the incoming signal (being recorded) at the nominal field rate of 60 Hz. These pulses feed one side of a phase comparator. The other side of the phase comparator receives the nominal 240 Hz from the head tachometer. This normally is a symmetrical waveform from a multivibrator controlled by head speed.

A velocity detector also receives the nominal 240 Hz from the head tachometer. The velocity detector compares this signal to a fixed reference (not dependent on any external signals) which has a period equal to that of the nominal 240 Hz.

Note that each leading edge of a head-speed pulse is equivalent to one revolution of the head (360°), or an average of 65.6 picture lines, one-quarter of a field, or 4166 μs. But the square wave (as shown directly from the timing ring, Fig. 3-3) that results gives a reference only for each 180° of rotation, or 33 lines.

The added outputs of the phase and velocity circuits of the servo feed a head-motor control circuit which also receives the nominal 240 Hz from the head tachometer. Head-motor control might be a voltage-controlled oscillator or a headwheel "frequency" modulator.

The head-tachometer signal, which indicates the instantaneous speed and phase of the head relative to the recorded signal, is fed to the control-track recording head by way of a generator which mixes a 30-Hz frame pulse. This pulse is called the *edit* pulse, or the *control-track frame pulse.*

A 60-Hz sine wave is derived from the head-tachometer signal and used to lock the capstan to the headwheel speed.

Now go to Fig. 3-5. Waveforms 1 and 3 in Fig. 3-5A show the lineup of the leading edge of the headwheel-speed pulse with the fixed reference. This is the function of the velocity loop in the headwheel servo. Waveform 2 is the resultant output of the head-speed multivibrator.

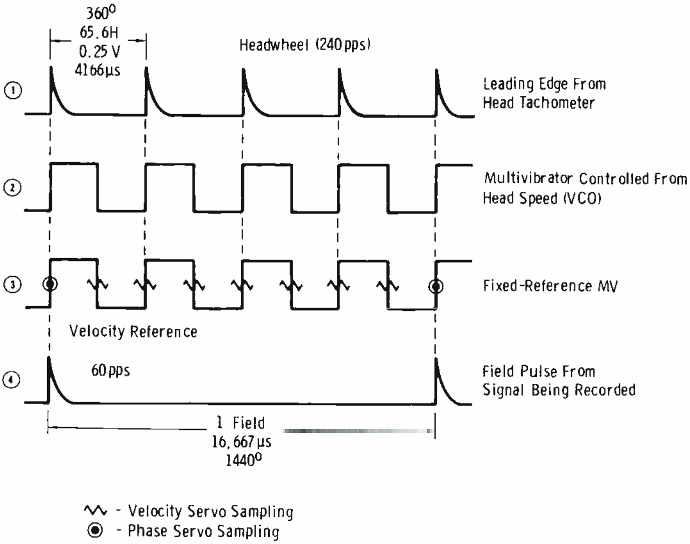
When the headwheel is slow (as in start-up), the pulses from the tachometer (waveform 5, Fig. 3-5B) will be farther apart than the pulses of the 240-Hz reference (waveform 6). An error voltage which depends on the difference between the two pulses is generated and serves to speed up the headwheel. When the two pulse trains reach identical periods, zero error voltage results, and the headwheel speed is maintained. This is done by a pulse-sampling technique (Chapter 7).

The velocity-lock condition (waveforms 7 and 8, Fig. 3-5C) means that an interval of about 33 picture lines is locked to a fixed reference within the velocity loop. You can see that this is a "long-time-constant" afc loop. Another way of looking at this is that the overall "horizontal rate" is an integration of the horizontal rate of 33 picture lines.

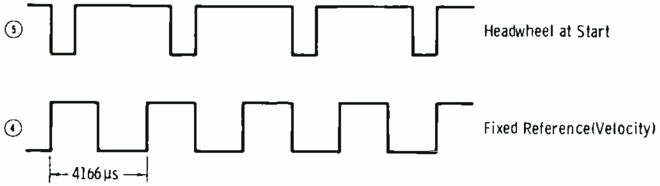
When this lock is obtained, the phase loop is enabled to compare the 60-Hz (field) reference from the signal being recorded to the horizontal envelope of about 33 lines. This 60-Hz sampling will then be on every fourth pulse of the 240-Hz signal. See waveforms 9 and 10 of Fig. 3-5C. This is the signal normally observed on the monitoring cro in the headwheel servo position.

3-3. THE PLAYBACK MODE

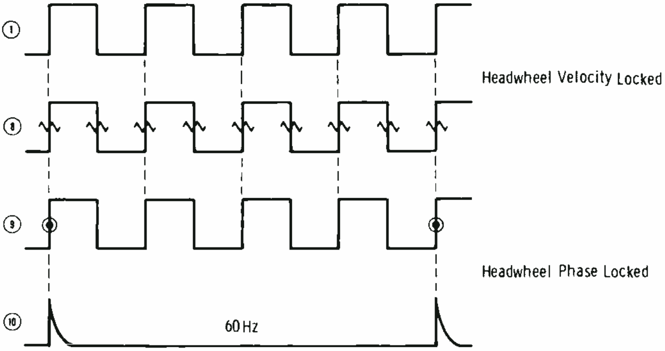
More circuitry is involved in the playback mode than in the record mode. There are two reasons for this. (1) Electronic switching is required to select only the head that is in contact with the tape. This prevents spurious signal and noise outputs from being fed to the demodulator from the high-speed heads not in direct tape contact. (2) An additional servo control is necessary for the capstan motor. The speed of the tape must be controlled by a continuous comparison of the control track laid down during recording (240 Hz) with the 240-Hz signal derived from the head-shaft tachometer.



(*A*) *System waveforms.*



(*B*) *Pulses at start-up.*



(*C*) *Phase lock.*

Fig. 3-5. Velocity and phase lock of headwheel (record mode).

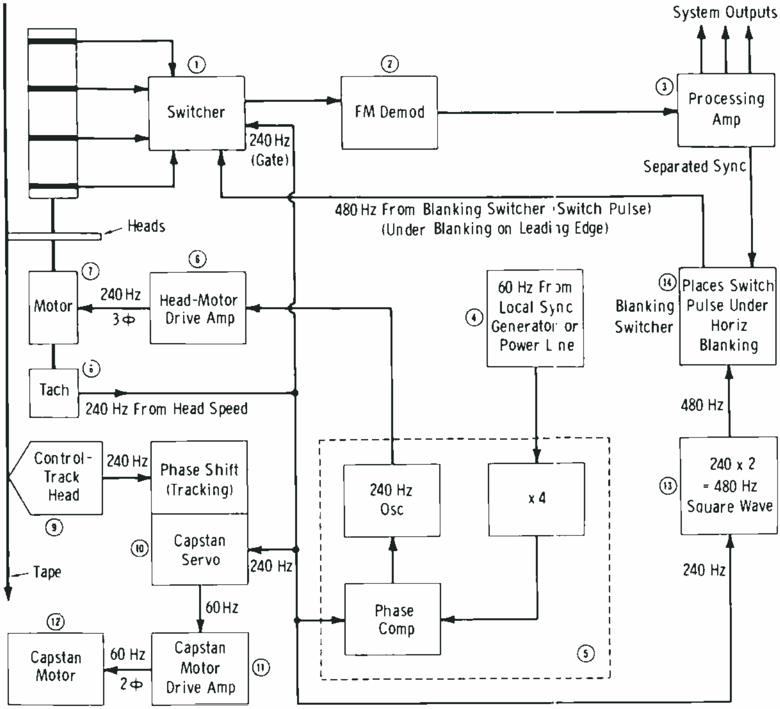


Fig. 3-6. Basic block diagram (playback mode).

This ensures that the video heads "track," or pass directly over the recorded video tracks on the tape. Failure of such control causes the relative positions of the heads along the length of the tape to drift. Thus, a head could bridge two adjacent recorded tracks rather than remaining over a single track.

A block diagram of the basic playback system is shown in Fig. 3-6. In the following explanation of the playback system, the numbers refer to those used to identify the various blocks in Fig. 3-6

1. The relatively low-level (about 2 to 5 millivolts) output from the head slip-ring brush assembly is amplified in individual preamplifiers before being fed to the switcher unit. For simplicity, the preamps are not shown in Fig. 3-6. The switcher combines the individual head inputs into a sequential and continuous single output. A 240-Hz signal from the head tachometer presets the gates. A 480-Hz signal, derived from the same source but with the leading edge placed under horizontal blanking, is used to trigger the actual switch. This technique is further explained in the discussion for item 14.
2. The fm demodulator extracts the useful video signal from the frequency-modulated carrier.

3. The processing amplifier cleans up the blanking and sync intervals of the demodulated video.
4. Either the local sync generator (color) or the 60-Hz power line (optional for monochrome) is used as the initial reference for the head-motor power.

   Caution: This *does not* mean that the reproduced signal from the tape system can be treated as a local signal for lap-dissolves or local superimposition. Neither horizontal- nor vertical-sync pulses from the tape are necessarily coincident in time with the external pulses from the local sync generator. Unit 4 is used *only* for an initial yardstick to supply a stable comparison.

NOTE: All modern recording systems do permit local lap-dissolves, supers, and special effects. At this time, however, we are studying only the most basic requirements of the magnetic video recording system. The details of refinements which allow this type of operation are in Chapter 7. The basics are outlined in Section 3-4.

5. The head motor is controlled by the same servo system that is used in the record mode, except that the initial reference signal is the local sync generator (or 60-Hz power line).
6. The head-motor drive amplifier serves the same function as for recording.
7. The head motor functions the same as for recording.
8. The signal from the head tachometer is routed to units 1, 5, 10, and 13, as shown in Fig. 3-6.
9. The control-track head reproduces the recorded control track.
10. The capstan servo compares the control-track signal (which is indicating the relative position of the heads during recording) with the head-motor tachometer signal (which indicates the playback speed and phase). From this comparison, an error signal is developed which slightly modifies the frequency of the 60-Hz oscillator used as the initial power source to drive the capstan motor. Note that a control (termed the tracking control) is provided to shift the phase of the control-track signal. If, for example, head 1 is reproducing vertical sync, tracking can be shifted so that head 2, 3, or 4 reproduces vertical sync. This allows matching of heads to obtain optimum reproduction from a tape recorded by a different head.
11. The capstan-motor drive amplifier serves the same function as for recording.
12. The capstan motor serves the same function as for recording.
13. A 480-Hz square wave is formed from the 240-Hz tachometer signal.
14. The leading edge of the 480-Hz square-wave switch pulse is made to occur during the horizontal-blanking interval. This prevents switching of channels during an active line interval; such switching results in transients in the picture.

Fig. 3-7 shows the basic principles of the switching function. Switcher-channel inputs are gated by two 90°-related, 240-Hz signals. Two 480-Hz, 180°-related pulses chop the signal at a 960-Hz rate to place the head outputs in the proper sequence in a single channel. (Details of this operation are given in Chapter 5). NOTE: The techniques used by Ampex and RCA differ, but the principle is the same.

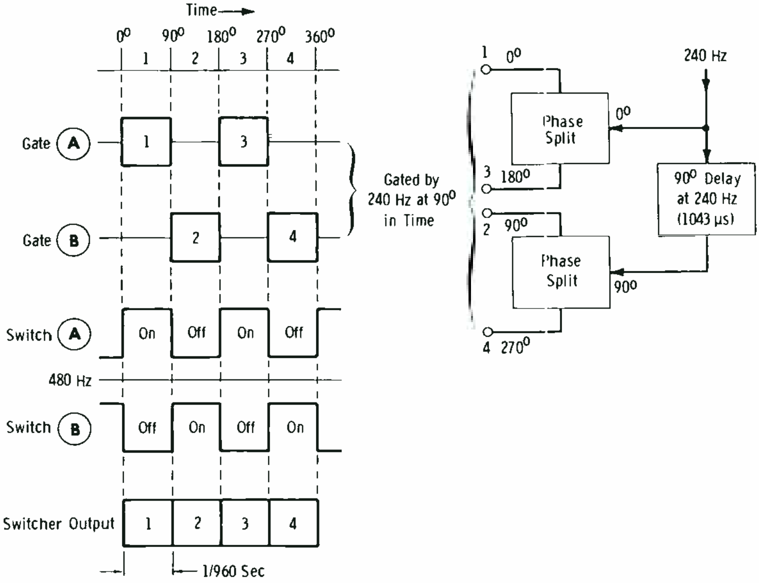


Fig. 3-7. Basic playback-switching functions.

3-4. SYNCHRONOUS PLAYBACK

First of all in playback requirements, remember the information as it is timed in recording: the headwheel must rotate one-half revolution (33 TV lines, or ⅛ field) before a timing reference is encountered to control headwheel velocity. When the tape is played back in the same manner as described above, there is no lock with station sync.

The tape sync timing in playback varies considerably relative to fixed station sync. The afc loop in the velocity servo has a long time constant which only follows the average drift across approximately 33 lines of picture information. This, in modern terminology, is a rather "loose" servo. In this internal mode of playback operation, there is no line-to-line feedback information from the tape signal itself to control the playback headwheel velocity.

If you have access to a recording system, you can demonstrate this to yourself by locking the picture monitor to local sync, while displaying the tape playback signal on the same monitor. This is why local sync generators cannot be genlocked to a tape playback in the internal mode of operation. The jitter relative to local sync exceeds genlock requirements. It is also why, when it is necessary to handle the tape playback signal for lap-dissolves or special effects, the "reverse genlock" principle must be used. The tape playback system itself must be locked and phased to the local sync generator.

Typical side-to-side (horizontal) jitter and drift of internal-mode playback of video tape is around 0.1 to 0.2 μs (100 to 200 ns), relative to station sync. This is the stability of the servos alone, to which you must add any geometric errors resulting from imperfectly aligned systems and normal tolerance of components. These are velocity errors resulting in line-to-line errors in the reproduced image. Obviously, in the case of geometric error, there are line-to-line errors in the signal sync time-space relationship. Now group all of these into one term: *time-base error.*

Let us see what the playback requirements are, to get even the very minimum stability of time base necessary to treat the tape signal as a local signal. This means "genlocking in reverse," or making the signal from the tape playback system coincident in time and stability with the local sync generator.

See Fig. 3-8. The first requirement is that the signal from the tape system be phased and then locked to the vertical rate of the local sync generator. Tape vertical alignment (tva) occurs when the tape-signal frame rate equals the reference vertical frame rate, which is the local sync rate. To do this, feedback information from the output signal of the tape system must be used to control the headwheel and capstan. This feedback information must contain a comparison between the signal coming from the tape and the local sync signal.

The added circuitry over that of Fig. 3-4 is enclosed in dash lines in Fig. 3-8. In the headwheel servo, the demodulated tape sync is compared to the local reference vertical sync. So, the signal input to the phase comparator now consists of an output from a variable delay circuit, which in turn is dependent upon coincidence between local and tape vertical-rate pulses.

In the capstan servo, the control-track signal (240 Hz) is divided (by 8) to the frame rate of 30 Hz, which is reset by the 30-Hz tape-frame pulse for coincidence. The tape-frame pulse is generated from the vertical-sync interval of the tape being played. A reference frame pulse is generated from both horizontal- and vertical-rate pulses of the local sync generator. The horizontal rate must be used to sense the field used for frame reference; in the RCA system, this is field 1, in which a full line precedes the vertical interval. Field 2 has ½ line preceding the vertical interval; this is the reference field for the Ampex system.

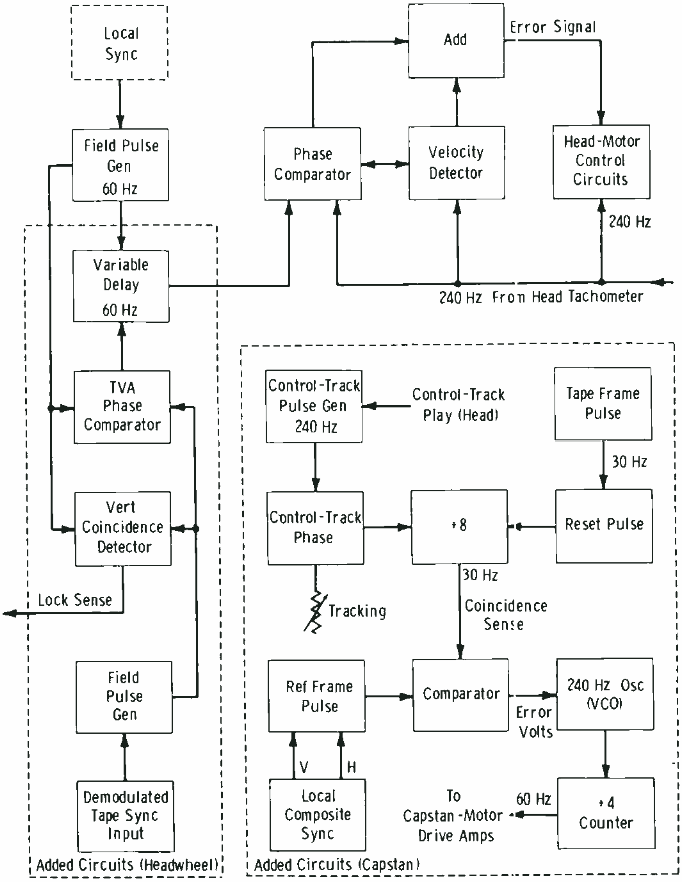


Fig. 3-8. Basic servo units (vertical alignment) for playback.

A voltage-controlled oscillator (vco) running at a nominal frequency of 240 Hz is varied in frequency in accordance with the amount of error generated in the comparator. Since the tape-frame pulses have a definite time and phase relationship with the head tachometer during recording, the capstan is "slipped" across the heads until the head playing back vertical sync is "tracked," in phase with *local* vertical-rate pulses.

This type of coarse vertical framing permits roll-free switching from local to tape sources, but there is still no coincidence with local horizontal-rate timing. Thus, additional tape horizontal alignment (tha) circuitry is required for feedback and controlling information. This will be discussed in Chapter 7. Assume for the moment that we have a tape playback signal which is "genlocked" by the local sync generator.

Now what have we done thus far in time-base stabilization? We have "tightened up" the playback servos so that we should be able to use the tape signal as we do any other conventional studio gear, such as live cameras, and film cameras. We can mix or lap-dissolve the tape-system output with any other local signal source.

In reality, we may or may not have achieved this, depending on the degree of geometric error remaining. This is why modern tape systems incorporate video time-base correcting devices which are employed in conjunction with tva and tha. Remember that tva and tha are servo functions only; they do not involve sensing errors of the headwheel or drum which result from imperfect alignment with the signal recorded on the tape (the geometric errors of Chapter 2). The correcting devices are Time Error Compensation (Amtec) for Ampex and Automatic Time Correction (ATC) for RCA. Either of them reduces residual errors to less than 0.03 μs, or 30 ns (when combined errors are within 1 μs initially).

It is obvious that a 30-ns jitter, when the picture is locked to the local sync generator horizontally and vertically, is not observable. This amount of jitter represents about one part in 2000 at the tv line rate of 15,750 Hz. But what about the color time base? The color-sync burst contains a frequency of approximately 3.58 MHz. This burst is the phase reference for all the chroma information carried in the sidebands of the chroma subcarrier of the video signal. At 3.58 MHz, one cycle represents approximately

$$\frac{1}{3.58(10^6)} = 0.28\,\mu\text{s} = 280 \text{ ns}$$

Then

$$\frac{280}{360} = 0.8 \text{ ns per degree}$$

Now, if you have a color-tape signal that exhibits as much as 30-ns jitter, there are $30/0.8 = 37.5°$ of burst jitter. Quite simply, this means the color phase will jitter over 37° to 38° of the range, which is intolerable. So for color, additional video time-base correction units are required. These units are Color Time Error Correction (Colortec) for Ampex and Color Automatic Time Correction (Color ATC) for RCA.

In practice, the monochrome error correction must be made first, then the color error correction. Timing errors can now be reduced by this combination to about 2 ns, or approximately 2.5° of jitter at 3.58 MHz. Since the jitter at the color-subcarrier time base must be about 5° to be noticed, the result is quite satisfactory.

3-5. THE AUDIO SYSTEM

In the previous drawings of the tape transport, it was noted that the audio heads are spaced in distance (and time) from the video heads. This distance is 9.25 inches, and since each picture frame occupies one-half inch along the tape, the corresponding sound for a given picture frame leads the picture by 9.25 × 2, or 18.5, frames. Perfect *lip sync* is maintained because the same audio head is used for both recording and playback. The only problem which arises is the editing (splicing) of the tape between rapidly spoken words (or continuous music) so that proper picture continuity can be maintained.

Since the tape speed is 15 in/s, the spacing in time between the sound and the corresponding picture frame is equal to (9.25/15), or 0.61 second. It is obvious, therefore, that for most editing, the first frame pulse following a spoken word may be selected for the splice (described in Chapter 10).

Conventional audio magnetic-tape methods are used for the sound track. A plot of the amount of remanence as a function of the strength of the signal field is given in Fig. 3-9. This type of transfer curve has no linear portion that would allow an undistorted signal output. Therefore a high-frequency bias (between 85 and 100 kHz) is added to the audio current, as shown.

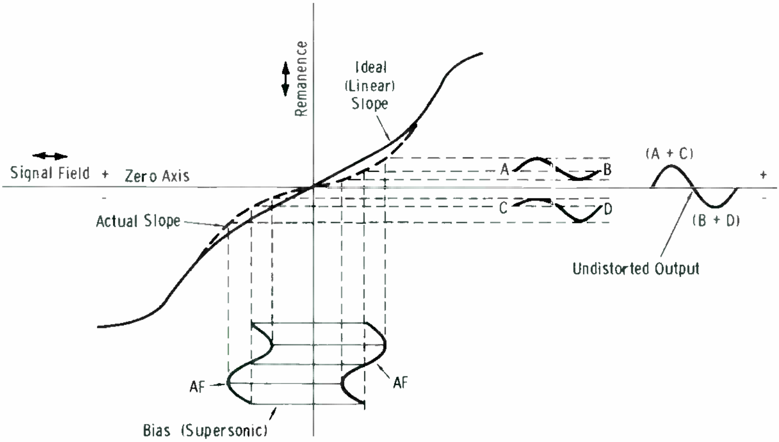


Fig. 3-9. Effect of supersonic bias.

The audio component on the plus side of the zero magnetization axis results in a distorted waveform in which loop A is larger than loop B. The audio component on the minus side results in a distorted wave in which loop C is smaller than loop D. The algebraic sum of A + C equals the algebraic sum of B + D when the loops are combined on the axis of operation, resulting in an undistorted output.

The axis of easy magnetization of the iron-oxide particles on video tape is aligned transversely across the direction of travel to favor video response. This places a slight limitation on audio bandwidth and signal-to-noise ratio, as compared to conventional 15-in/s audio tape recording. It should also be noted that the audio track on the video tape is only about 70 mils (0.07 inch) wide as compared to the conventional quarter-inch audio tape.

Review Fig. 3-1 for the audio head location. Fig. 3-10 illustrates the details of the post assemblies and the sequence of the upper and lower tape-section heads. Note the dual function of each post. Note also that a cue-track simulplay head is not provided. This position (bottom of third post) is occupied by the control-track simulplay head. The control-track record head is on the vacuum guide (Figs. 2-24 and 3-1.)

Fig. 3-11 shows the basic function of the rec/play changeover relay for audio in any tape system. The relay contacts in this drawing are shown in the play position. In this position, the contacts act as follows:

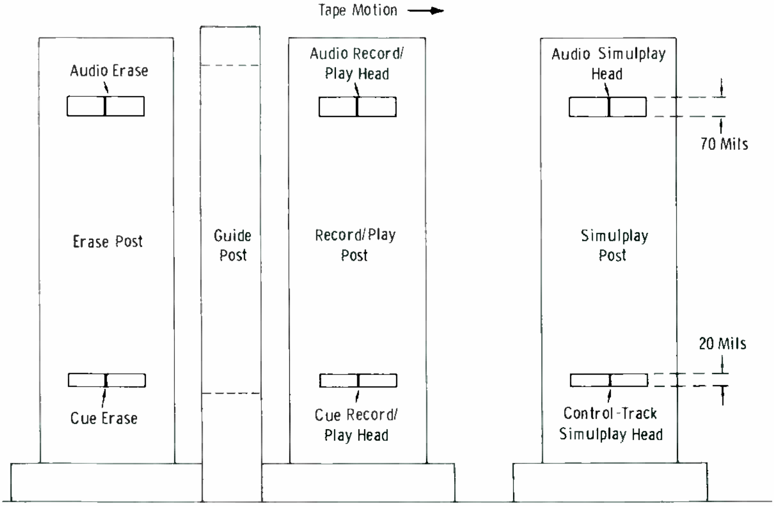


Fig. 3-10. Audio post and head arrangement.

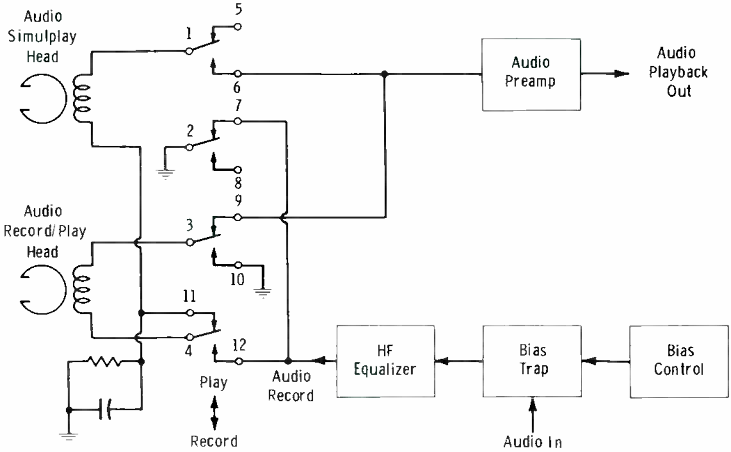


Fig. 3-11. Audio record/play relay (playback position).

1. The audio record/play head is connected to the preamplifier input. This is done through contacts 3 and 9.
2. The circuit of the simulplay head is opened by contacts 1 and 5.
3. The output of the high-frequency equalization circuit is grounded (through contacts 2 and 7) to prevent cross talk.

When in the record mode, the relay contacts accomplish the following:

1. Contact 4 connects to contact 12 to feed audio and bias into the record/play head. The other side of the head returns to ground through contacts 3 and 10.
2. The audio simulplay head is connected (through contacts 1 and 6) to the input of the playback preamplifier to permit monitoring. The simulplay head reads the audio (delayed) as it is laid down on the track by the record head.

NOTE: The high-frequency equalizer in the recording circuit is switched when the speed is changed (15 to 7½ in/s and vice versa), to provide proper equalization for the selected speed.

Maintenance, measurements, and adjustments of the audio system are covered in Chapter 12.

EXERCISES

Q3-1. What is your visualization of "video" relative to the video heads?

Q3-2. In the record mode, what signal supplies the initial timing information for the headwheel motor?

Q3-3. In the record mode, what signal supplies the initial timing information for the capstan motor?

Q3-4. In the record mode, what are the horizontal and vertical time bases of lockup?

Q3-5. In a nonsynchronous playback mode, what are the horizontal and vertical time bases of lockup?

Q3-6. In the framing (switchlock) playback mode, what are the horizontal and vertical time bases of lockup?

Q3-7. In the synchronous (genlocked) playback mode, what are the horizontal and vertical time bases of lockup?

Q3-8. What is the time base of (A) monochrome (coarse) time-error correction and (B) color error correction?

Q3-9. In the basic (nonsynchronous) playback mode, what signal supplies the basic timing information for the capstan motor?

Q3-10. What is the sequence of operation of the phase and velocity loops of a headwheel (drum) servo in either the record or play mode?

CHAPTER 4

The Tape Transport, Air Systems, and Control Circuitry

The RCA TR-70 tape transport with head cover removed is illustrated in Fig. 4-1. The Ampex VR-2000 tape transport was shown in Fig. 1-12.

4-1. FUNCTIONAL DESCRIPTION OF TAPE TRANSPORT

The tape-transport system is contained on the tape-transport panel, which is waist high and sloped back at a 45° angle to facilitate tape loading. The structural support for the tape-transport panel consists of a thick cast aluminum plate which is ground smooth on both sides. The front surface of the plate provides a reference plane from which the mounting dimensions of the various mechanical assemblies are calculated.

The following items are mounted on the tape-transport panel:

1. Drive and brake assemblies for the supply and takeup reels.
2. Capstan and pinch-roller assemblies.
3. Counting roller and counter.
4. Take-up and supply tension arms.
5. Vacuum-guide positioner and guide solenoid.
6. Selective erase head and tape lifter. The term "selective" is used because sometimes only portions of the tape are to be erased; for example, in editing procedures (Chapter 10), video is sometimes erased without erasing the control track.
7. Audio heads and audio preamplifier module (including the record/play changeover relay).
8. Mounting facilities and connections for the headwheel panel.
9. Air guide.
10. Head-hours meter.

Tape motion is controlled by three independent motors which drive the supply reel, the capstan, and the take-up reel. During record or play-

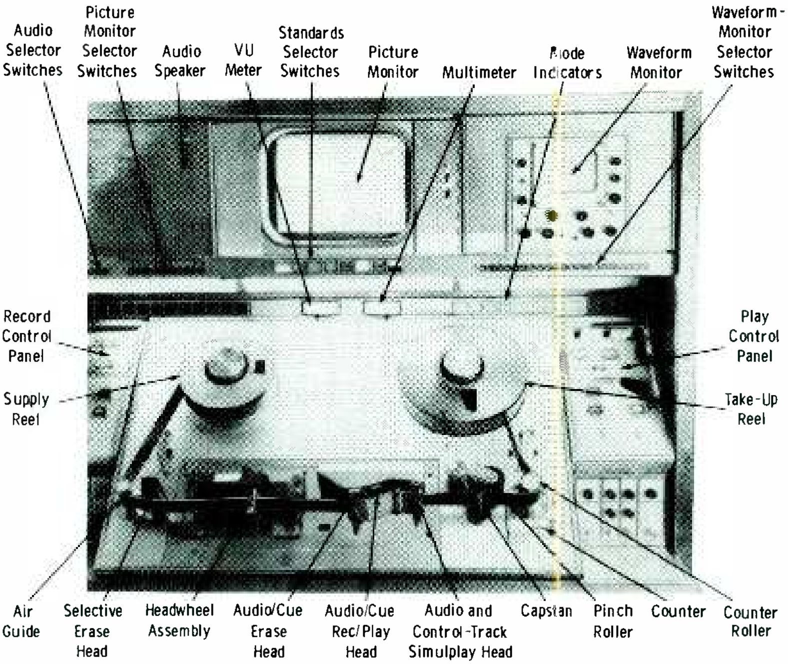


Fig. 4-1. RCA TR-70 tape transport.

back, the tape speed is controlled by the capstan; the supply and take-up reels merely provide constant torque. In the wind mode, the tape is pulled by the take-up reel, and the supply reel provides tension by pulling in the opposite direction. The reel brakes are applied automatically whenever the machine is placed in the stop mode. A foot-switch, located at the bottom center of the front of the machine, permits the brakes to be released so that the reels may be turned manually during tape threading.

The tension arms, located below each reel, take up excess tape if speed variations occur due to changes in operating modes. Tape-break switches, operated by either the take-up or supply tension arm, automatically stop the machine if the tape breaks or if the supply reel runs out of tape. A stationary, air-lubricated tape guide below the tension arm of the supply reel positions the tape for its approach to the headwheel. The air guide consists of a post that is perforated with tiny air holes and provided with flanges at the edges. Air is forced through the holes to lift the tape slightly off the surface. The flanges provide the guiding action. (In some more recent systems, the air holes have been eliminated, and rotating guides are used instead.)

Tape from the supply reel proceeds under the tension arm, over the air guide, past the tape lifter to a two-inch-wide selective erase head, and then to the headwheel, which rotates at right angles to the tape motion. Below the headwheel, a vacuum guide establishes suction which curves the tape transversely to fit the wheel and holds the tape tightly so that the video heads contact the tape. The guide position, which determines the head-to-tape pressure, is determined by a lead screw driven by the vacuum-guide positioner motor behind the tape-transport panel. The motor is controlled by the guide servo system (described in Chapter 7.)

After leaving the headwheel, the tape passes under the control-track head, which records or plays back a 240-Hz sine wave mixed with narrow 30-Hz frame pulses. The 240-Hz signal is used during playback to establish the timing of the capstan servo system so that the video heads scan along the recorded tracks. The frame pulses permit locating the correct points at which to cut the tape during tape splicing, and they serve other uses in the servo systems.

Next, the tape passes under three supports in sequence; each support contains two heads concerned with tracks at opposite edges of the tape. The first support contains the audio/cue erase heads, which remove video signals from the appropriate areas to provide space for recording on the audio and cue tracks. The second support holds the cue and audio record/playback heads. The third support holds the simultaneous playback heads which permit monitoring the audio and control tracks during recording. Because of the distance between the headwheel and the audio and cue heads, the two sound tracks are recorded 9.25 inches ahead of the corresponding video tracks. Located between the audio/cue record/playback head post and the simultaneous-playback head post is the tape-edge guide post which produces the required tape "wrap" around each head.

The tape then proceeds to the capstan and pinch roller. The pinch roller, which is actuated by a rotary solenoid during recording and playback, provides friction which enables the capstan to pull the tape. The capstan motor is driven synchronously by the capstan servo system so that the tape motion is related to the headwheel motion. The tape speed is either 7½ or 15 inches per second as determined by a speed selector switch. The capstan motor drives a belt connected to the capstan flywheel and shaft.

After leaving the capstan, the tape passes under the counting roller and the take-up tension arm to the take-up reel. The counting roller is geared to a four-digit resettable counter which indicates elapsed time during recording and playback and permits locating desired portions of the tape during rewind. The counter indicates minutes and seconds and has a capacity of 99 minutes and 59 seconds, at a tape speed of 15 in/s.

4-2. AIR SYSTEMS

It is probably apparent at this point in our studies that air systems play a vital role in the tape-recording system. The description of a specific system (RCA TR-70) will serve to give the student a practical view of the quadruplex-tape air system.

The machine performs a number of functions with the following four basic air systems:

1. Low-pressure air system for air and vacuum guides and tape lifter.
2. High-pressure air system for air bearing on headwheel and vacuum-guide air cylinder.
3. Cooling blower for heat removal.
4. Headwheel blower for cooling the headwheel motor.

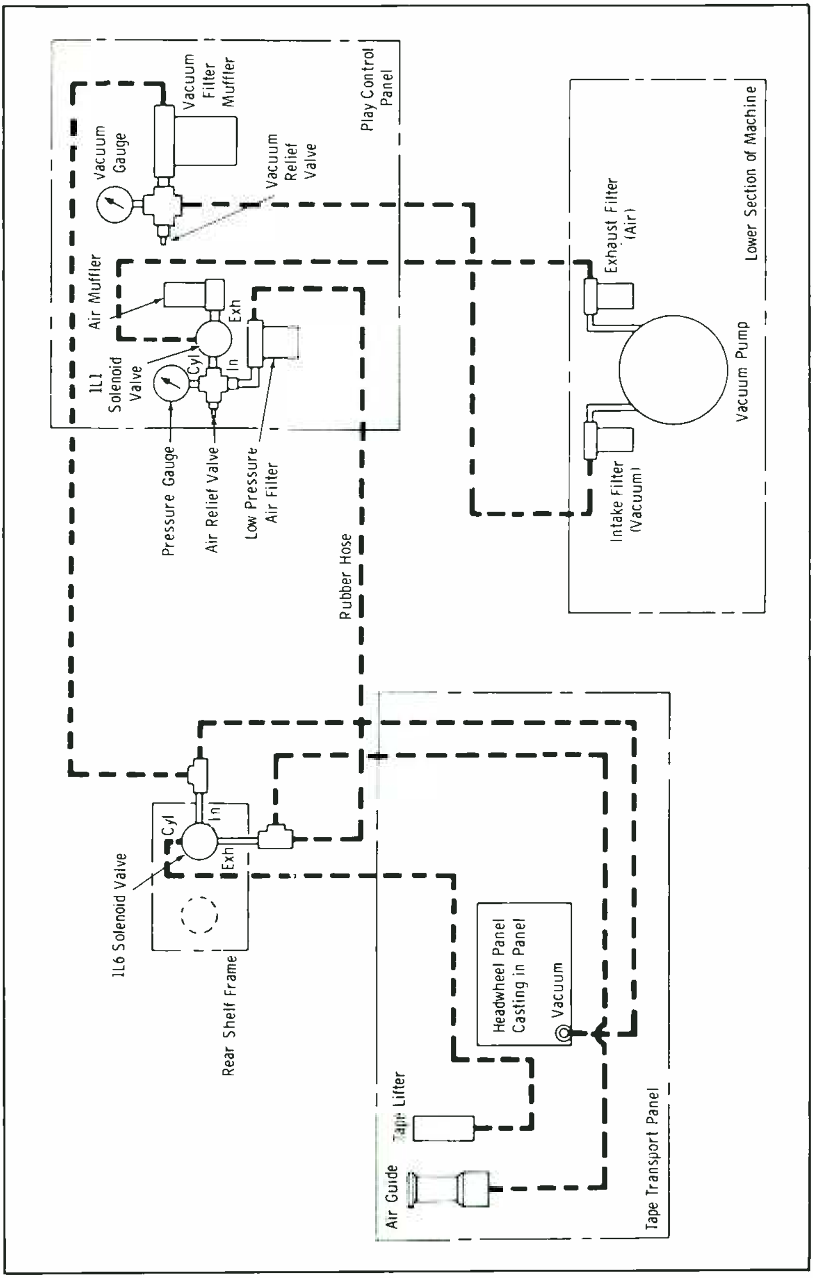
The high- and low-pressure air pumps and cooling blower are located on the lower section of the machine, and are accessible from the front or rear. Other parts are mounted on the front and rear of the tape-transport panel and behind the play control panel.

Low-Pressure Air and Vacuum System

The low-pressure air and vacuum system (Fig. 4-2) provides air for the air-lubricated tape guide, vacuum for the tape lifter on the tape-transport panel, and vacuum for the vacuum guide on the headwheel panel. Both the air and vacuum functions are performed by a single pump of the oil-free, rotary-vane type. The pump motor directly drives a slotted rotor which is mounted eccentrically in a cylindrical air chamber. As the rotor rotates, centrifugal force causes four carbon vanes on the rotor slots to press against the cylinder wall. This action creates a vacuum at the pump inlet and drives compressed air from the outlet. The pump is provided with a filter/muffler and relief valve at the inlet (vacuum), and a muffler, filter, and relief valve at the outlet (air).

Vacuum System—Air drawn in through the slots in the vacuum guide on the headwheel panel flows through a short hose on the headwheel panel to an outlet below the panel mounting plate. A long hose runs from this outlet in the back of the machine, through a T connector on the rear shelf frame, then to the vacuum filter/muffler behind the play control panel. Vacuum passes through the filter/muffler and through a four-outlet connector on its intake side. The vacuum gauge monitors the vacuum level at this point, and a vacuum relief valve is connected to another outlet of the connector to permit adjustment of the vacuum level. The final outlet of the four-outlet connector is attached to a rubber hose that runs to the lower section of the machine. Here, the vacuum line is filtered prior to being connected to the intake side of the low-pressure air motor or vacuum pump. Thus, the vacuum guide obtains vacuum immediately when the low-pressure air pump is energized, and it holds that vacuum in all operating modes except when the motor is de-energized.

Exhaust Air System—Air supplied through the air guide on the tape-transport panel is fed from a hose attached to an outlet on the lower side of the panel. The hose extends to a T connector on the rear shelf frame, then to a low-pressure air filter behind the play control panel. After filtering, the air is supplied through a four-outlet connector and to solenoid



Courtesy RCA

Fig. 4-2. Low-pressure air and vacuum system.

valve 1L1 (Figs. 4-2 and 4-3). The two remaining outlets of the four-outlet connector are connected to a low-pressure air gauge and an air relief valve, respectively, so that air pressure may be monitored and adusted as required.

Air solenoid 1L1 is energized in any running mode of the machine (all modes except stop, standby, or setup) and permits air to be supplied to the air guide. When the machine is switched from a running mode to one which stops the tape reels, a time-delay circuit in the control module de-energizes the solenoid after a delay of approximately four seconds. This delay permits the air to continue to flow through the air guide until the tape reels have come to a full stop, thereby providing air lubrication at the air guide while the tape is still moving.

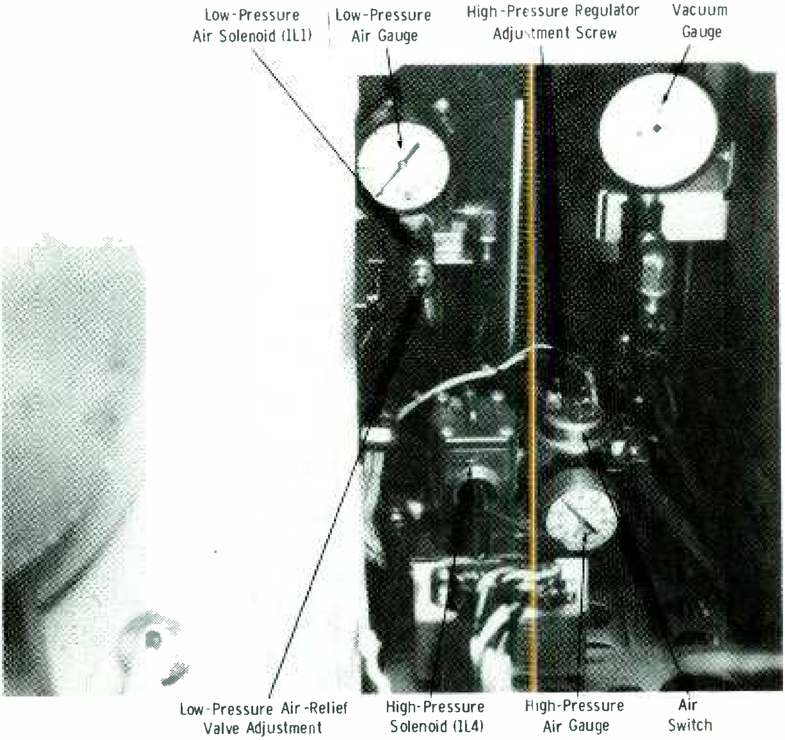


Fig. 4-3. Air system (front view) behind play control panel.

An air muffler is attached to one side of the solenoid valve (1L1) to reduce noise. The third outlet of the solenoid valve provides a connection for the hose that runs from this outlet to the air exhaust filter on the air-supply side of the low-pressure air or vacuum pump. With the motor of the low-pressure air and vacuum pump energized in all running modes of the machine, lubricating air is supplied to the air guide at all times that the tape is in motion.

Tape Lifter—The tape lifter on the tape-transport panel is activated by both air pressure and vacuum, which are supplied through solenoid valve 1L6 on the rear shelf frame. Each of the two T connectors mentioned previously in the descriptions of the vacuum and air flow have one outlet connected to solenoid valve 1L6. Only during the wind mode of operation is the solenoid valve set to permit exhaust air to flow through the solenoid valve and into the tape lifter. This causes a sapphire rod to extend lengthwise from the tape lifter on which the tape rides and thereby prevent the tape from passing across the selective erase head. When the machine is switched to a mode other than wind, the vacuum line is connected through the solenoid valve, and the air line is cut off from the tape lifter. The vacuum presents an assist force to the tape lifter and causes the sapphire rod to return immediately to its inserted position, thus causing tape erasure to commence with minimum delay upon resumption of tape movement.

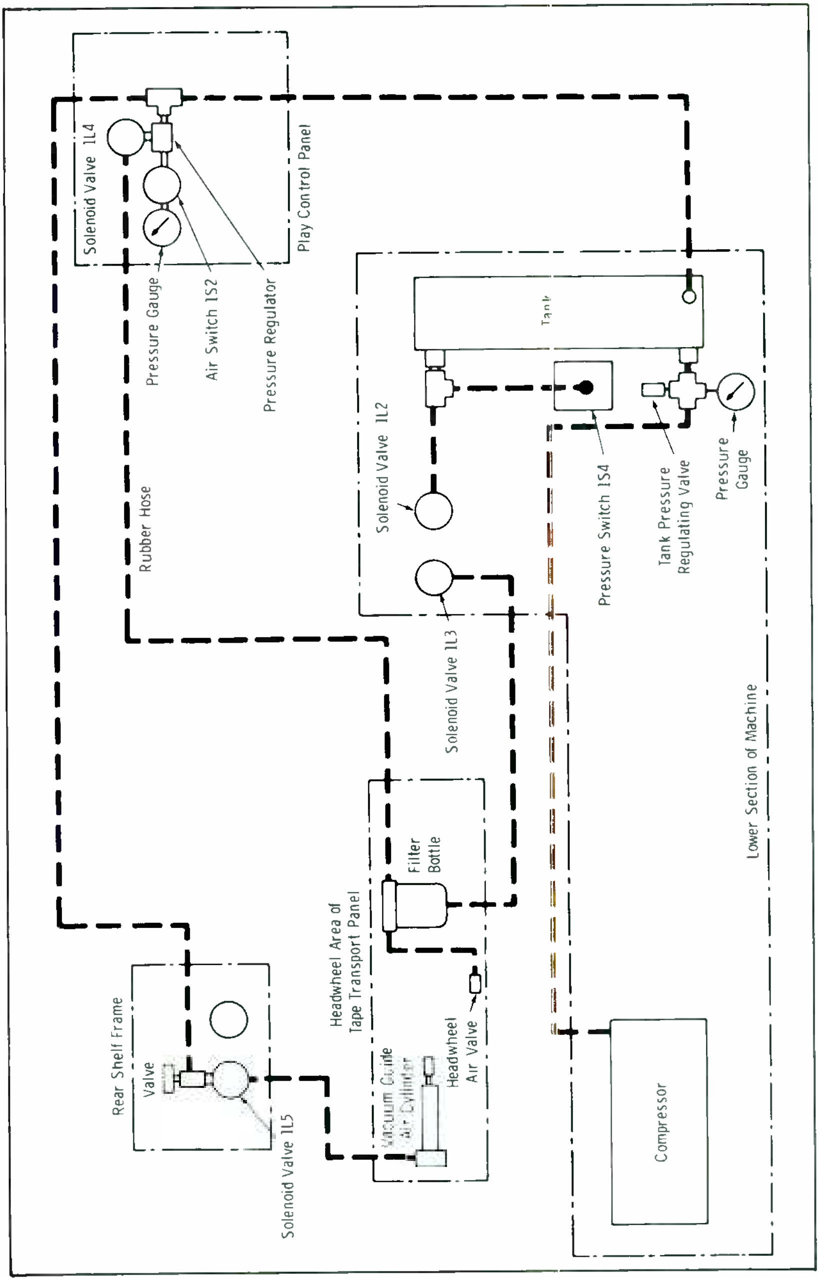
High-Pressure Air System

The high-pressure air system (Fig. 4-4) provides compressed air to function as an air bearing for the headwheel motor and to operate the vacuum-guide air cylinder. The system contains a compressor, air tank, tank pressure regulator valve, tank pressure gauge, air-sensitive pressure switch, high-pressure regulator and gauge, two selective air solenoid valves, air switch, output air filter, headwheel air valve, vacuum-guide cylinder, and two drain solenoid valves.

The compressor, air tank, tank pressure regulator valve, tank pressure gauge, air-sensitive pressure switch, and two drain solenoid valves are all mounted on the lower shelf of the machine. The air switch, high-pressure air regulator, high-pressure gauge, and one solenoid valve are mounted behind the play control panel. The output air filter, headwheel air valve, and vacuum-guide air cylinder are mounted on the tape-transport panel, near the headwheel panel. The air solenoid valve for the vacuum-guide air cylinder is mounted on a rear shelf of the machine frame.

Air-Tank Control—With the compressor operating, air is supplied to the tank through a rubber hose and the tank pressure regulating valve. Tank air pressure is controlled with the tank pressure regulator valve and monitored with the tank pressure gauge. A T connector is attached to an outlet at the lower part of the air tank. One outlet of the T connector is attached to a rubber hose that extends to the air-sensitive pressure switch (1S4). If the tank pressure exceeds the pressure limitation set on the switch, the switch opens its electrical circuit and prevents current from being supplied to the compressor, thus providing an on-off control for the compressor.

A rubber hose extends from the final outlet of the T connector to a drain solenoid valve (1L2). The solenoid valve remains closed while the



Courtesy RCA

Fig. 4-4. High-pressure air system.

high-pressure system is in operation; however, when the system stops, the solenoid valve opens and permits any accumulated water to drain from the air tank to a pan below the valve. Under normal conditions, the pan accumulates a small quantity of water which is evaporated and does not necessitate draining the pan.

Supply for Headwheel Air Bearing—High-pressure air is supplied from the air tank through a rubber hose to a T connector behind the play control panel. The T connector is attached to the high-pressure regulator, which may be adjusted to the desired level. Two outlets are provided on the high-pressure regulator. One outlet is connected to air switch 1S2. If the air-bearing supply to the headwheel fails, this switch places the machine in the stop mode to prevent the headwheel motor from being energized, and the red AIR PRESSURE indicator above the tape-transport panel is illuminated. The high-pressure gauge obtains its input on the opposite end of the air switch.

The second outlet of the high-pressure regulator is connected to air solenoid valve 1L4, which opens the air line to the output filter and headwheel air valve on the rear of the tape-transport panel. The output filter removes water from the air system prior to supplying the air to the headwheel motor. Accumulated water is retained in the filter and the hose that runs to drain solenoid valve 1L3 on the lower shelf of the machine. When the machine operation stops, the solenoid is de-energized and permits the trapped water to flow into a pan below the solenoid (same pan is used for solenoid 1L2).

The compressor motor is energized by air switch 1S2 and air-bearing relay 1K6 (not shown), which applies operating power to the motor.

Vacuum-Guide Air-Cylinder Supply—Air from the tank also is fed to solenoid valve 1L5, which is located on a rear-frame shelf behind the machine. An adjustment valve attached to the solenoid permits the air pressure to be adjusted to the correct level to set the operating speed of the vacuum-guide air cylinder. This is accomplished with a needle-valve control that is adjusted to barely allow air to pass. This needle valve should never be fully closed, since air passage to the headwheel would then be blocked. The output of solenoid valve 1L5 is supplied to the vacuum-guide air cylinder, which positions the vacuum guide and causes tape penetration by the headwheel according to the level determined by the lead screw on the vacuum-guide positioner assembly. The vacuum-guide air cylinder is located behind the tape-transport panel, near the rear of the headwheel panel.

Cooling Blowers and Air Filter

The motor that drives the low-pressure air and vacuum pump also drives a blower which is mounted directly behind the air pump. This blower provides forced-air ventilation to the modules below the tape-transport panel and to the voltage regulator on the lower shelf of the machine. Air enters the machine from the bottom shelf, through two flat rectangular filters mounted behind the removable front cover of the lower shelf of the machine. The filters are made with multiple layers of slitted and expanded aluminum which is impregnated with adhesive to trap dust and dirt.

Another cooling blower is provided for the record-amplifier module and associated filter. This blower is located adjacent to the headwheel blower, behind the tape-transport panel and directly above the record electrical filter.

Both blowers operate at all times that operating power is applied to the machine. If the air supply fails for any reason, an associated switch automatically places the machine in the stop mode. The passage of cooling air through the blower air vent positions the fin attached to the switch arm and holds the switch closed. If cooling air stops, the switch returns to its normally open position and opens the operating power circuit.

The headwheel blower is used to cool the headwheel motor and to keep it clean. The blower motor operates with ball bearings and is permanently lubricated. The blower is a multistage type having an oil-wetted wire filter in a single assembly.

Openings around the headwheel motor allow cooling air to be drawn in and circulate around the motor. The air then is drawn through a flexible pipe attached to the headwheel panel, and into the headwheel-blower filter. Dust and lint are collected in the rotating filter before the air is discharged around the blower motor.

4-3. TRANSPORT CONTROL CIRCUITRY

Early tape systems contained banks of relays for the rather complex control functions. In more recent systems, many of these relay control circuits have been replaced with solid-state flip-flops and a diode matrix.

A simplified block diagram illustrating the basic components of the mode control system is shown in Fig. 4-5. The mode control system consists essentially of the following:

1. Momentary-contact, illuminated mode-selector push buttons on the control panels.
2. Ten two-transistor binary flip-flop circuits, or "mode" modules, (one for each mode) and five "driver" modules.
3. A diode matrix which couples the output buses of the modules to the loads (localized control circuits) throughout the recorder.
4. Unlatch circuits which prevent the recorder from being in two modes at the same time (except audio and cue record modes).
5. Inhibit circuits which prevent direct transition between various modes.

As an example of the basic operation of the mode control system, assume that the recorder is in the stop mode and it is desired to enter the

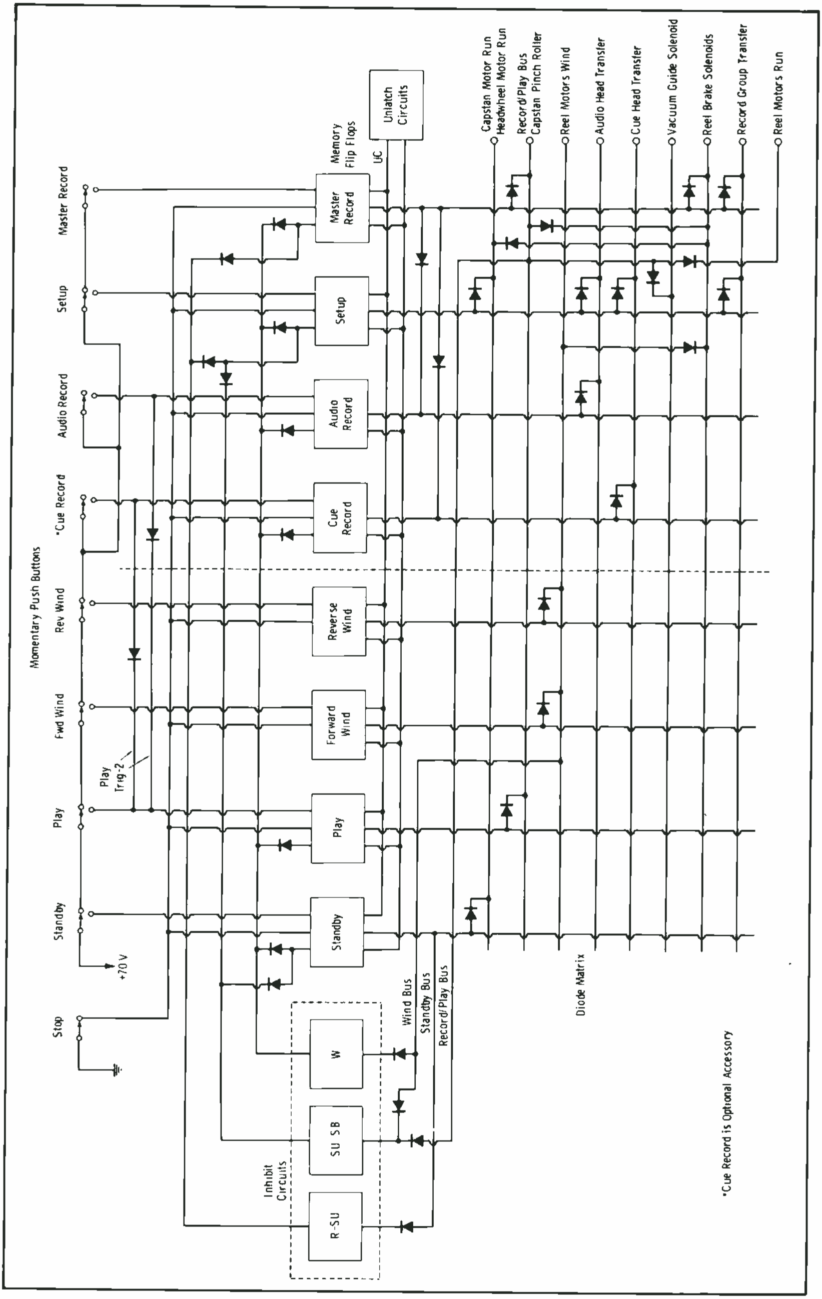


Fig. 4-5. Basic vtr control system.

master record mode. When the operator presses the MASTER button, a momentary-contact switch triggers the master mode module, which latches into the "on" condition and thereby energizes (grounds) a bus called the master record bus.

The record bus, along with the output buses of the other mode modules, is connected to the input of a diode matrix. This matrix may be represented as two sets of buses crossing each other at right angles but not directly connected to each other. In Fig. 4-5, the input buses from the mode modules are shown vertically, and the output buses are shown horizontally. Each output bus goes to a load or group of loads performing related functions, such as control of the headwheel motor, capstan motor, and capstan roller. The loads consist generally of transistor switches, relays, or solenoids. Where a solenoid is used, the output bus goes to a driver, or power-amplifier, module which actuates the solenoid when the bus is grounded. The driver modules are identical to the mode modules, but omission of a feedback resistor in the external circuit causes them to act as amplifiers instead of flip-flops.

The record bus is connected by an individual diode to each of the output buses which perform a function required for entry into the master record mode. Each diode is oriented to conduct when the record bus is grounded and to be cut off when the bus is ungrounded. Similarly, the other input buses are connected to their related output buses by diodes. Thus, when a particular input bus is grounded, all related output buses become grounded (through the diodes), and all loads required for entry into the desired mode are energized. This arrangement constitutes a simple, reliable control system which uses no moving parts except the momentary-contact push buttons which initiate the action.

When the machine is in the master record mode, it is undesirable to permit direct entry into certain other modes (such as setup or standby) without first going into the stop mode. To protect the machine from an error by the operator, unwanted transitions are inhibited automatically by transistor switches actuated either by the input buses to the diode matrix or by one of the related output buses. These inhibit circuits apply a voltage to the mode modules which control the unwanted modes. This voltage prevents the machine from entering the undesired modes even if the operator pushes the button requesting one of these modes.

When the recorder is in one mode (such as master record) and the operator presses the button of another mode which is not inhibited (such as the play mode), the first mode module must be turned off to prevent the machine from being in two modes simultaneously. To accomplish this, the output of each mode module (except the audio and cue modules) is connected to a bus, called the unlatch control bus, which goes to a transistor switch or unlatch amplifier. The output of the unlatch amplifier goes to another bus, called the unlatch bus, which is connected to the inputs of all mode modules. When the unit is in master record, a voltage is applied from the output of the master mode module to the unlatch control bus. However, this voltage is insufficient to actuate the unlatch amplifier. If the PLAY button is then pressed, the play mode module increases the voltage on the unlatch control bus to a level sufficient to actuate the unlatch amplifier. The unlatch amplifier then applies a voltage to the unlatch bus, and this voltage turns off the master module. The play module remains on because the trigger voltage overrides the unlatch voltage. Since only one mode module is on, the voltage on the unlatch control bus decreases to the cutoff level, and the unlatch amplifier goes off until the next mode is selected.

The mode control systems for both Ampex and RCA also contain a tape-motion detector and play control system that permits safe direct transition from the wind mode to the play mode without having to actuate the STOP button. Overstressing of the tape is automatically prevented by delaying contact of the capstan roller with the tape until after the tape has come to rest. This circuit also prevents transition from the wind mode to the setup or record mode while the tape is in motion. These features are particularly desirable in remote or automatic operation where it is not convenient to ascertain when the tape has come to rest after winding.

EXERCISES

Q4-1. Give the sequence of fixed heads (A) across the top of the tape and (B) across the bottom of the tape.

Q4-2. What determines head-to-tape pressure?

Q4-3. What controls tape speed during record or playback operations?

Q4-4. What is the function of the tension arms?

Q4-5. What is the function of the tape lifter?

Q4-6. What elements are supplied by the low-pressure air system?

Q4-7. What elements are supplied by the high-pressure air system?

Q4-8. In Fig. 4-5, if the SETUP and MASTER RECORD push buttons were depressed simultaneously, in what mode would the system be placed?

CHAPTER 5

The Video and FM System

This chapter will treat the entire video-fm system, bypassing circuitry more appropriately termed "signal processing." Fig. 5-1 shows the functions to be studied in this chapter, while Fig. 6-1 (Chapter 6) illustrates the signal-processing subsystem.

5-1. FUNCTIONAL DESCRIPTION

There are only minor variations in the terminology for the functions shown in Fig. 5-1 for Ampex and RCA. The basic functions of each block follow.

Video Input: This unit provides for proper termination of the video line, and it includes a switch allowing unity or variable gain and chroma controls. The video input unit employs filtering to remove spurious high frequencies, and it provides pre-emphasis of the video signal to improve the signal-to-noise ratio. The pre-emphasized video is fed to the modulator. An amplified video signal from a stage prior to filtering and pre-emphasis is fed to the modulator afc for the purpose of establishing a black reference from the signal itself.

Modulator: This section clamps pre-emphasized video at black level to feed a capacitance-diode-controlled heterodyne-type modulator. The output is therefore fm.

Modulator AFC: This unit provides precise control of the black-level frequency of the fm modulator in accord with a crystal-controlled reference frequency from the fm reference module.

FM Reference (Recording Standards): This module provides the crystal-controlled reference frequency for the modulator afc. It also provides a white-reference frequency keyed into the vertical-blanking interval of the signal for a check of fm deviation. This white pulse is removed prior to the video output of the system.

Record Equalizer: The record equalizer provides compensation of the record drive signal so that constant current in the video head is maintained over the fm passband.

Record Amplifiers: The output level from the record equalizer is increased to a value sufficient for recording on tape. There is one amplifier for each of the four heads.

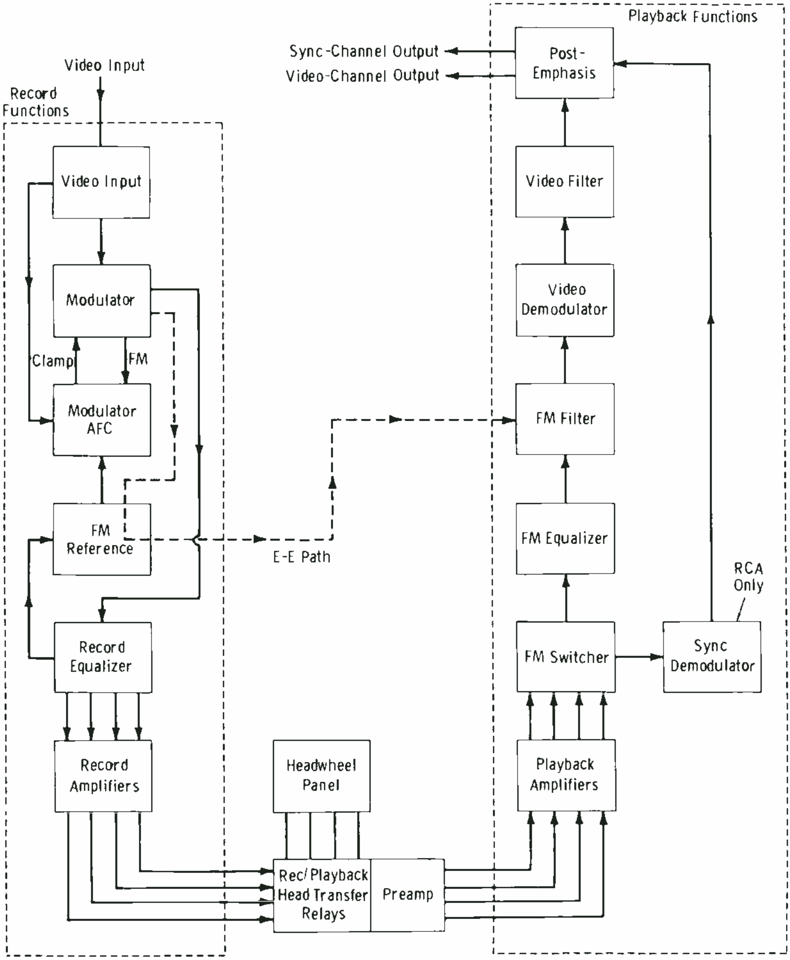


Fig. 5-1. Simplified block diagram of typical video and fm system.

Playback Amplifiers: These amplifiers provide agc, head-resonance compensation, and aperture compensation for correcting the playback characteristic. There is one amplifier for each of the head channels.

FM Switcher: This unit switches between heads during playback, connecting the head scanning the tape to the output. It includes separate switching for two output channels, one for the video (picture) and one for the sync.

Sync Demodulator: The fm signal is limited and demodulated for the sync channel.

FM Equalizer: This circuit provides additional aperture compensation for the overall playback equalization characteristic.

FM Filter: This filter provides the precisely controlled overall response characteristic required for optimum signal-to-noise ratio and frequency response of the tape playback system.

Video Demodulator: The fm signal is amplitude-limited and demodulated to push-pull video.

Video Filter: This section provides the low-pass filter characteristic after demodulation required for optimum noise, moire, and frequency response. Appropriate filters are selected for each fm standard (low-band monochrome, low-band color, or high-band).

Post-Emphasis: This unit includes the necessary post-emphasis characteristic for the demodulated video, and it also provides switching-transient suppression and video line-output functions.

The video and fm system performs two major functions. These are: (A) to record incoming video information on storage tape by means of quadrature heads and (B) to retrieve video information from tape storage (through the same heads) for playback.

A separate group of modules is used for each of the two functions. Modules in the record function convert the incoming video to fm and supply this fm signal through contacts on the record position of relays in the fm preamplifier module to the quadrature heads on the headwheel. During playback, fm is extracted from the tape by the heads, amplified through the fm preamplifier, and supplied to the group of modules performing the playback function for conversion back to video for further use in the machine.

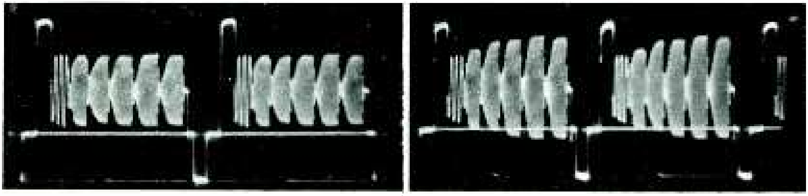
Special circuitry is included in the video and fm system to permit checkout and adjustments in the system without the use of the quadrature heads. This is the electronic-to-electronic (E-E) circuit, which connects the record and playback functions back-to-back for setup adjustments. NOTE: Fig. 5-1 should be referred to often during the remainder of this chapter to keep in mind the sequence of operations.

Sections 5-2 and 5-3 will consider the basic modulation-demodulation process as typified by earlier (low-band) systems such as the Ampex 1000C and the RCA TRT-1A. A number of these systems are still in daily use. Then, Section 5-4 will consider the important refinements of the combined modulation-demodulation process in most recent systems, typified by the Ampex VR-2000 and AVR-1, and the RCA TR-70.

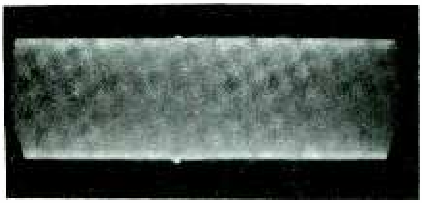
5-2. BASICS OF THE MODULATION PROCESS

The basic function of the modulation process is illustrated in Fig. 5-2. The video input (Fig. 5-2A) is pre-emphasized (Fig. 5-2B), to improve the signal-to-noise ratio, and is used to frequency-modulate a carrier (Fig. 5-2C) before being applied to the rotating video heads.

The frequency-modulated carrier permits a carrier frequency only slightly higher than the highest video frequency to be used without objectionable nonlinearity caused by the magnetic medium. The reproduction of the low-frequency portion of the video band is excellent, even though the fm carrier is in a region of poor magnetic performance. Reproduction of the higher video frequencies is excellent because the lower sidebands that they produce fall into a frequency band of high magnetic performance (Fig. 5-3).



(*A*) *Input.* (*B*) *Pre-emphasized.*



(*C*) *Fm rf output.*

Fig. 5-2. Basic modulator action.

The block diagram of the RCA modulator (Fig. 5-4) will serve to illustrate a typical modulation process. The incoming video signal is applied to the deviation-control potentiometer. From the center arm of the potentiometer, the video signal is applied to a pre-emphasis network to improve the signal-to-noise ratio. The output of the pre-emphasis network is applied simultaneously to a video amplifier and a sync-stretch amplifier. The sync-stretch stage provides nonlinear amplification which stretches the sync region and compresses the white region of the signal.

The video amplifier is a conventional stage with no bypass capacitor connected across the cathode resistors. Thus, it provides considerable degeneration which reduces the stage gain but stabilizes the operation of the amplifier. The video output signal is taken from a low-impedance cathode circuit and capacitively coupled to the control grid of the re-

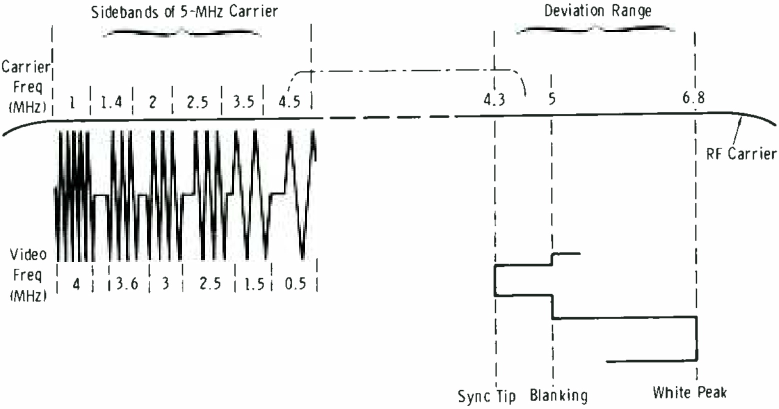


Fig. 5-3. Carrier deviation and sideband energy distribution for a 4-MHz video input signal.

actance tube. The purpose of the reactance-tube modulator is to frequency-modulate a radio-frequency oscillator. The modulator accomplishes this by changing the amplitude variations of the input signal into a varying reactance which is connected across the tank circuit of the oscillator. The plate voltage of the reactance tube is held constant by a voltage regulator, to insure that the clamp bias voltage applied to the grid of this tube holds the carrier frequency limit constant for the tip of sync.

The fm output signal of the 46-MHz oscillator is applied to the control-grid circuit of a mixer stage. Here, it is heterodyned with the master-

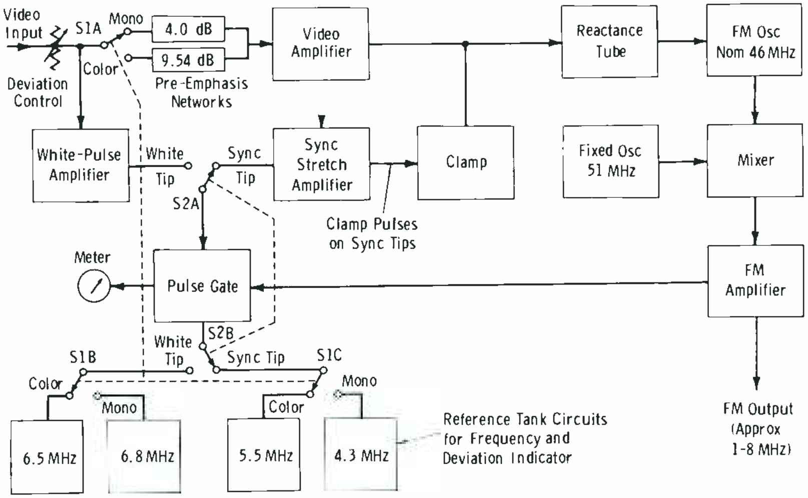


Fig. 5-4. Simplified block diagram of RCA TRT-1A modulator.

oscillator signal, which is injected into the suppressor-grid circuit (Fig. 5-5). The frequency of the master oscillator is 51 MHz, but it is not critical. The operation of the master oscillator is the same as that of the fm oscillator. The coupling between fm-oscillator stages (Fig. 5-5) is through common cathode impedance L8 and plate-to-grid coupling capacitor C17. There are two heterodyne signals from the mixer; one is the sum of the master-oscillator and fm-oscillator frequencies, and the other is the difference between the two oscillator frequencies. The output of the mixer is applied to a two-stage amplifier (Fig. 5-4). Inductors in the control-grid circuits of these amplifiers provide high-frequency peaking to keep their frequency response flat. Also, these coils prevent unwanted oscillator-frequency signals and their sum from getting into the fm output. The amplifier output signal is frequency-modulated, with a center frequency of approximately 6 MHz (midway between 4 and 8 MHz for a signal with 50 percent duty cycle). A portion of the output voltage is applied to the cathode of the pulse-gate tube (Fig. 5-4). This tube is biased at plate-current cutoff, except when its control grid receives positive-going pulses.

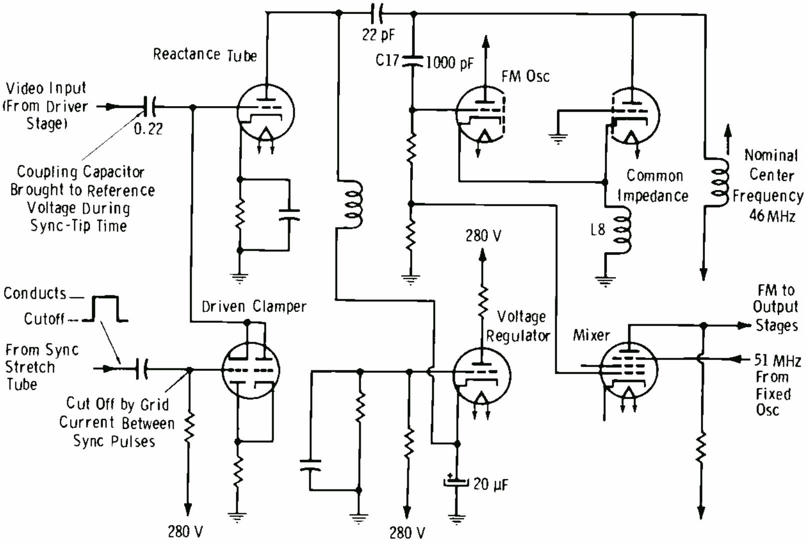


Fig. 5-5. Simplified diagram of modulator, clamp, and mixer.

A portion of the input video signal is applied to the white-pulse amplifier. Both sections of this stage are biased so as to stretch the white information and compress the sync. When switch S2 is placed in the White-Tip position, one of the two rf reference circuits (depending on the position of switch S1) is energized during the whitest part of the picture. The rf voltage generated by the reference circuit is rectified by a germanuim diode, and the amount of current is indicated on the meter. Maximum deflection of the meter is obtained when the frequency of the carrier output equals that of the reference circuit selected. When S2 is in the Sync-Tip position, positive sync-tip pulses force the gate tube into conduction, thereby permitting the fm carrier frequency at the sync tips to be checked with the other two reference circuits.

The Ampex 1000-C modulator employs slightly different oscillator frequencies, but the principle of operation (heterodyne to obtain carrier frequency) is the same for systems following the original Ampex Model 1000-A. The Ampex 1000-C includes the Ampex standard monochrome (somewhat higher pre-emphasis than RCA) and color networks, as well as a considerably higher pre-emphasis termed *Ampex Master Video Equalization* (AMVE)—any one is available by means of a push-button switch. In addition, the equalizer components are plug-in units.

The Ampex 1000-C modulator incorporates built-in crystal-controlled test signal generators. Since carrier and deviation are set differently for color than for monochrome, the modulator provides separate presetting adjustments for the two. The recorder can be switched, either locally or remotely, for either color or monochrome operation. The switchover automatically actuates the correct preset carrier and deviation values in the modulator.

The following crystal-controlled test frequencies may be selected by push buttons on the Ampex modulator:

5.0 MHz—Monochrome blanking level
5.5 MHz—Color sync tip
6.5 MHz—Color peak white
6.8 MHz—Monochrome peak white

Two additional positions are also available on the Ampex. They allow the user to plug in units for any special crystal-controlled frequencies.

The Ampex 1000-C modulator employs a carrier frequency clamped at the blanking level during the back-porch interval (Fig. 5-6). The sync is separated from the composite signal (waveform A) and differentiated (waveform B) to form leading-edge and trailing-edge spikes. The trailing edge is used to form a clamp pulse (waveform C), which drives the clamper at the blanking level on the back porch.

5-3. DEMODULATION BASICS

The purpose of the demodulator is to receive the fm carrier from either the switcher (playback mode) or the modulator (record mode) and extract the video information from the carrier signal. A block diagram of the RCA TRT-1A demodulator unit is shown in Fig. 5-7. It illustrates the necessary processes for wideband demodulation. During the playback mode of operation, relay K1 is unenergized, allowing the input signal from the 2 × 1 switcher to appear at the grid of amplifier stage V1A. Simultaneously, it grounds the input from the modulator chassis. In the record mode of operation, 24 volts dc is applied to K1. This energizes the relay and reverses the foregoing situation. The input signal from the modulator is now applied to the grid of amplifier V1A while the input from the 2 × 1 switcher is grounded.

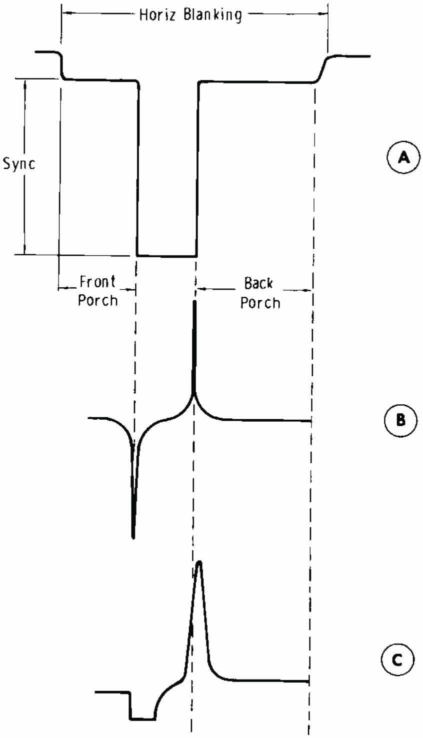


Fig. 5-6. Derivation of clamp pulse from sync for back-porch clamping.

Stage V1A acts as a straightforward fm amplifier. A coil and capacitor are employed in the plate circuit to obtain the proper frequency response. The amplified fm signal is then coupled to the control grid of phase splitter V1B. (Stages V1A and V1B are shown as a single block in Fig. 5-7.)

Two fm signals 180° out of phase are taken from the plate and cathode circuits of V1B and fed to the control grids of push-pull amplifiers V2 and V3. Approximately 50 dB of limiting is achieved by diode clippers to minimize dropouts and other effects of amplitude modulation.

The balanced output voltage is fed into four successive stages of push-pull amplification, each consisting of matched pairs of tubes. Push-pull amplifiers V12 and V13 raise the level of the clipped fm signal to 23 volts (peak-to-peak). The signal from the plate circuit of V13 is fed directly to a control grid of phase splitter V14, while the signal appearing in the plate

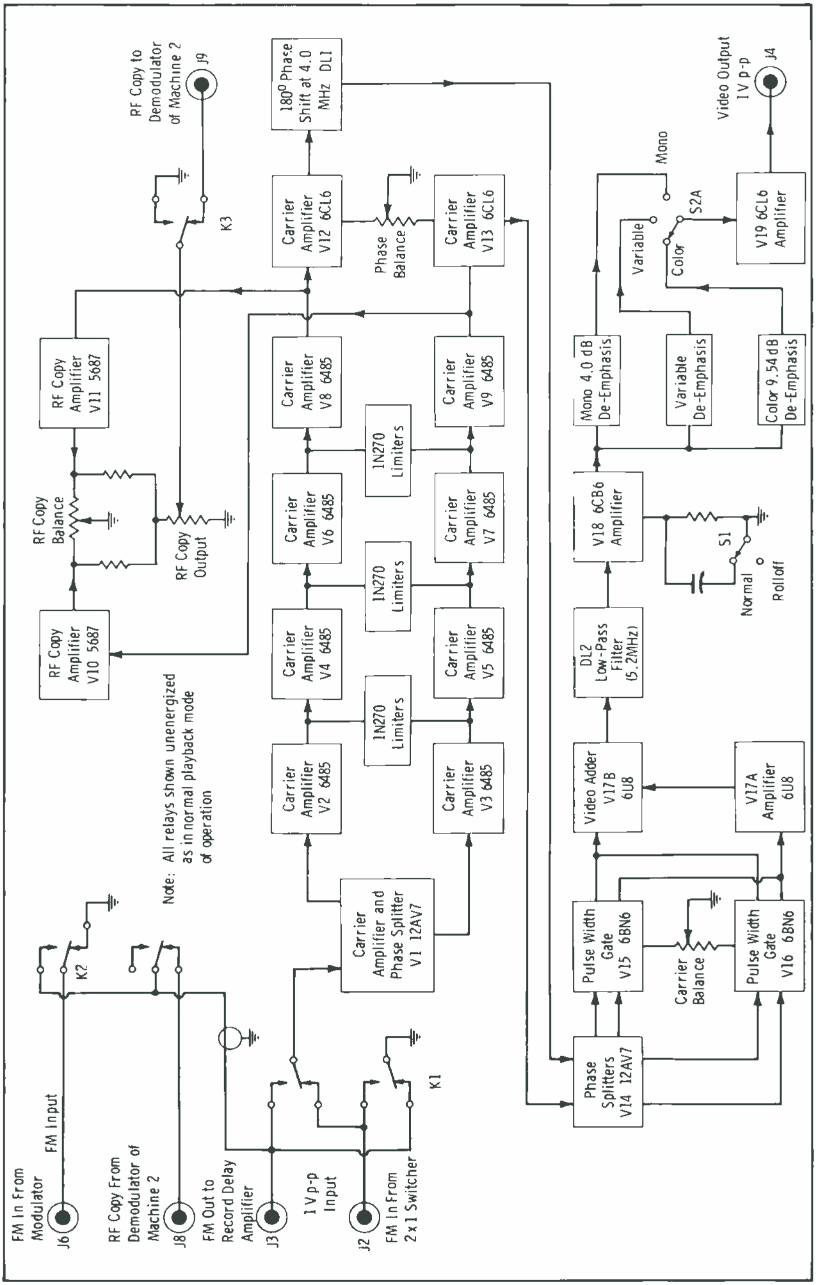


Fig. 5-7. Block diagram of the RCA TRT-1A demodulator.

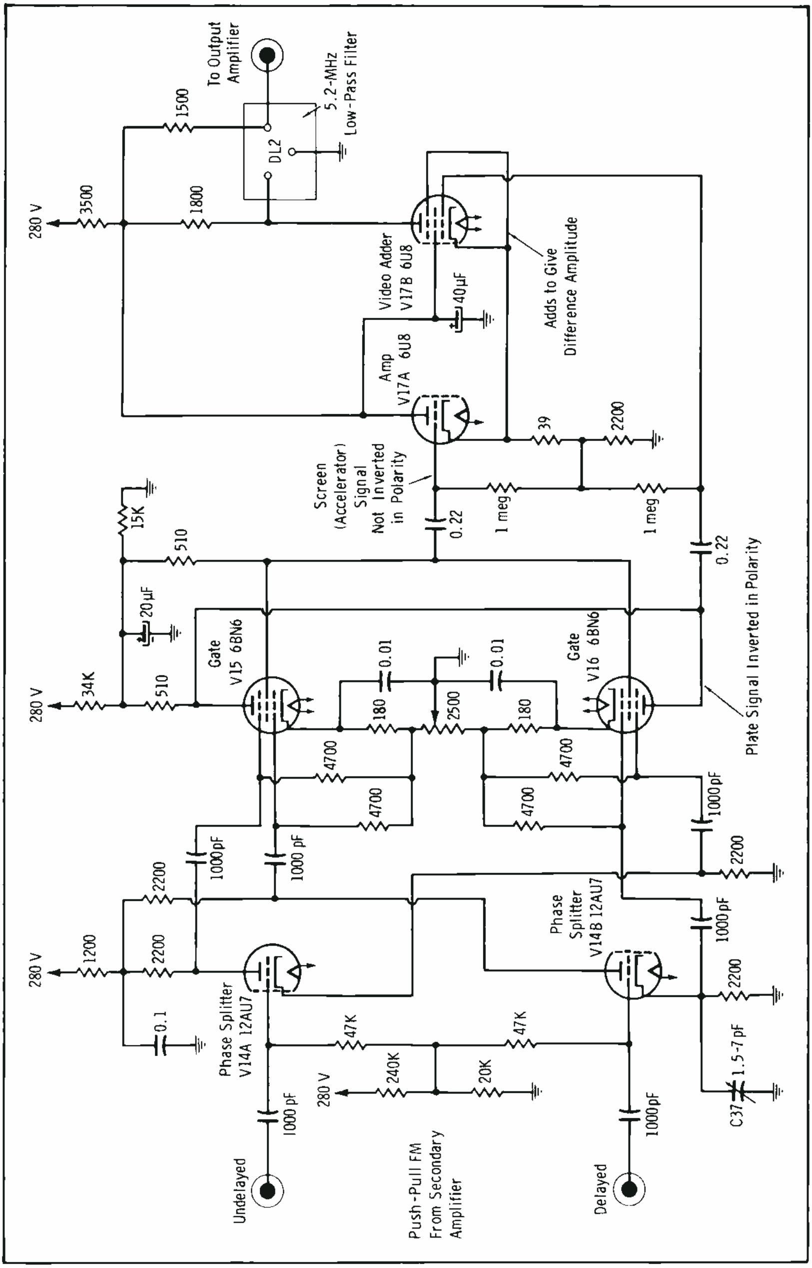


Fig. 5-8. Simplified diagram of duty-cycle (pulse-width gating) section of RCA TRT-1A demodulator.

circuit of V12 passes through delay line DL1 before being fed to the opposite control grid of V14. Delay line DL1 shifts the signal phase 180° at 4.0 MHz, thus enabling the signals which appear at the control grids of V14 to be in phase at that frequency.

Each section of phase splitter V14 supplies two signals 180° out of phase to a pair of matched 6BN6 tubes (V15 and V16) comprising the discriminator stage (Fig. 5-8). The signal appearing in the plate circuit of V14A is applied to the suppressor grid of discriminator tube V15, while the signal appearing in the cathode circuit of V14A is fed to the suppressor grid of discriminator tube V16. The signal appearing at the plate of V14B is fed to the control grid of V15, while the signal appearing at the cathode of V14B is fed to the control grid of V16.

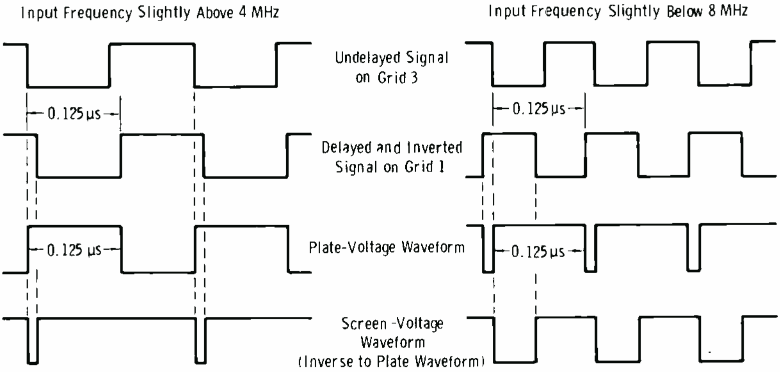


Fig. 5-9. Demodulator waveforms for one of two gate tubes.

Tubes V15 and V16 may be considered as pulse-width gating tubes because of their ability to produce pulses of varying width and constant amplitude. The characteristics of these tubes are such that plate current will flow only during the time a positive voltage appears at the control and suppressor grids simultaneously. Therefore, the width of the negative pulses appearing in the plate circuits of V15 and V16 is equal to the overlap width of the positive pulses applied to their signal grids (Fig. 5-9). The widest negative plate pulse occurs when the signals are in phase, and the narrowest plate pulse occurs when the signals are oppositely phased. If the suppressor grid is negative, the current is to the screen; if it is positive, the current is to the plate. The duration of plate current in either tube is directly proportional to the phase difference between the signals applied to the control and suppressor grids. The net result is that the 6BN6 discriminator amplitude-versus-frequency slopes are inherently linear.

Pulses appearing in the plate circuit of V15 and V16 do not occur simultaneously, but are uniformly interspaced in midpositions because of the phase-splitter action of V14. Thus, if the sets of pulses are well balanced, the combined gate output consists only of video information carried by even harmonics of the fm carrier.

The characteristics of the 6BN6 tube are such that the sum of the plate and accelerator currents tends to remain constant and independent of both signal-grid potentials. Thus, a signal current in the plate circuit must be accompanied by a nearly equal signal current of opposite polarity in the accelerator circuit, thereby effectively providing a push-pull output from each gate. The push-pull output signals are fed to cathode-coupled adder stage V17B (Fig. 5-10). Note that the varying duty cycle from 4 MHz to 8 MHz results in a dc level which represents the instantaneous frequency—effectively converting frequency change to dc change.

Video-adder stage V17B receives video information from the plate and accelerator circuits of discriminators V15 and V16. This information is added by V17B and appears at the plate. The video output is then fed into a 10-section low-pass filter (DL2) which removes the carrier harmonics and unbalanced fundamental carrier frequency above 5.2 MHz. When the deviation of the fm carrier does not occur lower than 5.2 MHz, as in color operation, this filter adequately removes small unbalanced carrier components that would degrade the video signal. However, when deviation occurs down to 4.3 MHz, with blanking at 5.0 MHz as in monochrome operation, discriminator balance requires more careful adjustment to keep blanking free of residual carrier not removed by DL2.

The video signal from filter DL2 is fed into video amplifier V18 (Fig. 5-7). In the plate circuit of this tube is a de-emphasis network which matches the pre-emphasis circuit located on the modulator chassis. These circuits serve to improve the signal-to-noise ratio.

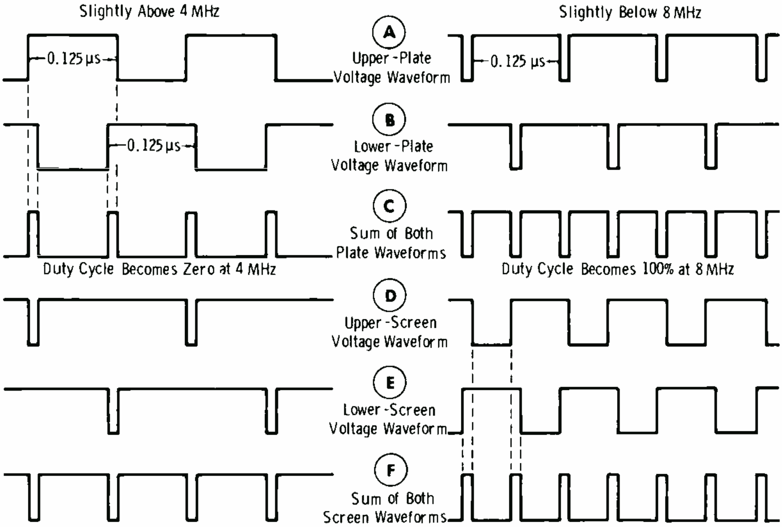


Fig. 5-10. Demodulator waveforms for both gate tubes together.

Switch S2 also opens or shorts a lead fed to the chroma-processor chassis (color equipment). This lead is in series with a circuit which operates a relay on the processor chassis. Its purpose is to make certain that the relay is not triggered by false color bursts when the tape recorder is operated in the monochrome mode.

A series-resonant circuit is located in the cathode circuit of V18. This circuit may be switched out, to compensate for small high-frequency losses inherent in the modulation and demodulation processes, by placing normal-rolloff switch S1 in the rolloff position. This position may be desirable to reduce excessive noise for either mode of operation of the tape recorder. However, when S1 is placed in the rolloff position, signal resolution is lost with the noise.

Output stage V19 operates as a conventional video amplifier. The final video output signal is taken from its cathode and fed to the 2 × 1 switcher chassis through output jack J4.

The discriminator slopes may be seen readily by applying a 1-volt peak-to-peak sweep signal to input jack J2 and observing the waveform at output jack J4. Fig. 5-11 indicates the ideal waveform (solid line) obtained with the demodulator well balanced and switch S2 (color-monochrome) in the monochrome position. The single-line slope from 4 to 8 MHz is the discriminator slope used for demodulation. The large envelope at the left is the second harmonic which appears to be cut off at 2.6 MHz but is actually cut off at 5.2 MHz, the cutoff point of DL2.

A simplified block diagram of the Ampex 1000-A demodulator is shown in Fig. 5-12. During replay, the signal enters the demodulator from the switcher assembly and is fed to a 60-dB limiter strip. The limiter strip, in turn, drives a delay-line type of demodulator. The delay is chosen to repre-

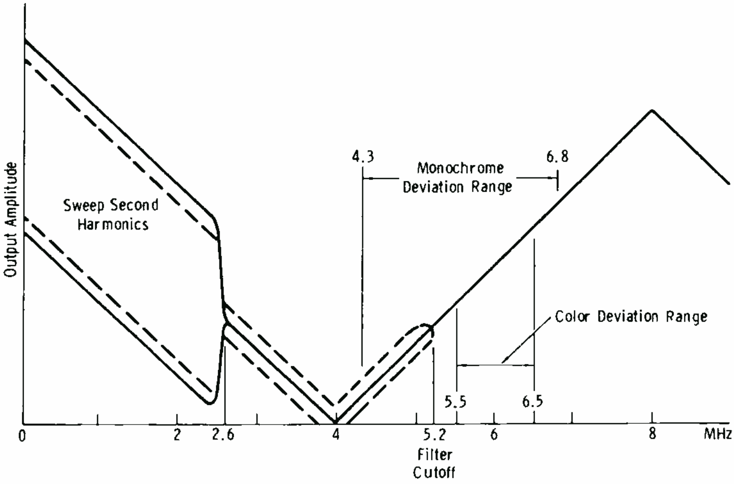


Fig. 5-11. Video-sweep response of demodulator.

sent a 90° phase shift at the carrier frequency of 5 MHz (or 0.05 microsecond). The signal is split into two paths at the output of the last limiter stage. One path proceeds directly to the grid of the adder tube, while the other goes through the delay line before being fed to the adder stage. The diagrams in Fig. 5-13 illustrate what happens when the carrier frequency, a lower frequency, and a higher frequency are passed through this circuit. The resultant amplitude varies as a function of frequency; therefore, fm demodulation is accomplished.

The am signal thus produced (which still contains an fm component) is detected by a pair of diodes driven by a transformer, as shown in Fig. 5-12. The transformer acts as a phase splitter to provide the signal for full-wave rectification, which is employed to achieve full-time signal recovery and to cancel the unwanted second harmonics of the rf signal. After further amplification, a low-pass filter eliminates all of the double frequencies developed in the full-wave rectifier diodes and most of the carrier frequency (filter cutoff is approximately 4.5 MHz).

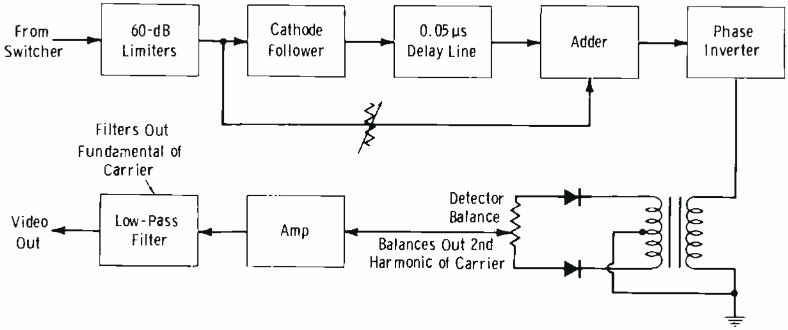


Fig. 5-12. Simplified block diagram of Ampex demodulator.

5-4. REFINEMENTS IN MODERN MODULATION-DEMODULATION SYSTEMS

To get a good visualization of one of the basic problems of video tape recording, it is necessary to consider the modulation and demodulation

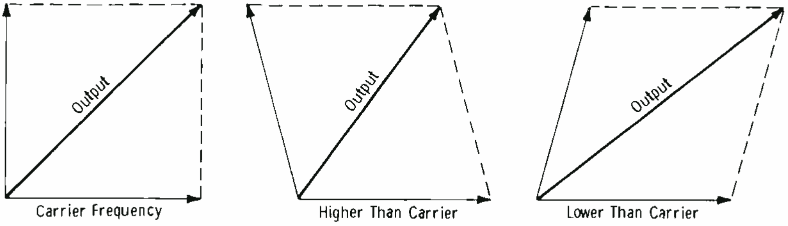
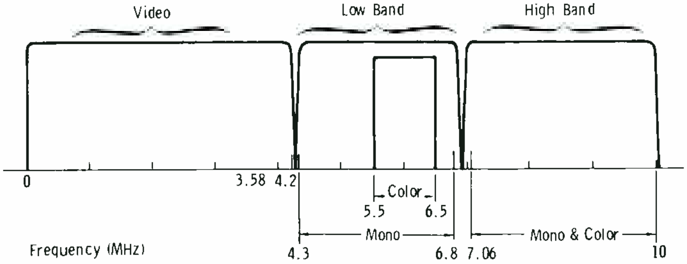


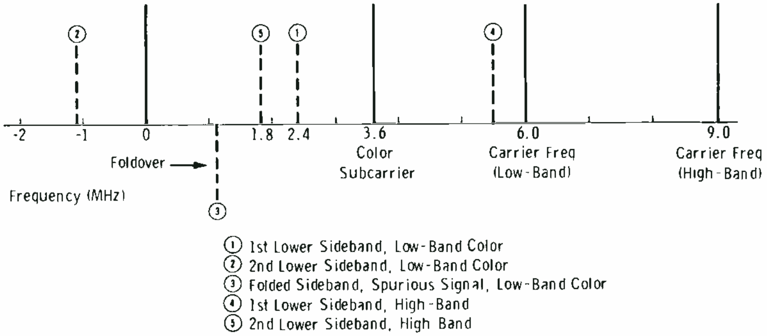
Fig. 5-13. Vector analysis of delay-line demodulator.

processes together. Study Fig. 5-14 carefully. Fig. 5-14A is a plot of signal versus frequency of the video signal itself and the carrier and deviation frequencies of low-band and high-band recorders.

The carrier frequency is deviated by the varying amplitudes of discrete frequencies in the video signal. This produces upper and lower sidebands with energies particularly strong at the second-order and third-order sidebands (first and second upper and lower sidebands).



(*A*) *Vtr carrier and deviation frequencies.*



(*B*) *Carrier frequencies vs color sidebands.*

Fig. 5-14. Frequencies in video recording.

In low-band operation (for monochrome) even though the lower deviation edge is adjacent to the highest-frequency video input component, little effect is noticed in normal picture content. You will see the spurious effect of this on the high-frequency wedges of a monoscope pattern, or on the higher multiburst frequencies. It appears as a "beat" or moire interference on this type of test signal. But the monochrome *program* signal has very low energy at the upper end of the passband, so very little subjective interference can be noticed with this type of signal.

Now consider the low-band color operation. Here there is a discrete frequency of high energy (the color subcarrier) beating with the instantaneous fm carrier. As deviation is increased, the sidebands increase rapidly in amplitude. Hence it is necessary to reduce the deviation in low-band color operation as compared with low-band monochrome operation.

Now refer to Fig. 5-14B. Assume the average carrier frequency (50-percent APL) to be 6 MHz for low-band color. Also assume that the color subcarrier frequency is 3.6 MHz instead of the actual 3.579545 MHz. This allows for easy computation to make a point.

The first lower sideband (for the color frequency) occurs at $6 - 3.6 = 2.4$ MHz. The second lower sideband then is $2.4 - 3.6 = -1.2$ MHz. Thus the excess energy which attempts to occur below zero frequency "folds over" as a spurious signal at plus 1.2 MHz. The energy distribution becomes rather broad around this frequency, and a strong moire pattern (interference pattern) appears in the color information. This, of course, increases in intensity with degree of saturation (amplitude) of the color signal. Hence it is very pronounced on color bars.

Since the low-band video heads had an upper "shelf" of around 7.2 MHz, the upper sidebands were discarded and corresponding standards were adopted. Modern low-band recorders used strictly for monochrome still reflect this condition. But modern high-band recorders, which can also be switched to low-band operation, are different. The first and second *upper* sidebands are now accommodated, and a distinct improvement in video signal processing is possible. Thus, you will see an improvement even in low-band color quality on modern systems.

At this point, improved video-tape modulation methods will be discussed. The terms "heterodyne" and "dual heterodyne" will be used to describe the function. To avoid any possible confusion, it is necessary to clarify the difference between modern heterodyne modulators and the older "heterodyne color" systems used by both Ampex and RCA.

In these original attempts at color video tape, the station subcarrier-generator signal was used as a reference against which to measure "jitter" of the subcarrier component coming from the tape playback. This combined signal was changed in frequency (heterodyned) to obtain a signal corresponding to the jitter. The jitter error was cancelled, and then the frequency was heterodyned back to normal. In this system, no definite relationship exists in the final output signal between the trailing edge of sync and the frequency of the subcarrier. Hence there is no "dot interlace," and the signal is "nonphased" to local sync.

The "heterodyne color" technique is now only a matter of historical interest and is not treated here. However, it is the reason for the special mode of operation provided on modern recorders by means of nonphased color (NPC) circuitry.

The reactance-tube heterodyne modulator described in Section 5-2 (which did provide standard dot-interlaced color) has now been replaced by a "dual heterodyne" modulation technique. This method has a much less severe limitation on the differential-gain, axis-shift, and phase-shift characteristics than that of the reactance control circuit.

All circuits are now almost strictly solid state. Exceptions are in the first stage of the video-head playback preamplifier (where nuvistors are used) and in the video-head record drivers.

In solid-state modulators, the voltage-variable diode capacitor is used. A review of this application in video modulators is presented in Section 5-5. Since this device has a nonlinear capacitance voltage relationship, the result is about the same as that obtained with the average reactance circuit (Fig. 5-15).

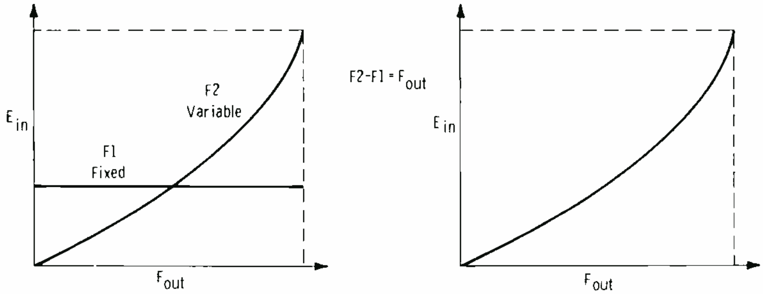


Fig. 5-15. Typical characteristics of reactance circuit.

The new dual heterodyne technique (Fig. 5-16) overcomes this limitation. One oscillator operates at about 100 MHz and the other operates at about 108 MHz. Under modulation, they are deviated in opposite directions, with the result that cancellation of amplitude-frequency nonlinearity takes place. The actual modulator frequencies depend on the particular manufacturer and model number, but the principle is the same.

The difference frequency (modulated carrier) is obtained from the low-pass filter (Fig. 5-16). Video feed-through and even-order harmonics are 180° out of phase at the output, resulting in improved suppression. The overall modulation transfer characteristic also results in about a 2-to-1

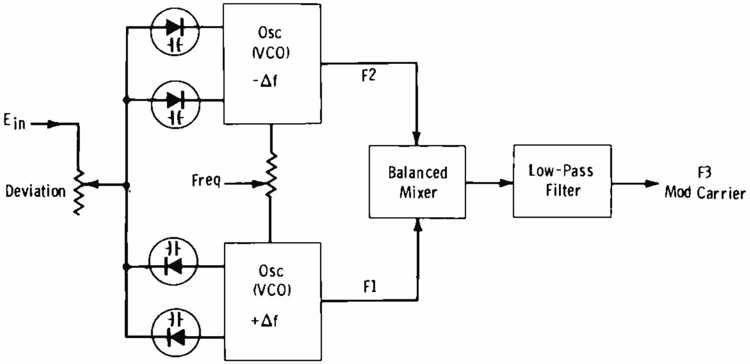


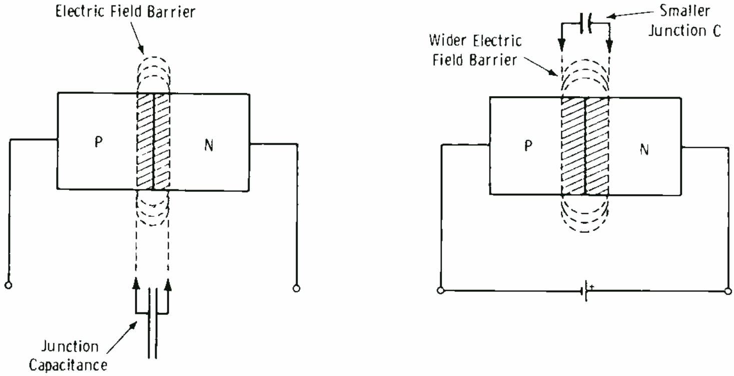
Fig. 5-16. Dual heterodyne modulation.

increase in dynamic range. The main point to keep in mind is that the variable-reactance diodes are arranged in complementary fashion so that oscillator frequencies F1 and F2 change in opposite directions with respect to the input signal.

5-5. MODULATION CIRCUITRY

We will first review the characteristics of the voltage-variable-capacitance diode. The width of the barrier in a pn junction is influenced by the voltage across the junction. Since an electrostatic field is thus produced, there is the equivalent of two plates of a capacitor in which the spacing between the plates is governed by the voltage (and current) of the junction.

Figs. 5-17A and 5-17B illustrate this effect. Anything that increases the width of the pn junction barrier is equivalent to spreading apart the plates of the capacitor, resulting in less capacitance. As the reverse bias is decreased, the junction capacitance increases.

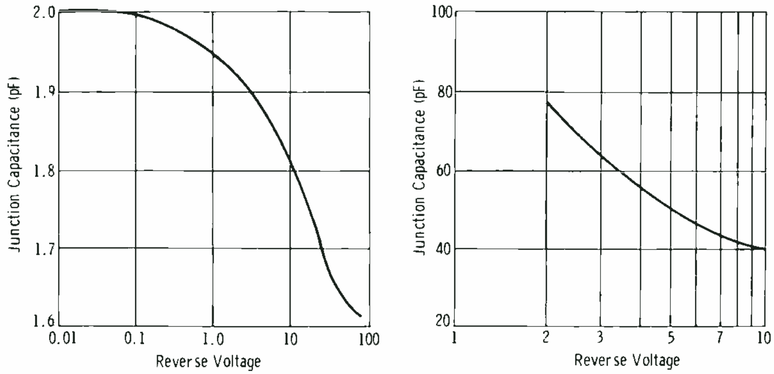


(*A*) *Zero bias.* (*B*) *Reverse bias.*

Fig. 5-17. Voltage-variable-capacitance diode.

Fig. 5-18A illustrates the junction-capacitance curve typical of nearly all signal diodes. Note that, in the reverse-voltage region of operation, the capacitance change is quite small over a 100-volt excursion. By comparison, Fig. 5-18B is an example (only) of the curve for one type of variable-capacitance diode. There are many different types of variable-capacitance diodes with different sensitivites in capacitance per volt of change. All of these diodes typically have a nonlinear relationship between capacitance and voltage change, as shown by this graph.

Some common circuits employ a voltage-variable diode capacitor, which may be known as a "variable-capacitance diode," "varicap," or "varactor." This is a diode which is manufactured to maximize certain physical and chemical features affecting junction capacitance. Fig. 5-19 shows three symbols for this type of diode that may be found on schematic diagrams.



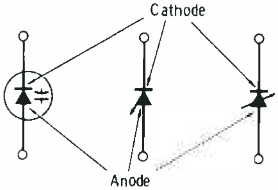
(*A*) *Typical small-signal diode.* (*B*) *Variable-capacitance diode.*

Fig. 5-18. Variation of junction capacitance with voltage.

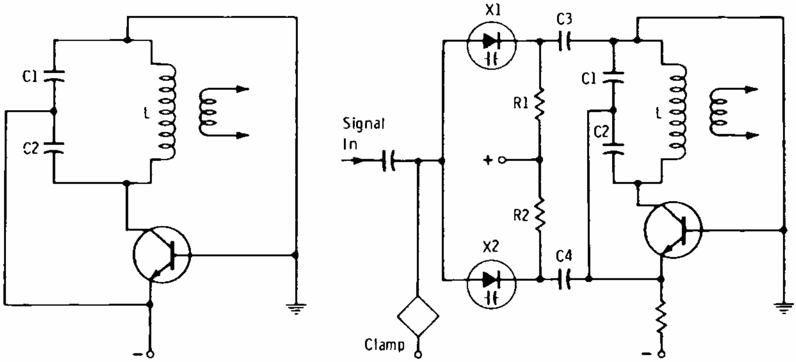
Like the zener diode, the variable-capacitance diode is always operated in the reverse-biased condition. Capacitance decreases with increased reverse bias; that is, the capacitance varies inversely with the reverse bias voltage. The capacitance-versus-voltage relationship is nonlinear. The diode normally has a greater change in capacitance for a given change in applied voltage than the effective capacitance change in a conventional reactance-tube circuit.

When the total capacitance used to resonate a tuned circuit is split and used to form a feedback voltage divider, a Colpitts oscillator results. Fig. 5-20A illustrates a transistorized Colpitts oscillator, in which C1 and C2 together set the effective capacitance with which L resonates. Remember that part of this capacitance is "hidden" in junction capacitance of the transistor. The important point at this time is to understand the effect of a capacitance diode on an LC tuned circuit.

Fig. 5-19. Symbols for voltage-variable-capacitance diodes.



Now look at Fig. 5-20B. This is the same circuit as the one in Fig. 5-20A, but with added components. Variable-capacitance diodes X1 and X2 must remain reverse biased at all times; this bias is supplied through resistors R1 and R2. Capacitors C3 and C4 are large and have negligible reactance to, let us say, a video signal. Now assume that a video signal is applied with sync in the negative polarity. The effective capacitance of X1 and X2 varies with the instantaneous video voltage. Since the diodes are effectively connected to the tank circuit, the resonant frequency is varied in step with the instantaneous video voltage variation. Let us see now in which direction the frequency changes between sync tip and peak white. Since sync is the most negative signal, the reverse bias is increased. Since capacitance varies inversely with the reverse bias, capacitance decreases, *increasing* the output frequency of the oscillator. The same reasoning tells us that as the signal goes toward peak white, the frequency *decreases.* The result is a frequency-modulated (but nonlinear) output.



(*A*) *Colpitts oscillator.* (*B*) *Fm Colpitts oscillator.*

Fig. 5-20. Application for voltage-variable-capacitance diodes.

Note that with the same type of transistor and the same polarity of video input signal, the polarity of X1 and X2 could be reversed, with the reverse bias now *negative* rather than *positive.* In this case, the oscillator would be caused to *decrease* in frequency at sync tip and increase in frequency as the signal swings toward peak white. If the same video signal is fed to both inputs of the foregoing oscillator circuits, one oscillator increases in frequency as the other decreases. This is a push-pull type of frequency modulation which tends to cancel the nonlinearity of modulation resulting from the nonlinear voltage-capacitance relationship of voltage-controlled capacitance diodes. When this type of modulation is not used, a nonlinear amplifier of characteristics inverse to those of the modulator restores linearity.

Obviously, this type of application is not limited to the Colpitts oscillator. Nor is it limited to the production of frequency modulation. For example, this type of diode is used in voltage-controlled delay lines (in place of the shunt capacitors) as applied to automatic time correction (ATC) in video tape recorders (Chapter 6).

A typical video-modulator circuit arrangement for a modern tape system is shown in simplified block form in Fig. 5-21. Pre-emphasized video is supplied through the deviation control, which allows proper setting of the

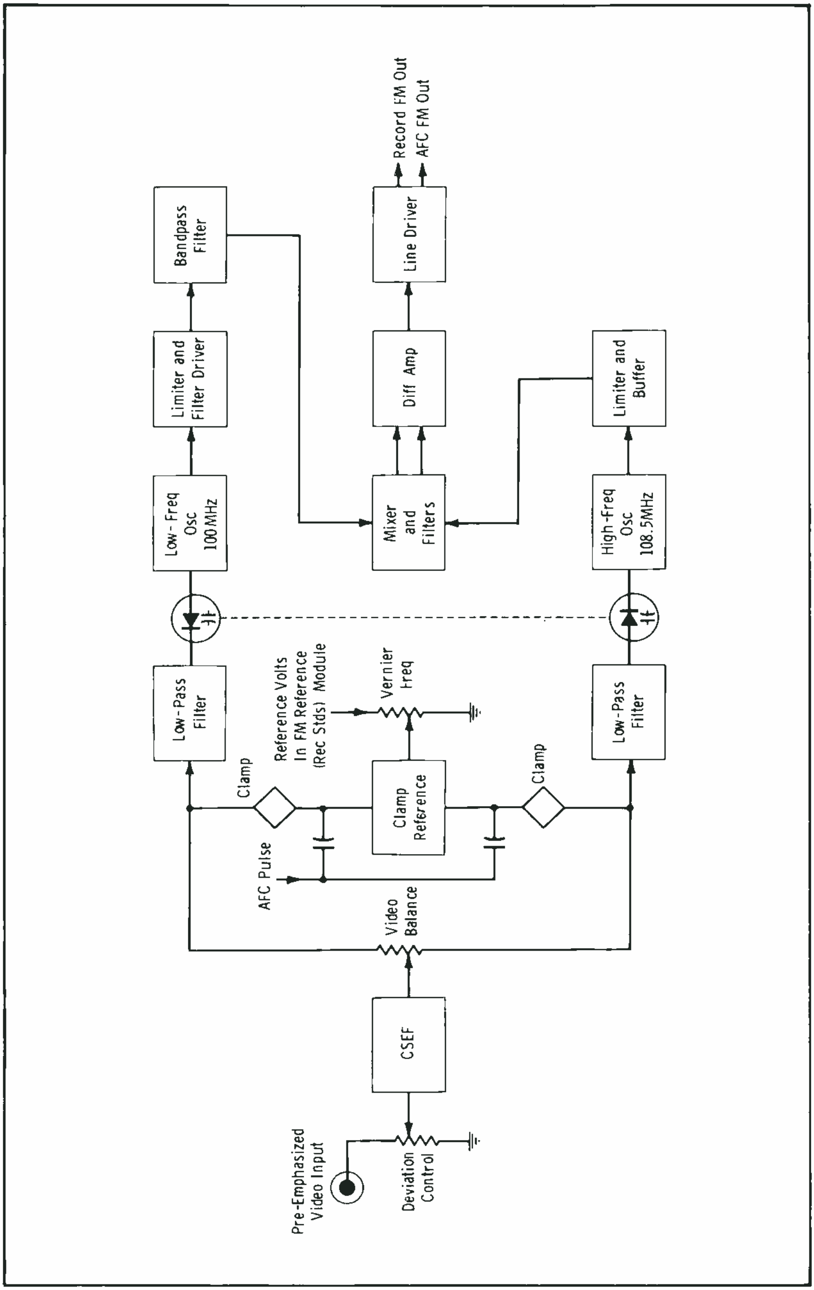


Fig. 5-21. Typical video modulator arrangement for television tape systems.

fm deviation depending on the recording standard used. The amplitude-controlled signal then goes to a pair of transistors in a complementary-symmetry emitter-follower stage (CSEF). The relative outputs from these two emitter followers are balanced by means of the video balance control and fed to the two fm oscillators through low-pass filters and across a clamping arrangement in both the low-frequency and high-frequency oscillator paths.

The low-pass filters are used to prevent rf from feeding back into the video circuits. The filters also usually provide part of the reactance required for the oscillator tuned circuits that follow the varactors.

Video in each channel is clamped (either during the back-porch interval or the tip-of-sync interval) to a reference voltage potential. Since this potential is part of the reverse-biasing voltage on the varactors, it becomes an influence on the operating frequency of the oscillators. This reference voltage is dependent on the following:

1. A dc level from the fm reference (record standards) module. This reference voltage depends on the particular standard selected.
2. The position of the vernier frequency control on the modulator.
3. A fixed basic bias level usually obtained from a zener diode and resistor network.
4. The afc error pulse amplitude and polarity.

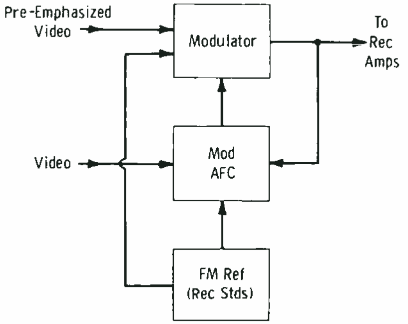
Each oscillator output is limited to remove amplitude modulation that would cause spurious frequency components in the modulator output. The output of the low-frequency limiter is amplified and passed through a filter having a bandpass of 90 to 110 MHz to remove all undesired components from the low-frequency channel. The output of the high-frequency limiter is supplied to a buffer amplifier and then to one side of a mixer circuit the opposite side of which receives the filtered output from the low-frequency oscillator.

The low-frequency channel drives the mixer in push-pull by means of a transformer. The high-frequency channel drives the mixer in an unbalanced manner. Eventually, the high-frequency signal is cancelled by the common-mode rejection of the following differential amplifier; however, the components from the low-frequency channel are not cancelled. A mixer balance network is included to permit accurate balancing of the mixer, to avoid generation of spurious frequencies.

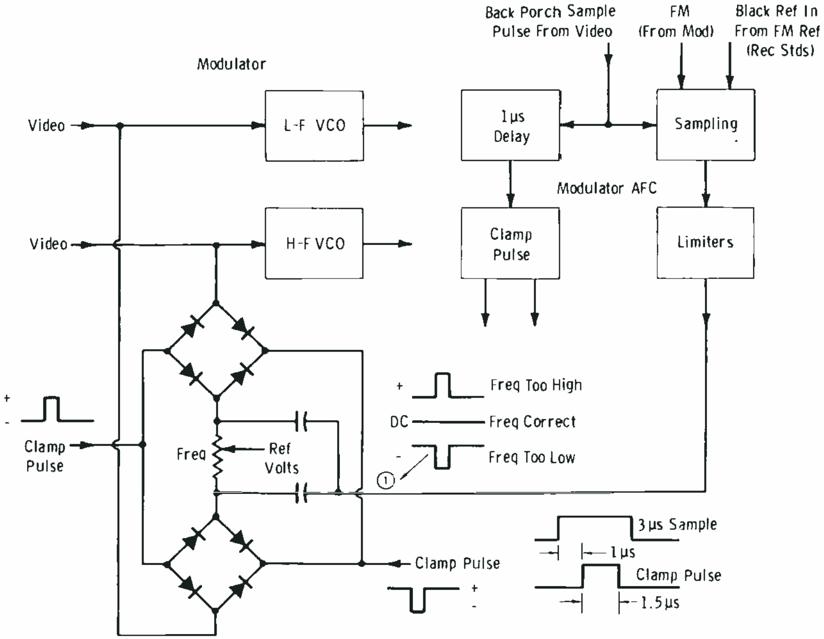
Outputs from the mixer are supplied (actually through low-pass filters having linear phase-shift characteristics) to the differential amplifier in push-pull. These signals are combined to form a single-ended output to feed the line driver. The line driver supplies two outputs. One output feeds the modulator afc module. The other output is coupled through a network that compensates for phase-shift characteristics of the bandpass filter in the low-frequency oscillator channel. The phase-compensated signal is fed to the record equalizer module, usually through a low-pass filter to remove residual high-frequency products that have not been cancelled in the mixer.

Modulator AFC

All modern tape systems employ a means of automatic frequency control (afc) for the video fm modulator. See Fig. 5-22A. Pre-emphasized video is fed to the modulator afc. The fm reference circuitry supplies crystal-controlled reference frequencies. The output of the modulator is also fed back to the afc circuitry.



(A) Application in system.



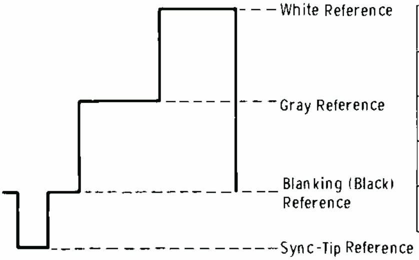
(B) Method of providing afc.

Fig. 5-22. Modulator afc function.

In Fig. 5-22B, note that each of the voltage-controlled oscillators (vco) is returned to a clamping bridge. For the clamping-pulse duration (which occurs at a 15.75-kHz rate), each vco is returned to a reference voltage. Since the effective capacitance of the varactor diodes depends on voltage, this sets the frequency of the oscillators.

Observe at this time that there is capacitive coupling to each of the clamped reference returns from point 1.

The afc essentially has three inputs: (1) a back-porch sample pulse formed from separated sync from the incoming video, (2) the fm output from the modulator, and (3) a crystal-controlled black-reference frequency from the fm reference (or record standard). The sampling pulse is around 3-μs wide. The clamp pulses are formed from a trailing-edge delay circuit so that they are delayed from the leading edge of sampling by about 1 μs with a duration of about 1.5 μs.



(*A*) *Relationship to waveform.*

Reference	Low-Band Mono MHz	Low-Band Color MHz	High-Band MHz
Sync Tip	4.28	5.50	7.06
Blanking	5.00	5.79	7.90
Gray (50% APL)	6.00	6.00	9.00
White (Peak)	6.80	6.50	10.00

(*B*) *Frequency chart.*

Fig. 5-23. Reference carrier frequencies.

Note that the reference is at blanking level (blanking frequency of the vco) and that the modulator output during this interval is being sampled and compared with the black-reference oscillator frequency. Any difference between the modulator output frequency and the frequency of the crystal reference appears as a pulse fed back to point 1 of the modulator. The amplitude and polarity of the pulse depend on the degree of frequency difference and the direction of difference, respectively. The presence of the pulse changes the clamped reference voltage return of the vco so that the oscillator frequency increases or decreases as required. Note that this reference is back-porch level; both RCA and Ampex now clamp on the back porch for the modulator afc reference.

Exactly how does clamping on the back porch affect the modulator? During normal operations, the vco's are corrected in frequency line by line at the frequency of the back-porch level (see Fig. 5-23).

The other reference frequencies shown in Fig. 5-23 are available as test frequencies in most recent systems. Also in these systems, you will find a "white reference" pulse in the demodulation circuitry; this pulse permits checking and setting the deviation for proper recording level.

The SMPTE standards for modulation carrier frequencies list an outside limit of ± 50 kHz. Modern vtr's with afc hold these frequencies well within ± 12 kHz; in fact, warning lights indicate when this limit is exceeded.

FM Reference (Record Standards)

The following description of the fm reference module in the RCA TR-70 system will serve to illustrate the functional aspects of the circuitry. The Ampex terminology is "record standards."

The fm reference module ensures that recordings are made according to established standards. The module is also part of the built-in test equipment in the machine. Three basic purposes are served, as follows:

1. *Standards Generator:* The standards generator supplies a dc voltage to the modulator module; the voltage is related to the machine operating standard and controls the modulation frequency according to the selected standard. This function also generates crystal-controlled standard test frequencies to coincide with gray, black, and white signals according to the selected operating standard.
2. *White Insert:* This function inserts (by electronic switching) the selected white test frequency into the vertical-blanking interval for the E-E mode of operation and during certain tests in the playback mode.
3. *Sweep Generator:* The sweep-generator function provides linear ramp pulses that are supplied to the modulator module during certain tests and cause that module to function as a sweep generator.

With three distinct functions performed by this module, three signal paths are required. Each signal path is described below. See Fig. 5-24 during the following analysis.

A negative 20 volts is supplied from the standards switcher to one of five inputs on the fm reference module. The particular input supplied is determined by selection of one of five operating standards. Once inside the module, the minus 20 volts is fed in parallel to the oscillator control diode matrix and to one center arm of relay K3, K4, or K5.

Each of the fixed contacts of relays K3, K4, and K5 is connected to a precision resistor. The minus 20 volts is thus fed through the particular resistor associated with the selected standard, and this resistor forms a voltage divider with another precision resistor that is common to all the selected resistors. The opposite end of the common resistor is permanently connected to positive 20 volts; therefore, a precisely controlled dc voltage is made available from the voltage divider for the modulator-module carrier frequency.

Relays K3, K4, and K5 remain de-energized during normal operation to provide a black modulation-frequency control level to the modulator module. However, during tests, a gray modulator output frequency is required, and the relays become energized by a ground signal originating in

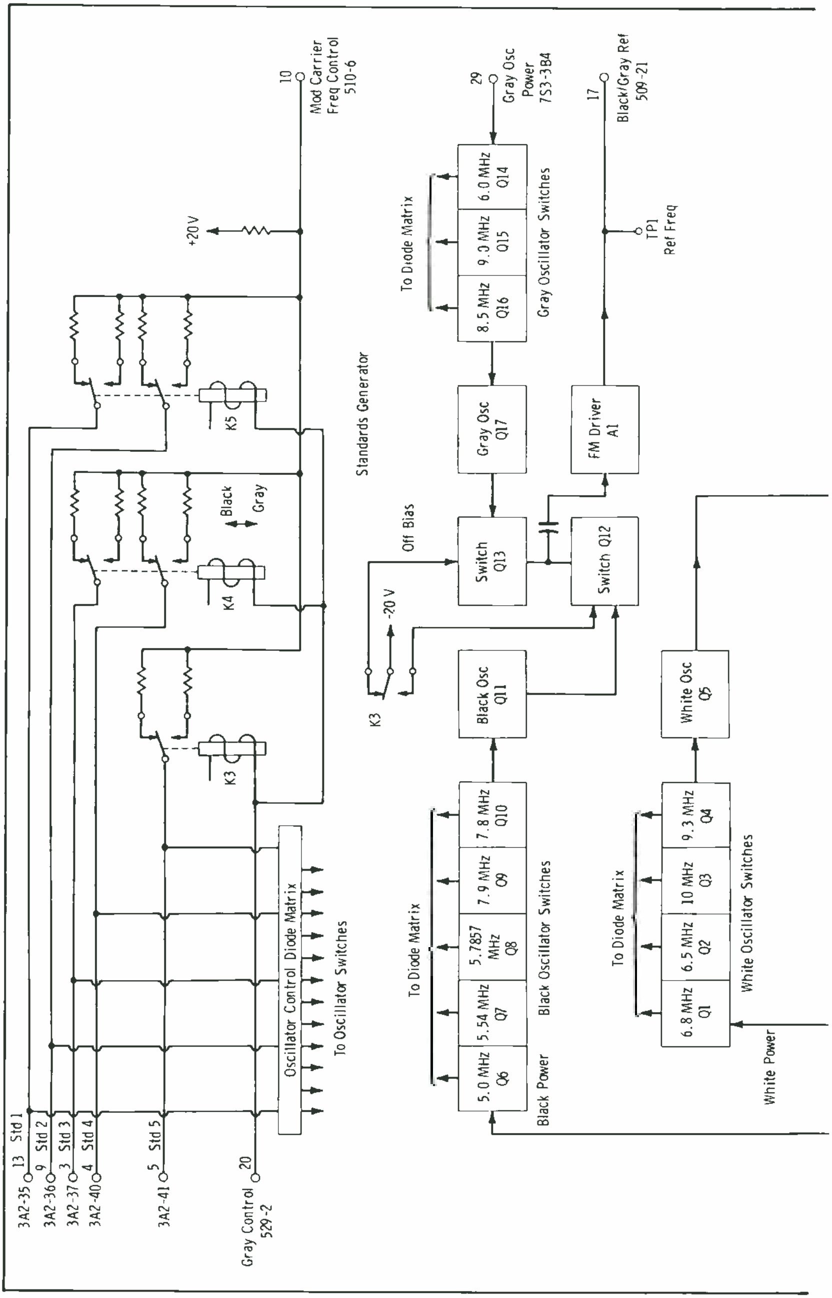
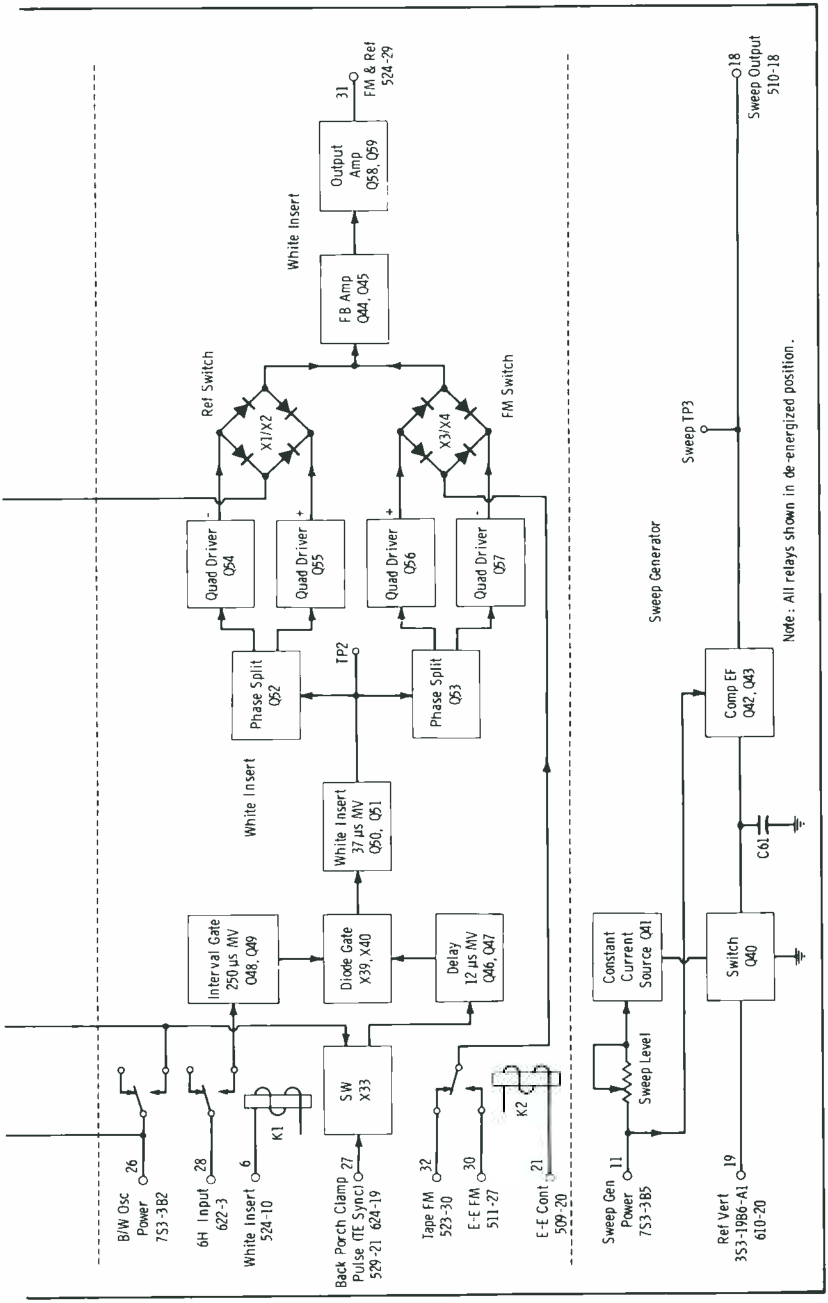


Fig. 5-24. Block diagram of RCA



TR-70 fm reference module.

the fm test panel. This selects a different resistor for the voltage divider and provides a gray dc control for the modulator.

As mentioned earlier, the minus 20 volts supplied by one of the five standards is also fed to the oscillator control diode matrix. This matrix produces control levels which activate specific transistor switches so that the precise reference frequencies required for the standard selected are produced by the crystal-controlled oscillators. The correct switches are thus preset in the gray, black, and white oscillators, so that merely the application of power to one or more of the oscillator circuits is required to obtain the correct gray, black, or white reference frequency from that oscillator. The particular frequency and the associated transistor switch that is selected, as well as the position of the TEST SELECT switch on the fm test panel, are listed in Table 5-1.

Table 5-1. Frequency-Standard Selections

			Standard				
Test Select Position	**K3 K4 K5**	**Function Activated**	**1 525 LB Mono**	**2 625 LB Mono**	**3 525 LB Color**	**4 525 High-Band**	**5 625 High-Band**
Norm or Freq	Off	Black Sw Black Freq	Q6 5.0 MHz	Q7 5.54 MHz	Q8 5.785 MHz	Q9 7.9 MHz	Q10 7.8 MHz
		White *Sw White Freq	Q1 6.8 MHz	Q1 6.8 MHz	Q2 6.5 MHz	Q3 10 MHz	Q4 9.3 MHz
**Input	On	—	—	—	—	—	—
Noise	On	Gray Sw Gray Freq	Q14 6 MHz	Q14 6 MHz	Q14 6 MHz	Q15 9 MHz	Q16 8.5 MHz
**Res	Off	—	—	—	—	—	—

°Activated only in E-E mode or in play mode when white insert function is selected.
°°No reference frequency is generated in this mode.

The principles of operation of all frequency generators are similar; thus, a description of the gray frequency generator (Fig. 5-25) will suffice. The gray frequency generator consists of an oscillator (Q17) and three quartz crystals (M10, M11, and M12). Each crystal is associated with a transistor switch (Q14, Q15, and Q16, respectively), which activates one of the crystals on command in a manner described below.

The emitters of the three switching transistors are connected to a common bus which is bypassed to ground by capacitor C34. This bus is held at a nearly constant dc level of minus 0.45 volt by resistors R79 and R80. The bases of the three switching transistors receive their input control signals from the diode matrix, and are biased by 11K resistors R73, R75, and R77, which are connected to the plus 20-volt supply.

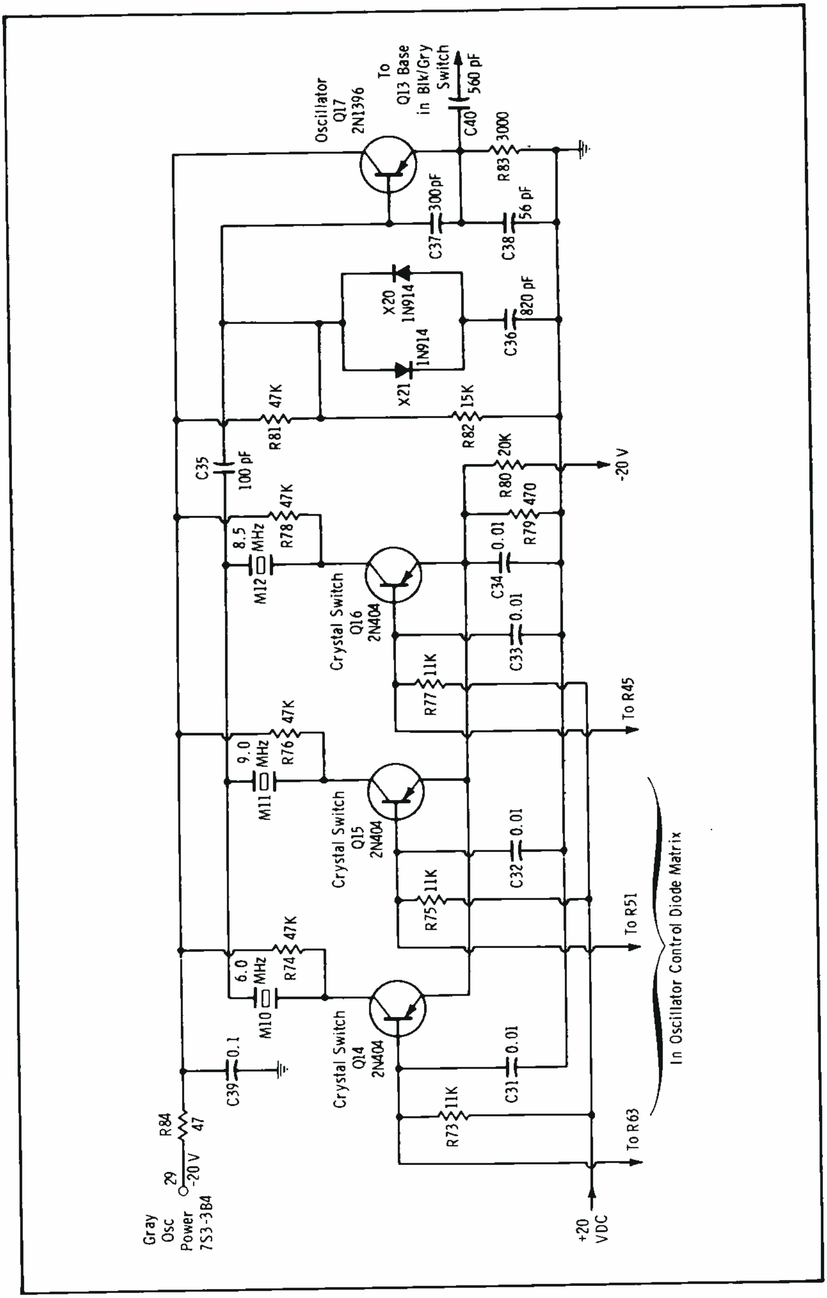


Fig. 5-25. Simplified schematic, gray-frequency generator.

In the absence of a negative control signal from the diode matrix, the transistors are cut off by the positive base bias. This opens the series circuit from the oscillator through the crystal, the switching transistor, and capacitor C34 to ac ground.

To activate a crystal, the base of the associated transistor switch is driven negative by an output from the diode matrix; the transistor switch saturates and connects one side of the crystal to ground through capacitor C34. The opposite side of the crystal is connected to a common bus by which all crystals in the generator are coupled (through capacitor C35) to the base of oscillator transistor Q17.

A Colpitts configuration is used for the oscillator circuit, with the collector of Q17 connected to ac ground. The selected crystal, which represents the resonant circuit in the oscillator, is effectively connected between the base and collector of Q17 because of the saturated condition of its grounded switching transistor. Oscillation is sustained by feedback caused by the connection of the emitter to the capactive voltage divider consisting of C37 and C38.

Diode clipper X20-X21 limits the base voltage swing so that the output level becomes independent of transistor characteristics. Bias resistors R81 and R82, with emitter resistor R83, establish the dc conditions in the oscillator. The oscillator output is coupled through capacitor C40.

Power for the gray-frequency generator is supplied only when the noise test mode has been selected by the TEST SELECT switch on the fm test panel. (Refer to Table 5-1 for the frequency obtained for each operating standard.)

The black-frequency generator supplies the black-reference frequencies used in the modulator afc module. It functions in a manner similar to that of the gray generator just described, except that five oscillator output frequencies can be obtained instead of three.

The white-frequency generator contains four switch-controlled crystals that control the frequency of the white oscillator (Q5).

Both the gray and black oscillators supply their outputs to transistor switching circuits that permit only one oscillator output to be supplied at any given time. Switch Q13 controls the gray-oscillator output, and switch Q12 controls the black-oscillator output. Either switch is de-energized according to the position of relay K3, which biases off either Q12 or Q13. The unbiased output is then amplified through fm-driver subassembly A1 and supplied to the modulator afc module as the black or gray fm reference frequency.

For the white insert and timing description to follow, see Fig. 5-26. For components discussed, see Fig. 5-24. The white oscillator and crystal switches remain inoperative until they are energized through relay K1. With reception of a white-insert signal from the fm filter module, K1 operates and connects operating power to the white oscillator and its associated switches.

The white-reference frequency is injected into the fm path by an electronic switching arrangement using diode bridges X1/X2 and X3/X4. Normally, the bridges are biased so that fm is supplied through the electronic switch. However, when white insert is selected, the bias is reversed for short intervals, and the white-reference frequency instead of fm is supplied during those intervals. The timing intervals of the reference switch and fm switch are such that the reference switch permits 37-microsecond pulses to pass during a 250-microsecond interval of vertical blanking (Fig. 5-26).

A white-insert command from the fm filter module actuates relay K1, which energizes the white oscillator and enables diode gate X33. Simultaneously, K1 allows the 6H pulses supplied from the tape sync processor module to trigger the 250-microsecond interval-gate multivibrator (Q48,

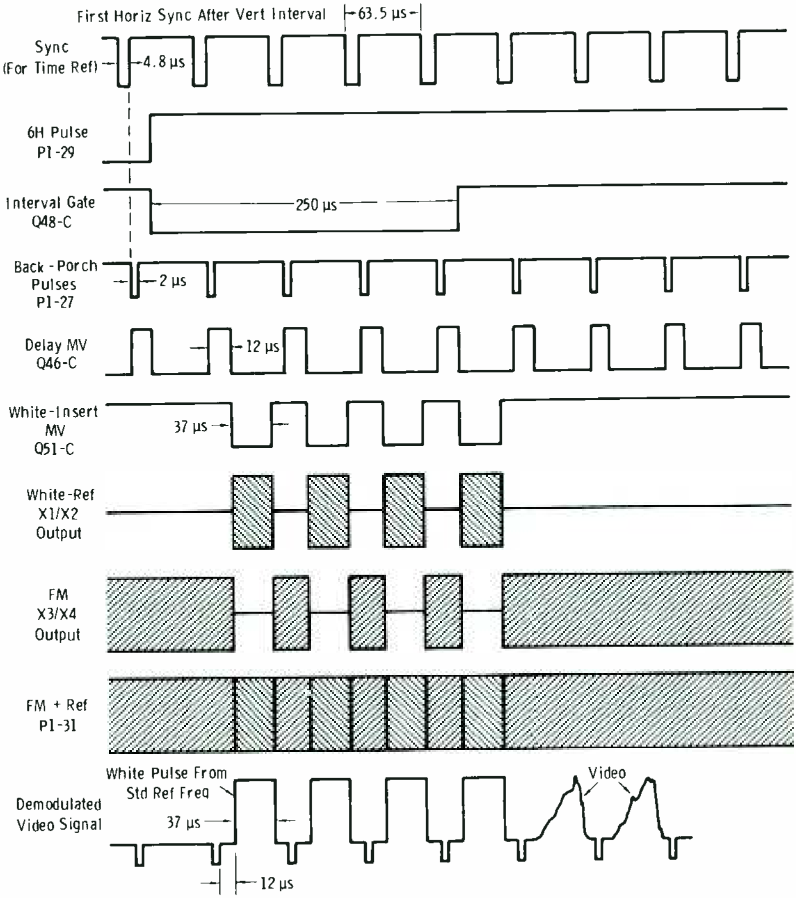


Fig. 5-26. Timing diagram, white-insert interval.

Q49). As shown in Fig. 5-26, the positive-going trailing edge of the 6H pulse triggers the interval-gate multivibrator, which provides a negative level of 250-microseconds duration to the diode gate (X39, X40).

Diodes X39 and X40 form a negative-input AND gate. The diode gate remains enabled for the 250-microsecond interval of the negative level. During this time, a series of back-porch, or trailing-edge (TE), sync pulses supplied from the tape sync processor module and passing through gate X33 have been continuously triggering the 12-microsecond delay multivibrator (Q46, Q47). This multivibrator effectively delays the trailing edge of sync by 12 microseconds and is constantly supplying delayed trigger pulses to the diode gate at a horizontal rate.

The diode gate is enabled for 250 microseconds; therefore, only a limited number of delayed sync TE pulses pass through the gate. Those that pass trigger the white-insert multivibrator (Q50, Q51), which supplies an equal number of 37-microsecond pulses. These pulses are split in phase through Q52, and the opposite polarities are amplified through Q54 and Q55 and applied at opposite ends of the quad diodes in bridge X1/X2. This is the white-insert diode bridge that functions as the reference switch.

The white-oscillator output frequency is supplied from Q5 to the input of quad diodes X1/X2. As the 37-microsecond pulses are supplied to the quad diodes, they forward bias the diodes and permit the white-oscillator output to pass through the reference switch. Thus, during vertical intervals, white frequencies are supplied to the input of feedback amplifier Q44 and Q45.

The 37-microsecond pulses supplied from the white-insert multivibrator are supplied to two phase splitters simultaneously. One output is fed to phase splitter Q52 (described previously), while the second output is fed to Q53. The opposite polarities from Q53 are amplified through Q56 and Q57, and these outputs are applied at opposite ends of quad diode bridge X3/X4. This is the fm diode bridge and functions as the fm switch.

Tape fm is supplied from the fm equalizer module during playback. In the E-E mode, E-E fm is supplied from the record equalizer module, and relay K2 is activated by the E-E control signal from the modulator afc module. Thus, in either mode, fm signals are supplied to the input of the fm switch.

The polarities of the white-insert gating signals supplied from the 37-microsecond multivibrator are arranged on both diode bridges so that one bridge is forward biased while the opposite bridge is simultaneously reverse biased. Thus, the fm diode bridge is forward biased except during the time of white insert. This permits fm to pass at all times except for 37-microsecond periods immediately following the vertical-sync interval, at which times the white-insert diode bridge becomes forward biased and allows the white frequency to pass.

The fm signal with the white frequency inserted is amplified through feedback amplifier Q44, Q45. Unity-gain amplification takes place in the output amplifier (Q58, Q59) to supply an output of 0.5 volt peak-to-peak to the fm filter module.

Negative-going reference vertical pulses are supplied from the linelock module to the discharge switch (Q40). The latter produces ramp sweep signals that are used during video-head resonance tests. The sweep level is set by a front-panel control, which sets the current level from current source Q41 to charge the ramp capacitor (C61).

The ramp pulses formed across the capacitor are coupled to complementary emitter followers Q42 and Q43. The pulses are then supplied to the modulator module where they substitute for video signals from the video input module during head tests. The linear fm sweep provides response data which are used during the head antiresonance adjustments.

5-6. COMBINED MODULATION-DEMODULATION FREQUENCY RESPONSE

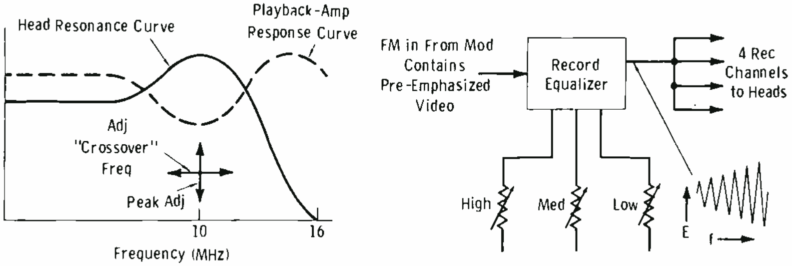
Basic to understanding the video-fm function in tape recorders is a knowledge of the respective response characteristics of each portion of the signal path. Current standards specify that all pre-emphasis and de-emphasis be placed in the video portion. This then requires that the rf portion of the signal path (fm carrier) have flat response over the passband of interest. In practice, this means that the record current in the video heads (actually fm) must be independent of frequency over the passband of interest.

Fig. 5-27A shows the effect of head resonance and the correction necessary in the rf playback portion to compensate for this effect. Due to head resonance and various characteristics of the recording path, the record equalizer (Fig. 5-27B) contains critical adjustments normally made only by the manufacturer at the factory. The overall result must be independent of head record currents with respect to frequency in the passband. This obviously requires very tight specifications between different video-head assemblies.

Any variations in head response that do occur are compensated for in the rf portion of the playback system by means of individual head "equalization" controls (Fig. 5-27C). Shown in Fig. 5-27C is the antiresonance network necessary to compensate for the head characteristic of Fig. 5-27A. The variable resistor is a *Q*, or damping, control to adjust the peak amplitude of correction (also shown in Fig. 5-27A).

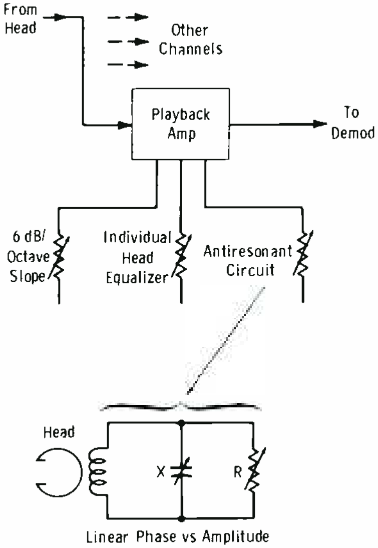
After compensation, the fm carrier (rf response) should be "flat" going into the demodulator, as in Fig. 5-27D. After video is extracted from the rf, the video de-emphasis circuit complements the video pre-emphasis applied ahead of the modulator (normally in the video input module).

Video pre-emphasis and de-emphasis standards are set by the SMPTE de-emphasis curve of Fig. 5-28A. The pre-emphasis curve is complementary to the de-emphasis curve—simply turn the curve "upside down" and change the dB values from minus to plus to obtain the pre-emphasis curve.

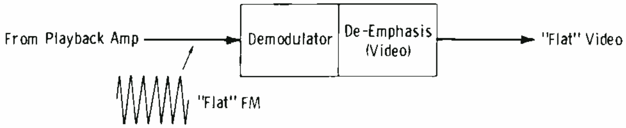


(A) Head resonance and compensation.

(B) Record equalization arrangement.

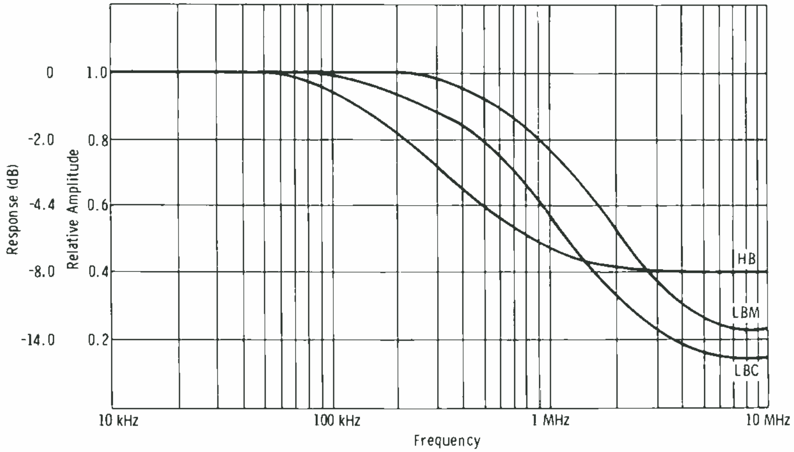


(C) Head-response compensation.

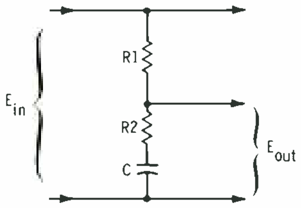


(D) Demodulator input and output.

Fig. 5-27. Frequency characteristics in signal path.



(*A*) *Response curves.*



Standard	R1 : R2	T1 μs	T2 μs
Low-Band Mono	4:1	0.132	0.0264
Low-Band Color	6.56:1	0.24	0.03175
High-Band	1.5:1	0.6	0.24

T1 = (R1 + R2)C   T2 = (R2)(C)

(*B*) *De-emphasis network.*   (*C*) *Resistors and time constants.*

Fig. 5-28. SMPTE de-emphasis.

Proper frequency and transient response of the system depend not only on the magnitude of emphasis, but also on the *shape* of the curve. Therefore, the slope of the curve is stated as a time constant.

The curves can be defined as the normalized impedance of the network of Fig. 5-28B. The SMPTE specifications can be simplified by putting them in the more practical forms of Figs. 5-28B and 5-28C. The SMPTE specifications are:

Low-Band Monochrome (LBM):

$$T = 0.132\ \mu s$$
$$X = 4.0$$

Low-Band Color (LBC):

$$T = 0.240\ \mu s$$
$$X = 6.56$$

High-Band:

$$T = 0.600\ \mu s$$
$$X = 1.5$$

where,

T is the time constant,
X is the ratio of R1 to R2 in Fig. 5-28B.

This information is tabulated in Fig. 5-28C.

In the de-emphasis network of Fig. 5-28B, let:

$$R1 = 320\ \text{ohms}$$
$$R2 = 80\ \text{ohms}$$
$$C = 330\ \text{pF}$$

When C is in picofarads, put resistance in megohms to get the time constant in microseconds. Then:

$$\begin{aligned} T1 &= (R1 + R2)\ (C) \\ &= (0.0004)\ (330) = 0.132\ \mu s \\ T2 &= (R2)\ (C) \\ &= (0.00008)\ (330) = 0.0264\ \mu s \end{aligned}$$

and

$$R1{:}R2 = 4{:}1$$

This is the proper de-emphasis network for low-band monochrome operation.

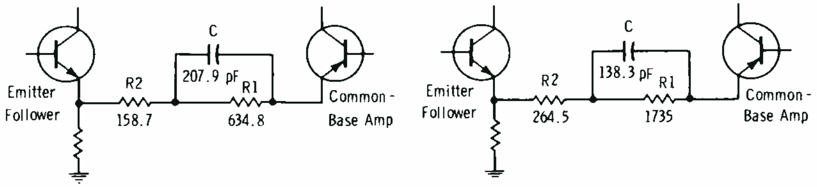
Examination of the R2-C network in Fig. 5-28B shows that as the frequency increases, the reactance of C becomes less, and the total impedance therefore becomes less. For example, on the high-band curve of Fig. 5-28A, C becomes a dead short at 0.4 relative amplitude (−8 dB) at 4 MHz.

In practice, the actual values of the resistors are modified by the impedances coupled back. For example, refer to the pre-emphasis (opposite curve to de-emphasis) networks of Fig. 5-29. These show the kind of actual values you will find in such networks in the latest systems. In these circuits the tolerance is ¼ percent for resistors and ½ percent for capacitors.

Let us digress briefly here to give you the proper perspective. The video and fm system has been designed to very exacting specifications. The net result is that third and fourth generation color dubs can be made that will provide quite suitable reproduction. Obviously, this requires excellent frequency and transient response, and low noise level, in the master recording. If you do not make dubs, you can get by with emergency parts replacements that are not exact. But it should be emphasized that you should obtain exact replacements as soon as possible. It all depends on how far you are willing to let the overall performance slip over a period of time. (Chapter 12 treats maintenance procedures.)

Note that in the networks of Fig. 5-29, capacitor C shunts R1 so that as the frequency increases, the net amplitude to the common-base amplifier increases. Exactly the same time constants are used as in the de-emphasis network which complements the particular mode of operation.

But, as stated earlier, the actual values of components must be modified for the type of circuit used. If you calculate the time constants in Fig. 5-29, you will see that the period is somewhat longer than that listed in Fig. 5-28C. But note how closely the ratio of R1 to R2 holds in each case.



(*A*) *Low-band monochrome.*

(*B*) *Low-band color.*

(*C*) *High band.*

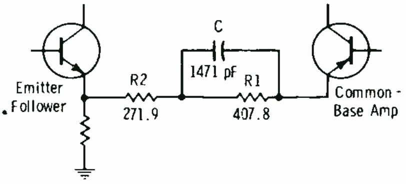


Fig. 5-29. Examples of actual pre-emphasis networks.

We have now progressed in our studies to the record equalizer function. Review Fig. 5-1 and note that this circuitry drives four record amplifiers (one for each individual head on the headwheel). These amplifiers provide a constant rf current across the passband so that frequency variations without amplitude changes occur. Approximately 100 volts peak-to-peak of fm carrier exists at the headwheel brushes in the recording mode of operation.

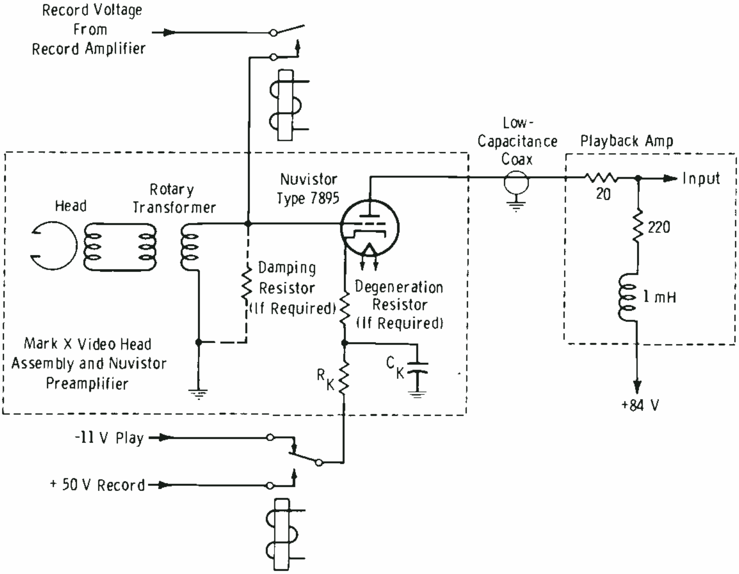
> NOTE: Early tape systems employed electronic quadrature correction circuitry in the record or playback mode of operation, or both. Modern video heads are constructed to within plus or minus 5 nanoseconds of quadrature error, and no electronic quadrature correction circuitry is used.

5-7. THE VIDEO PREAMPLIFIER

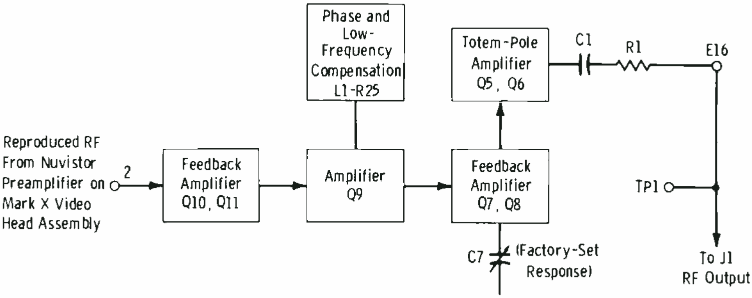
We will now look into the playback function of the system. In the playback mode of operation, only about 5 millivolts of signal exists at the input to the video preamplifier.

Fundamentals of the video preamplifiers for the Ampex Mark X head assembly are illustrated in Fig. 5-30. Note from Fig. 5-30A that during the play mode the cathode of the nuvistor is biased through a resistor from approximately −11 volts. This allows the nuvistor to amplify the reproduced signal which is coupled to its grid. The signal at the plate of the nuvistor is routed through a low-capacitance coaxial cable to the associated individual playback amplifier. This amplifier in turn supplies the individual-channel playback amplifiers containing the head-compensation circuitry.

During the record mode, the nuvistor is cut off because its cathode is biased by +50 volts through R_K. The nuvistor cathode impedance and C_K



(*A*) *Nuvistor preamplifier.*



(*B*) *Overall block diagram.*

Fig. 5-30. Video playback amplifier.

form a time constant. Capacitor C_K is necessarily small to permit the nuvistor to turn off rapidly enough to match the switching requirements of the Editec accessory (Chapter 10). The relatively small capacitance presented by C_K causes a phase error in the low rf frequencies during the play mode. However, this error is compensated in the individual playback amplifiers.

The video playback amplifier and the video record amplifier are physically placed on the same etched board, but they are completely separated electrically and are powered by separate power supplies. There are four such etched boards (one for each channel); each is located in one of the four head-channel units. Fig. 5-30B identifies the circuit functions and relationships of the playback preamplifier. Each of the playback amplifiers receives the rf signal (after amplification in an individual one-stage nuvistor preamplifier) reproduced by the video head with which it is associated. Each of the four nuvistor preamplifiers is integral with the Mark X head assembly.

The output of the associated nuvistor preamplifier enters the playback amplifier at pin 2 by way of a low-capacitance coaxial cable of specific length. The signal at pin 2 is applied to the emitter of Q11, which presents a very low input impedance. Transistors Q10 and Q11 form a feedback amplifier. The combination of the nuvistor and transistors forms a low-noise cascode circuit, of which the nuvistor is the input section and feedback pair Q10-Q11 is the output section.

The output of Q10 and Q11 is amplified by Q9 which produces a gain of approximately 2. Components L1 and R25 reduce the current feedback of Q9 at low frequencies, thus increasing the gain produced at these frequencies. This action compensates for the low-frequency losses and phase shift in the cathode circuit of the nuvistor stage. Between 1 and 15 MHz, L1 and R25 provide phase compensation; at frequencies below 1 MHz, they provide increasing gain as the frequency is lowered. Their principal purpose is that of phase compensation to maintain phase linearity of the reproduced video signal.

The output of amplifier Q9 is applied to the base of Q8, which with Q7 forms a feedback amplifier. This stage produces a gain of approximately 6. Variable capacitor C7 is factory adjusted to eliminate gain variations of fractions of a decibel at 15 MHz (arising from variations in transistor parameters or tolerances of other components). The combination of the nuvistor preamplifier, interconnecting cable, and playback amplifier is factory set by means of C7 to be flat within less than 0.1 dB between 1 and 15 MHz. (This is typical of many later stages in the video signal path.)

NOTE: The chain composed of the nuvistor preamplifier, the interconnecting cable, and the playback amplifier is arranged to produce a gain of 50 (± 10 percent) when terminated in 75 ohms, and when there is no unbypassed resistor present in the cathode circuit of the nuvistor. This means that a 250-millivolt output from the playback amplifier results from an output of approximately 5 millivolts from the head transformer.

The output of Q7 and Q8 is applied to the base of Q6, which with Q5 forms a complementary totem-pole amplifier (two-stage amplifier with a feedback factor of 1). The input and output voltages of this stage are the same, but the output impedance is of the order of 1 ohm.

5-8. THE PLAYBACK AMPLIFIER

Each playback amplifier (one in each channel, driven by the output of its associated preamplifier as just described) performs the following functions:

1. Compensation of head resonance.
2. Linear phase-amplitude response correction (cosine equalization of frequency response).
3. Automatic gain control (agc).
4. Fm level sensing for monitoring.

The circuit of each video head includes its own characteristic inductance, resistance, and stray capacitance plus the input capacitance of the associated nuvistor preamplifier. This causes resonance within the bandpass of the video head. The condition of resonance causes a change of group delay which must be compensated. These effects of head resonance are removed by the playback amplifier, the characteristics of which are made exactly opposite to those of the head.

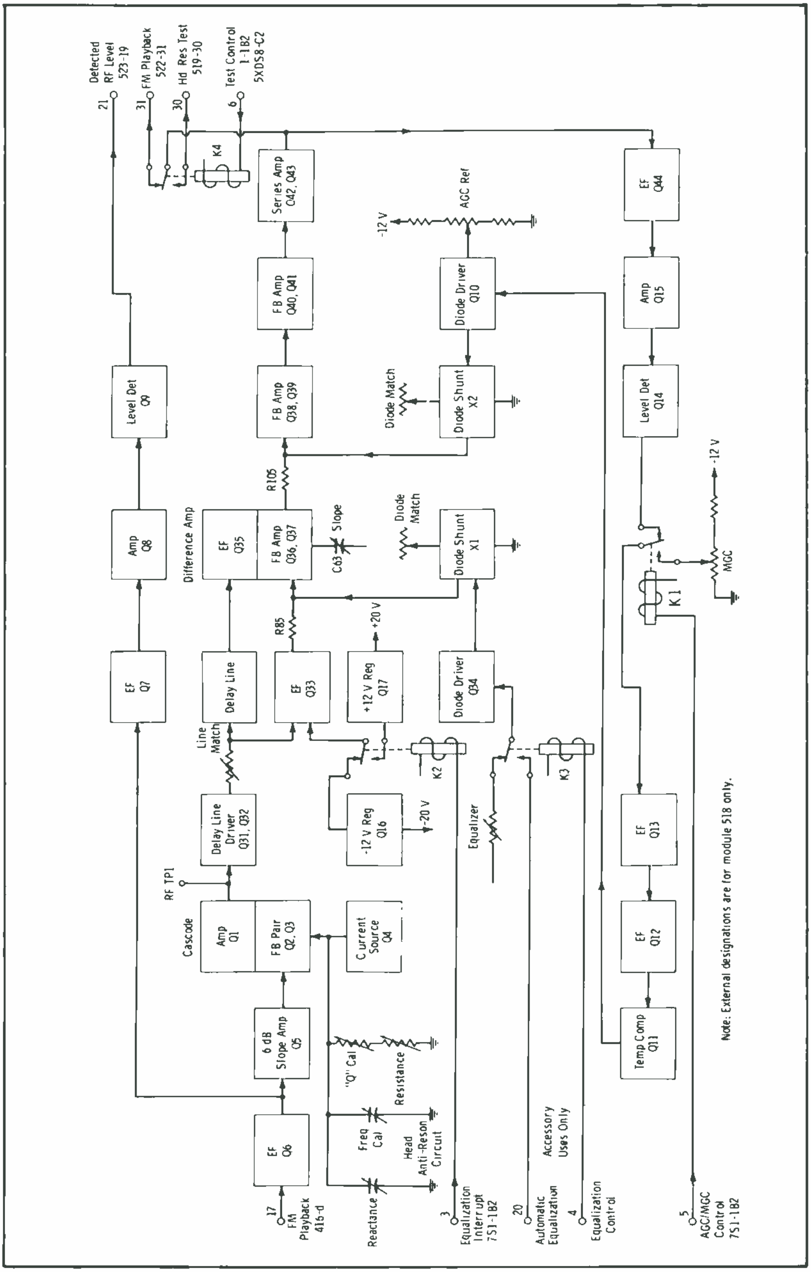
Fig. 5-31 is a block diagram of the playback amplifier in the RCA TR-70 equipment. To accomplish its functions, three major signal-flow paths are used. Each of these is described separately below.

Normal Signal Flow

During normal playback operation, relays K1, K2, and K4 remain deenergized, and playback fm from the associated channel in the fm preamplifier module is supplied to emitter follower Q6. This transistor drives two paths as follows:

1. The primary path, through slope-amplifier transistor Q5, which provides head-resonance compensation, linear phase-amplitude response correction, and agc.
2. The secondary path, through emitter follower Q7, which provides fm level detection for display on the cro.

In the primary signal path, transistor Q5 amplifies the playback fm signal in such a way that the output voltage increases with frequency at approximately 6 dB per octave. Slope amplifier Q5 drives the succeeding stages containing transistors Q1 through Q4 and the head-resonance compensa-



Courtesy RCA

Fig. 5-31. Block diagram of RCA TR-70 playback amplifier.

tion controls in the emitter circuit of Q3. These controls (REACTANCE and RESISTANCE) are located on the front panel.

Complementary characteristics provided by the head-resonance compensation circuit offset head phase nonlinearities in the head-resonance region. In addition to these complementary head characteristics, the head-resonance compensation circuit introduces a rolloff of approximately 6 dB per octave, which is offset by slope amplifier Q5.

The output of the head-resonance compensation circuit is taken from the collector of Q1 and fed to delay-line driver Q31-Q32. The latter feeds the signal through a line-matching potentiometer to a delay line and emitter follower Q33.

The delay-line output drives emitter follower Q35, which operates with feedback amplifier Q36-Q37 as a difference amplifier. The output of emitter follower Q33 drives resistor R85, which operates with diode shunt X1 to form a variable voltage divider. The voltage at the junction of resistor R85 and diode shunt X1 is applied to Q36 in the difference amplifier.

A combination of the functions of the delay line, variable voltage divider, and difference amplifier provides cosine equalization of the playback fm signal. Cosine equalization is required to compensate for frequency-response rolloff that occurs as a result of the finite gap width in the heads. Equalization corrects this rolloff of amplitude response while maintaining a linear phase response. The amount of correction is determined by the setting of the EQUALIZER control on the module front panel.

The equalized output from transistor Q37 in the difference amplifier is fed to another variable voltage divider consisting of resistor R105 and diode shunt X2. Voltage at the junction of R105 and X2 is amplified by feedback-pair amplifiers Q38-Q39 and Q40-Q41. This voltage divider has its voltage level determined by the agc feedback loop (described below), which controls the impedance of diode shunt X2.

After amplification through the feedback-pair amplifiers, the signal is fed to series amplifier Q42-Q43, from which the signal is routed to two paths. These are:

1. To the center arm of relay K4, then to either pin 31 as the playback fm output, or to pin 30 as the head-resonance test output.
2. To emitter follower Q44 and the agc loop.

A sending-end termination of 75 ohms is provided to the signal before it is applied to the contacts of relay K4. A receiving-end termination of 75 ohms is provided at either the fm switcher module (522) or the fm equalizer module (523), depending on whether relay K4 is de-energized or energized.

In the agc loop, the signal from series amplifier Q42-Q43 is fed to emitter follower Q44, amplified through Q15, and detected through Q14. In level detector Q14, the fm signal is peak-detected to yield a dc voltage that is proportional to the signal level. This dc level is fed through the normally closed contacts of relay K1 to emitter follower Q13. The signal is then coupled through emitter follower Q12 to Q11.

Transistor Q11 serves as a temperature compensator. This stage, with emitter followers Q12 and Q13, drives diode driver Q10. As the signal level increases, transistor Q10 is driven further into conduction, and there is more current through Q10 and diode shunt X2; this reduces the impedance of X2. The reduction of impedance reduces the signal level from the variable voltage divider (resistor R105 and diode shunt X2), resulting in a constant output level regardless of variations in the input signal level to the module.

Signal Flow for RF Level Detection

In this signal path, the playback fm signal is applied through emitter follower Q7 to amplifier Q8. The amplified signal is then supplied to level detector Q9. The circuits for transistors Q8 and Q9 are similar to those for transistors Q14 and Q15. However, the remaining portion of the peak-detection circuit is located in the fm equalizer module, where all four playback fm channels are combined into a single path.

Signal Flow for Head-Resonance Test

During head-resonance tests, an fm sweep signal is injected into one head at a time while the associated playback channel is selected with the CHANNEL SELECT switch on the fm test panel. In this test mode, relays K1, K2, and K4 are energized, and the fm signal is applied only to the selected playback amplifier module, which is modified as follows:

1. With relay K2 energized, the signal is inhibited from transistor Q33 but follows the delay-line path to the difference amplifier (Q35, Q36, and Q37), which now yields a flat response.
2. Energized relay K1 is now in the manual-gain-control position, and the gain of the amplifier is controlled by the setting of the front-panel MGC potentiometer.
3. Energized relay K4 now routes the signal to pin 30 and to the fm equalizer module, where the fm sweep signal is amplified, filtered, detected, chopped, and finally supplied to the cro for display of the head-resonance presentation.

Two series regulators are employed in the playback amplifier module to supply the minus and plus 12 volts (nominal) required in the module. Transistor Q16 provides regulated minus 12 volts from the minus 20-volt bus; similarly, transistor Q17 provides plus 12 volts.

5-9. ELECTRONIC CHANNEL SWITCHING

In the playback mode, the four video-head outputs must be sequentially switched to minimize noise and cross talk and to prevent two heads from reproducing identical information during the overlap period. Obviously, switching must be timed with the head revolution. Also, some means is provided to assure that any switching transients fall in the horizontal-retrace period so that they will not be visible in the reproduced picture.

Both Ampex and RCA perform this function in two principal switching operations. The first is a coarse 4-to-2 switching action that combines the outputs of heads separated by 180° on the headwheel; the second is a 2-to-1 precise switching action that combines the resulting paired outputs into a continuous signal. This method is illustrated in Fig. 5-32. Note that the only difference here is the head-numbering sequence of the two manufacturers (described in Chapter 2). In either case, the 4-to-2 switching action combines the outputs of heads that are 180° apart on the perimeter of the headwheel.

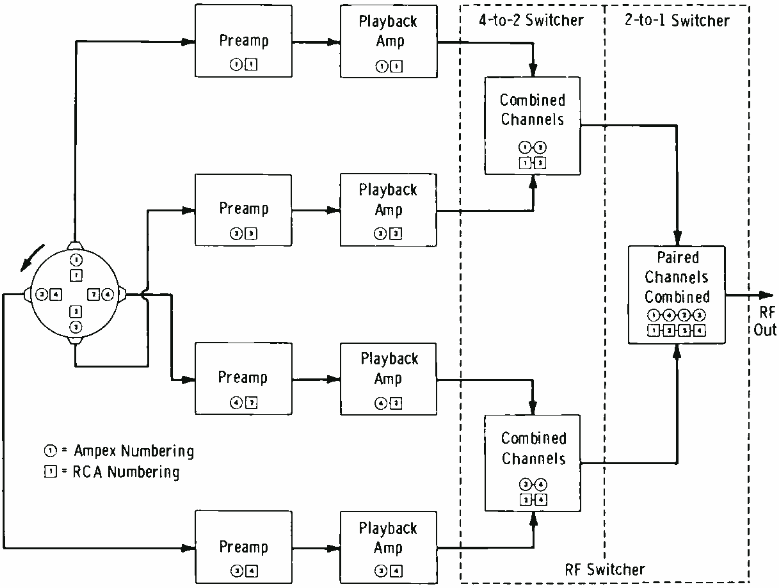


Fig. 5-32. Principle of rf switching systems.

If the basic differences are kept in mind, a description of the RCA TR-70 fm switching system will serve to outline the basic action of all electronic switching systems used in quadruplex playback. This description follows.

Purpose

The fm switcher module combines the fm outputs of the four heads as they sequentially scan the tape during playback. Precision switching in two separate channels (video and sync) places switching transients where they are least detrimental. In the video fm channel, the switching arrangement normally locates transients during the horizontal-sync interval, where the transients are later eliminated by substitution of regenerated sync. In the sync fm channel, switching occurs during the video portion of the playback signal, thus leaving the sync undisturbed by timing errors and transients. In addition, the sync fm channel has provisions for equalizing the fm prior to demodulation. (The fm equalizer module performs this function more accurately for the video fm channel.)

Besides combining the playback fm outputs from the four heads, the fm switcher module also generates a head-switching pulse that is used to activate a transient-suppression clamp circuit in the post-emphasis module (529). The fm switcher also generates a delayed signal that is referenced to the tonewheel output for use in the accessory Chrominance Amplitude and Velocity Error Corrector (Cavec) module (626). (See Chapter 9.)

> NOTE: The fm switcher module operates universally on all television standards. The descriptions that follow are simplified by referring to tonewheel rates only on the basis of a 60-Hz system (240-Hz basic tonewheel frequency). For 50-Hz systems, change the corresponding tonewheel frequency references to 250 Hz.

Because of the complexity of signal flow in this module, the description is divided into five groups. These groups are divided according to the functions of the module. Associated diagrams for pertinent groups are provided.

4 X 2 Coarse Switch

See Figs. 5-33 and 5-34. This circuit receives four fm inputs and one control input. The four fm inputs are supplied from the playback amplifier modules. Each of the inputs supplied to the fm switcher module is a short period of fm having a duration that corresponds to the time that the associated head is scanning a recorded tape. The periods of fm output from each channel occur sequentially and overlap in time, since one head begins its passage over the tape before the previous one has completed its scan.

A 240-Hz tonewheel (tw) pulse is used for the control input signal (see waveform A of Fig. 5-34). This tw pulse is generated in the tonewheel processor module (612). Its timing is based on a signal generated in a pickup coil by a notch in the tonewheel as the tonewheel rotates with the headwheel. The tw pulse thus has a definite relationship with the rotating quadrature heads. The tw pulse occurs near the center of the active tape scan by head 1.

Two gates are used in the 4 × 2 coarse switch to combine alternate input lines. Channels 1 and 3 are combined in the diode gate using X19 through X22. (See Fig. 5-34, waveforms B, D, and I.) Channels 2 and 4 are combined in the diode gate using X8 through X11 (waveforms C, E, and J). Switching between input channels occurs in each gate during the interval when neither input channel is supplying a tape fm signal.

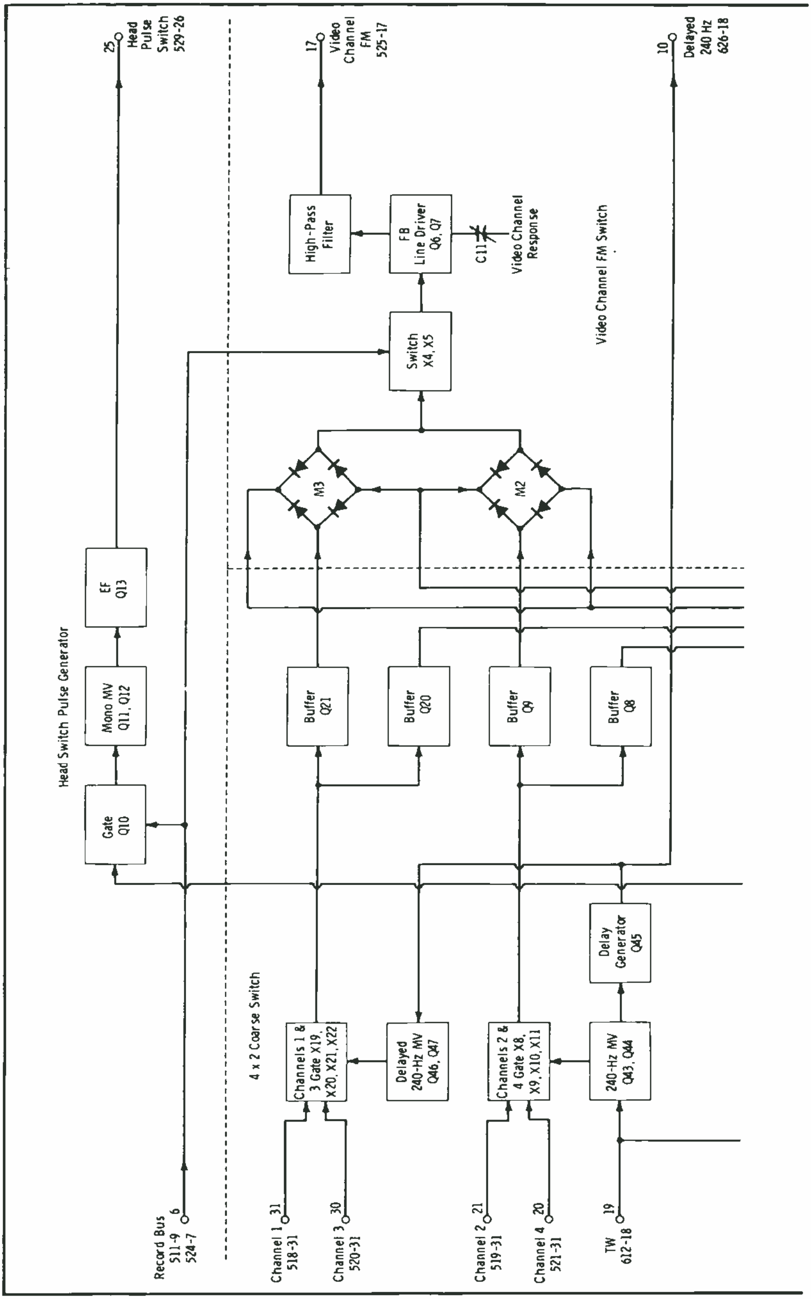
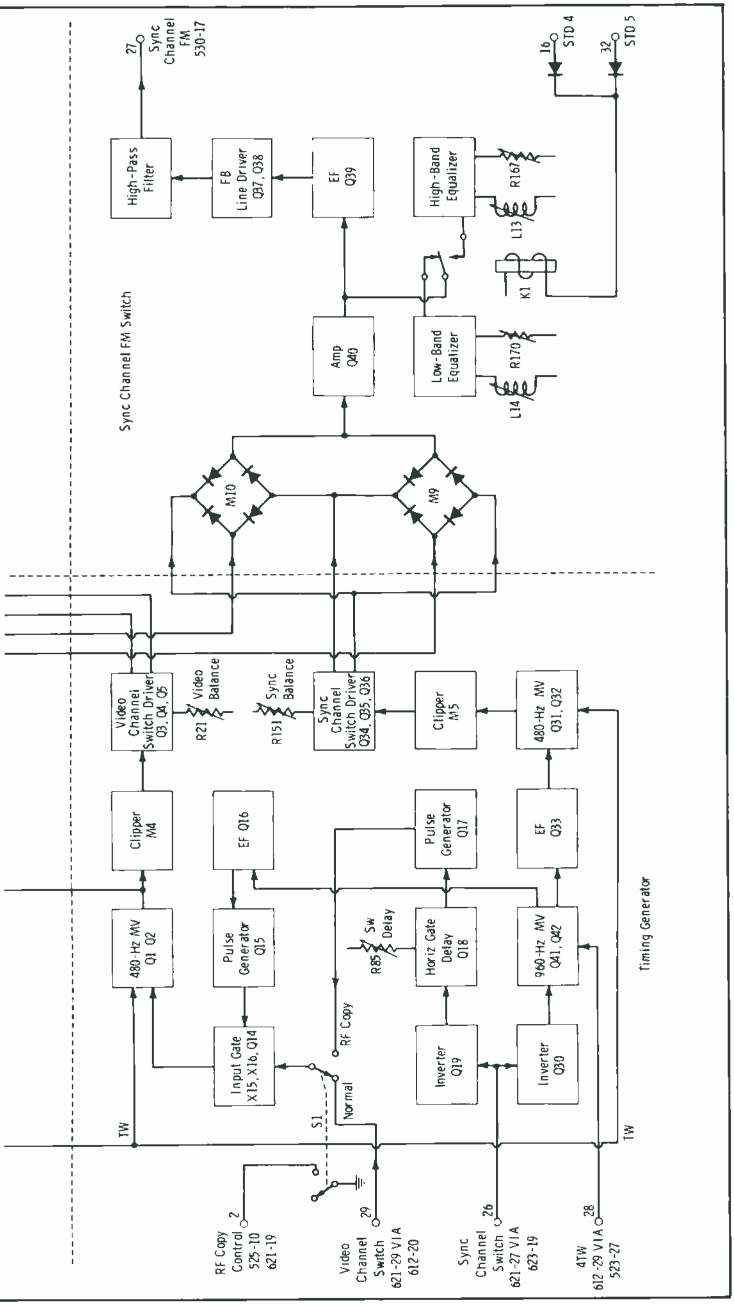


Fig. 5-33. Block diagram



of RCA fm switcher.

Switching between channels 2 and 4 is controlled by a monostable multivibrator using transistors Q43 and Q44. When triggered by the tw pulse, the multivibrator generates a 2080-microsecond pulse (waveform F) that corresponds to one-half the 240-Hz tw period. The polarity of the control signal from transistors Q43 and Q44 is such that the gate switches to channel 2 before head 2 begins to traverse the tape (switching actually occurs at the tw leading edge while head 1 is at the center of the tape). After head 2 has completed its traverse (2080 microseconds after the initial switch), the gate switches from channel 2 to channel 4. Thus, disturbances in the desired fm signal are avoided by gating the two input signals while both are inactive.

A similar sequence of operation occurs in the gate for channels 1 and 3. However, in this gate the tw pulse cannot be used directly to trigger the

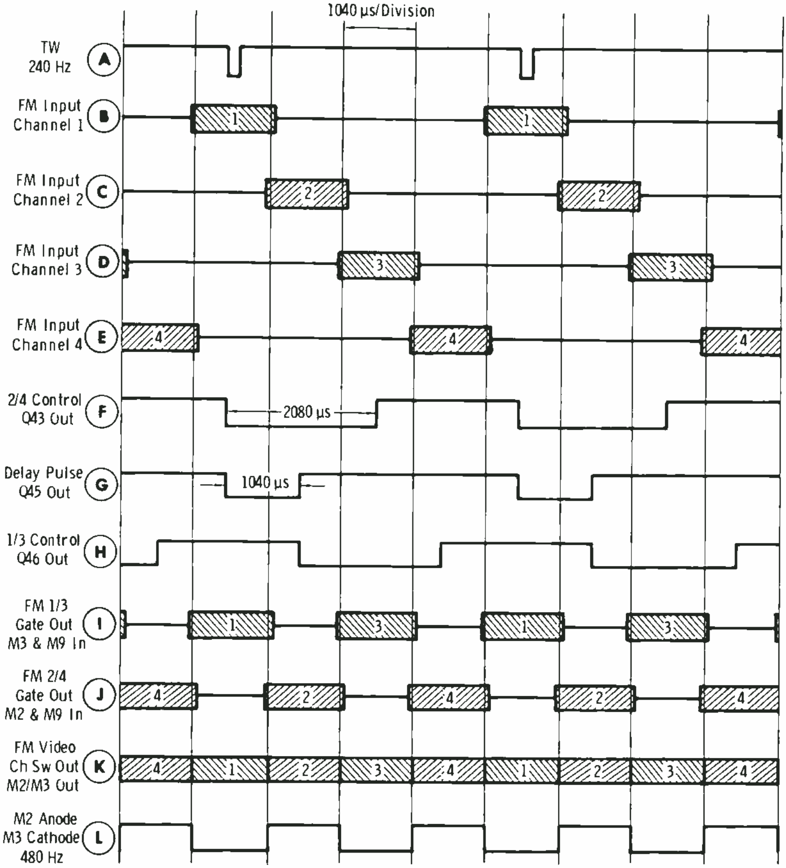


Fig. 5-34. Timing diagram for 4 × 2 coarse switch and video channel.

control multivibrator (Q46 and Q47). This would cause switching to occur during the active head traverse because the tw pulse is generated near the center of the active scan for head 1. To overcome this problem, the tw pulse is delayed for a time interval corresponding to 90° (1040 microseconds) of rotation of the headwheel by delay-generator transistor Q45 (waveform G in Fig. 5-34). The trailing edge of the delayed output pulse from Q45 then triggers the delayed 240-Hz multivibrator (Q46 and Q47, waveform H) and causes the gate for channels 1 and 3 to switch *between* the intervals when heads 1 and 3 are supplying fm.

Output from the gate for channels 1 and 3 (waveform I) is fed through buffer transistors Q21 and Q20 to one input of the video-channel fm switch and one input of the sync-channel fm switch, respectively. Similarly, the output from the gate for channels 2 and 4 (waveform J) is fed through buffer transistors Q9 and Q8 to the second inputs of the video-channel and sync-channel fm switches.

The delay generator (Q45) provides an auxiliary output for the fm switcher module through pin 10 to the Cavec module (626) when the latter accessory is used with the machine.

Video-Channel FM Switch

Two diode quads constitute an electronic switch controlled by precisely timed signals developed in the timing-generator circuits of the fm switcher module. One input to the electronic switch is the combined fm from channels 1 and 3 at quad diodes M3 (waveform I of Fig. 5-34). The second input is the combined fm from channels 2 and 4 at quad diodes M2 (waveform J).

The outputs of the two quads are connected in parallel to drive subsequent stages. The control points of the quads are connected in complementary fashion to the push-pull control signals so that the quads select the inputs alternately as a single-pole, double-throw switch. Switching occurs at each polarity reversal of the control signal, so the switch operates at a 960-Hz (4tw) rate when supplied with a 480-Hz control signal (waveform L).

The 960-Hz switching rate causes the quad diodes to select the channel 1 or 3 input while head 1 is traversing the tape. The quad diodes then switch to the channel 2 or 4 input, just as head 1 is leaving the tape and head 2 is beginning its scan. As head 2 completes its scan, the quad diodes switch again to the channel 1 or 3 input to select the output of head 3 as it starts across the tape. When head 3 is nearing the end of its active scan, the quad diodes switch away and select the channel 2 or 4 input once again as head 4 begins its traverse. Finally, as head 4 nears completion of its scan, the quad diodes return to the channel 1 or 3 input to begin the sequence again with head 1.

The output from the quad diodes is a continuous fm signal (waveform K in Fig. 5-34) resulting from the sequential selection of playback channels coordinated with the passage of the heads across the tape. Because the headwheel rotates 240 times per second, complete cycles in the selection of all four heads must occur at a 240-Hz rate, and selection of individual heads occurs at a 960-Hz rate.

Video-channel fm in its entirety (waveform K) is fed to a diode switch (X4 and X5), which is controlled by the record bus. This switch is open for operation in the record mode to prevent high-level recording fm, which may be picked up in the sensitive fm preamplifier module, from proceeding through the fm switcher module. Thus the switch eliminates possible cross talk in later stages.

Fm through the switch is supplied to a feedback line driver (Q6 and Q7) that restores the signal level lost in the switching circuits and the output termination. A high-pass filter is used between the line driver and the output terminal (pin 17) to allow usable fm to continue to the fm equalizer module (523), but to reject low-frequency offsets caused by minor dc unbalance in the 2 × 4 gates and M2-M3 switches.

Sync-Channel FM Switch and Equalizer

Refer to Figs. 5-33 and 5-34. Diode quads M9 and M10 in the sync channel function in the same manner as M2 and M3 in the video channel, except that timing of the switching process is advanced in the sync channel. However, unlike the arrangement in the video channel, the sync-channel fm does not pass through a separate amplitude-equalizer module prior to demodulation. Instead, playback losses are compensated for by simplified equalizers with fixed adjustments in the fm switcher module. Two separate equalizers in the module are optimized individually, one for high band and the other for low band. Relay K1 selects the proper equalizer. It is energized by standards bus 4 or 5 for 525- or 625-line high-band standards, and it remains de-energized for all low-band standards.

Either equalizer operates in conjunction with common-base amplifier Q40 to boost high-frequency fm signal components relative to the low-frequency components. Sync-channel video is used only to provide a source of tape sync undisturbed by switching pulses; therefore, adjustment of the equalizers is not so critical as in the video channel, and fixed controls can be used.

Equalized fm is fed through buffer emitter follower Q39 to the feedback line driver (Q37 and Q38). The fm is then filtered through a high-pass filter as in the video channel.

Timing Generator

The complexity of the timing-generator signal flow requires the description to be in three parts, each having a seperate block diagram and timing diagram.

Video Channel, Normal Operation—For this description, refer to Fig. 5-33, the simplified diagram in Fig. 5-35, and the waveforms of Fig. 5-36.

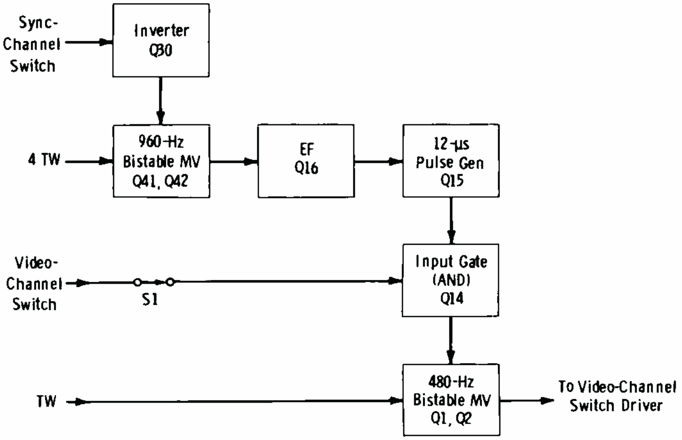


Fig. 5-35. Simplified diagram of video-channel timing generator for normal operation.

A sync-channel switch pulse having a repetition rate of 15,750 Hz is generated in the internal reference module (Chapter 6) and enters the fm switcher module through pin 26 (see waveform A of Fig. 5-36). The pulse is inverted by transistor Q30 and triggers the 960-Hz bistable multivibrator (Q41 and Q42). An additional trigger pulse for the multivibrator is the 4tw signal (waveform B) which is developed in the tonewheel processor module (523) and enters through pin 28. The tonewheel processor module contains the 4tw delay control that permits adjusting the 4tw pulse to the proper point in the head overlap interval.

The bistable multivibrator (Q41, Q42) is switched to one state by a positive-going transition of the 4tw signal that is coincident with the beginning of a new head traverse across the tape. The next sync-channel switch pulse to occur then causes the bistable multivibrator to change state again. This results in a negative pulse from transistor Q42 with its leading edge timed by the 4tw pulse and its trailing edge timed by the sync-channel switch pulse (see waveform C in Fig. 5-36). The multivibrator is immune to triggering by further switch pulses and is inhibited until it is again reset by the 4tw trigger as the next head begins crossing the tape.

Negative pulses from transistor Q42 are supplied at a 960-Hz rate to emitter follower Q16, which drives pulse generator Q15. The pulse from Q15 (waveform D in Fig. 5-36) has a duration of approximately 12 microseconds, with its leading edge timed by the leading edge of the sync-channel switch pulse.

The 12-microsecond pulse from Q15 is fed to one input of the input gate (Q14). A second signal to the input gate is the video-channel switch pulse (waveform E, Fig. 5-36), which is generated in the internal reference module. This second pulse has a repetition rate of 15,750 Hz and a nega-

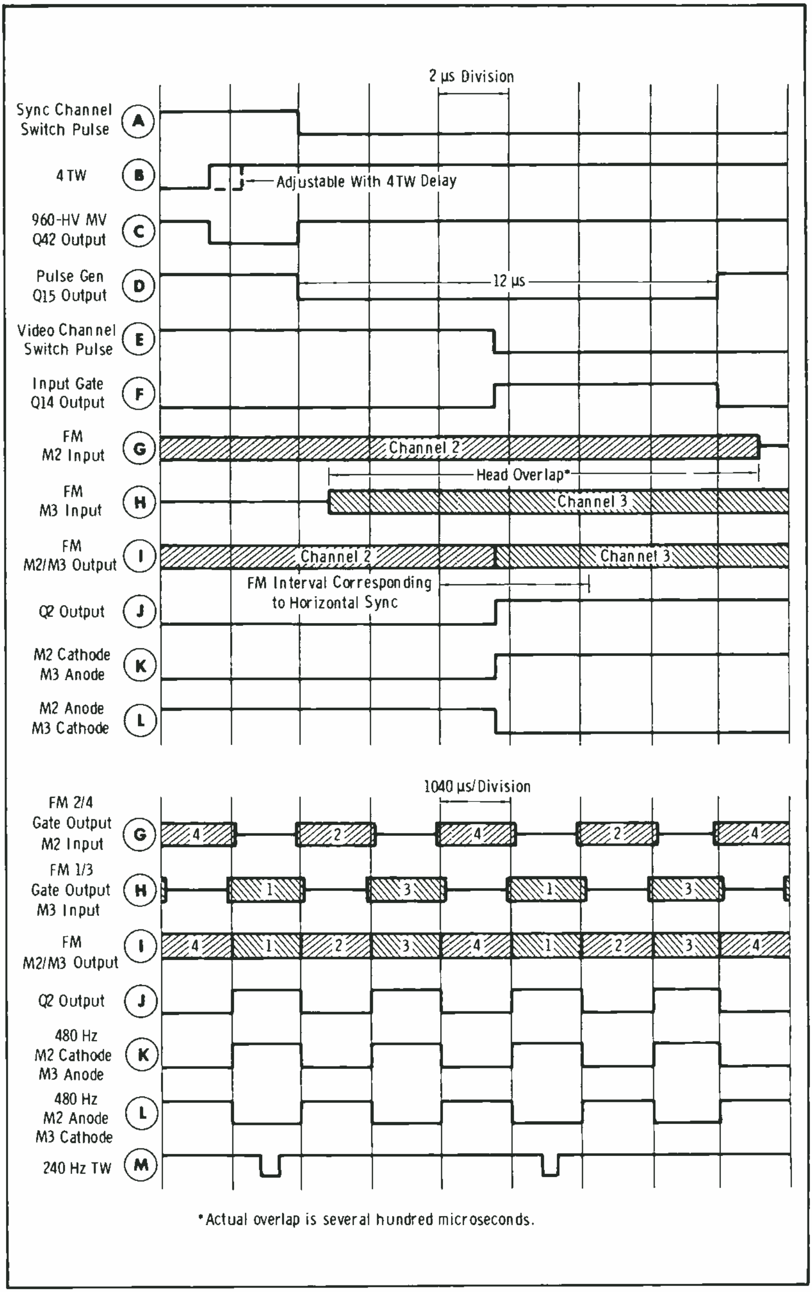


Fig. 5-36. Timing diagram for video channel, normal operation.

tive-going transition timed during the horizontal-sync interval at the precise instant that video-channel head switching is to take place. This signal is connected to the second input of the input gate when switch S1 is in the Normal position.

The input gate produces a positive output when both inputs are negative. This condition exists during the time interval between the leading edge of the 15,750-Hz video-channel switch pulse and the end of the 12-microsecond 960-Hz pulse (see waveform F, Fig. 5-36). In summary, the characteristics of this video-channel trigger pulse are determined as follows:

1. Leading edge: Video-channel switching pulse
2. Trailing edge: Sync-channel switch pulse plus a 12-microsecond interval generated in transistor Q15
3. Repetition rate: 4tw (960 Hz)

A positive-going output from transistor Q14 triggers bistable multivibrator Q1-Q2, which operates as a two-to-one frequency divider. The square-wave output from Q1-Q2 is at a 480-Hz rate (waveform J, Fig. 5-36) and is clipped by shunt limiter M4 (Fig. 5-33). The signal is then supplied to the video-channel switch driver, where push-pull control signals (waveforms K and L, Fig. 5-36) are developed to drive the video-channel precision switch (M2 and M3 in Fig. 5-33). The latter supplies a continuous fm signal (waveform I) from the inputs shown in waveforms G and H of Fig. 5-36. Proper phasing of the multivibrator is assured by introducing a tw pulse (waveform M) to reset it in the event that the phase is incorrect.

NOTE: Head overlap of adjacent channels is several hundred microseconds, but it is shown greatly reduced in the timing diagrams to simplify illustration of the various functions.

Video Channel, RF Copy Operation—For this description, refer to Figs. 5-33, 5-37, and 5-38. Playing back or recording a tape using the rf-copy

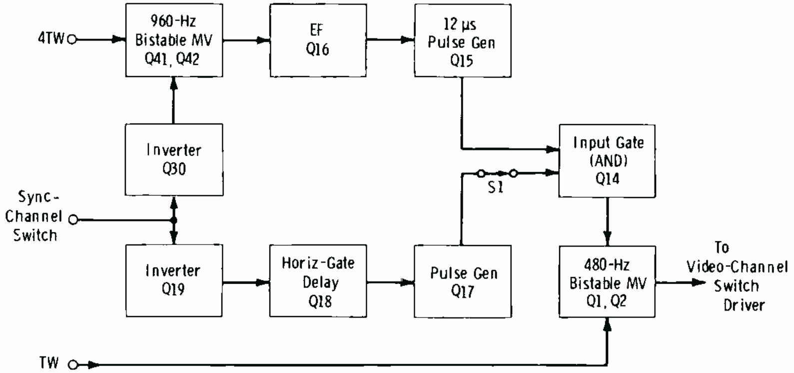
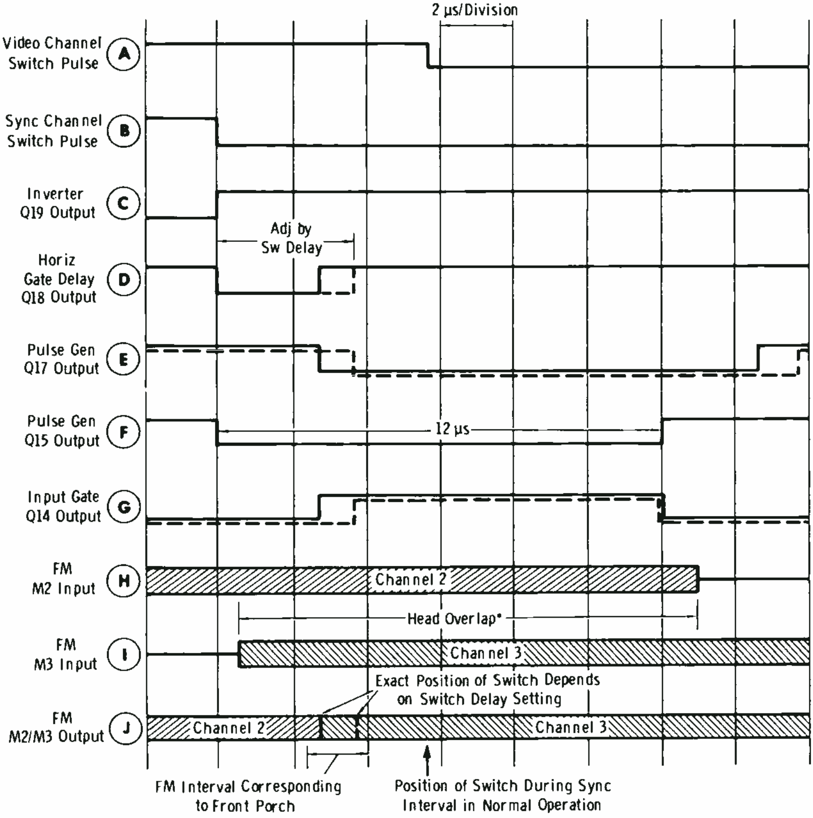


Fig. 5-37. Simplified diagram of video-channel timing generator, rf-copy mode.

mode of operation (direct re-recording of fm without intervening demodulation to video and subsequent modulation) requires the timing of the video-channel switching point to be changed. During normal video playback, head switching is positioned in the sync interval. This results in elimination of the switching transient from the video output by subsequent replacement of tape sync with regenerated sync. However, during playback of an rf copy recording, sync cannot be replaced because the signal was not demodulated at the time the copy was made. Therefore, switching is positioned in the front-porch interval, and switching transients are clamped out by the post-emphasis module (529) during final video playback. The advance in switching time is accomplished by replacing the video-channel switch pulse at the input gate (Q14) with another pulse having an adjustable delay; this occurs when switch S1 is placed in the rf copy position.



*Actual overlap is several hundred microseconds.

Fig. 5-38. Timing diagram for video channel, rf-copy mode.

A new, adjustable delay pulse is derived from the sync-channel switch pulse (waveform B of Fig. 5-38), which occurs almost six microseconds in advance of the video-channel switch pulse (waveform A). The sync-channel switch pulse is inverted by transistor Q19. The resulting output pulse drives horizontal-gate delay generator Q18. Here, a new delay pulse is generated; its leading edge is coincident with the input pulse, but its trailing-edge transition time (waveform D, Fig. 5-38) is determined by the position of SW DELAY potentiometer R85.

The variable-width pulse from transistor Q18 drives pulse generator Q17, where a new constant-width pulse (waveform E) is formed. The leading edge of this pulse is coincident with the trailing edge of the input pulse. Thus, the position of the pulse is determined by the setting of the SW DELAY control.

Pulse generator Q17 supplies the variable-delay pulse at a 15,750-Hz rate. The pulse is combined with the 960-Hz, 12-microsecond pulse (waveform F) from pulse generator Q15 in input gate Q14. (The pulse from Q15 is generated exactly as in normal operation.) The input gate produces a positive pulse (waveform G) each time the inputs from Q15 and Q17 are both negative.

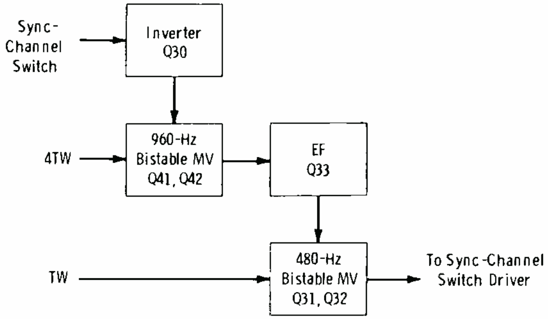
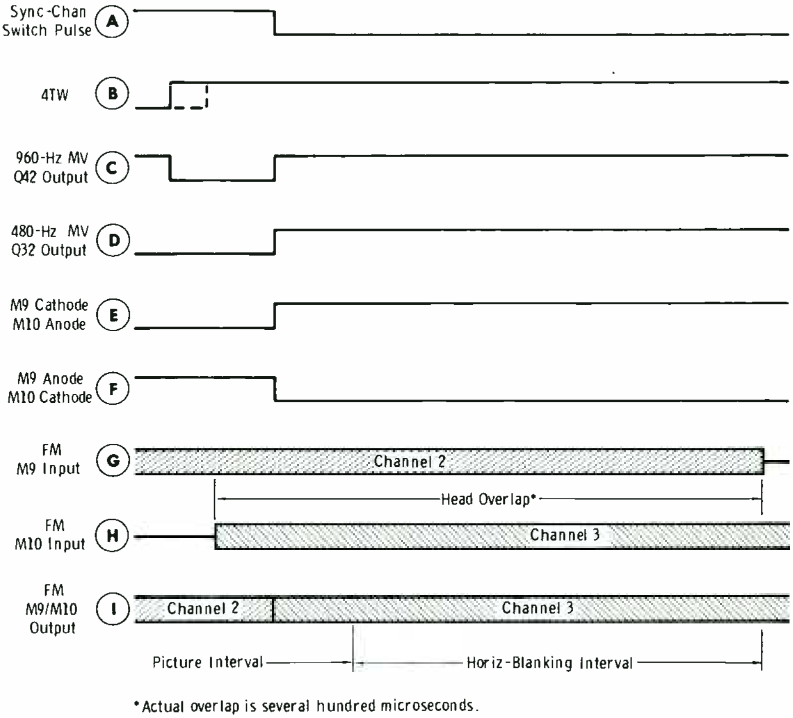


Fig. 5-39. Simplified diagram of timing generator for sync channel.

The resulting pulse from the input gate has a positive-going leading edge that triggers the 480-Hz bistable multivibrator (described previously). However, the multivibrator output transitions occur during the front-porch interval, and quad diodes M2 and M3 are switched accordingly. Thus, the output of the quad diodes (waveform J) is a continuous fm signal representing sequential switching between heads, with the switching point occurring in the front-porch interval as adjusted with the SW DELAY control.

Sync Channel—Refer to Figs. 5-33, 5-39, and 5-40 for this description. The 4tw input pulse (waveform B, Fig. 5-40) causes the 960-Hz bistable multivibrator to change state as a head is just beginning to traverse the tape. After the multivibrator has changed state, the next sync-channel switch pulse to occur passes through inverter Q30 and returns the multivibrator to its original state, where it remains until it is reset by the next 4tw positive trigger. This results in a 960-Hz negative pulse from the multivibrator (waveform C, Fig. 5-40). The leading edge of this pulse is determined by the positive-going 4tw pulse transition, and the trailing edge is timed by the sync-channel switching pulse.



*Actual overlap is several hundred microseconds.

Fig. 5-40. Timing diagram for sync channel.

Up to this point, timing generation is identical to that in the video-channel timing generator for the normal mode (see waveforms A, B, and C of Fig. 5-36.) However, in the sync-channel timing generator, instead of being applied to additional gating circuitry, the pulse from the 960-Hz multivibrator (Q41, Q42) is immediately coupled through emitter follower Q33 to trigger the 480-Hz bistable multivibrator (Q31, Q32). In addition, the tonewheel pulse is fed to the same 480-Hz multivibrator to assure proper phasing of the output.

Output 480-Hz pulses from transistor Q32 (waveform D in Fig. 5-40) are clipped by quad diodes M5 (Fig. 5-33) and then coupled to the sync-channel switch driver (transistors Q34, Q35, and Q36). Here, the push-pull control signals (waveforms E and F) are developed to drive the sync-channel precision switch consisting of quad diodes M9 and M10. The precision switch combines the outputs from the gate for channels 2 and 4 and the gate for channels 1 and 3 into a continuous fm signal (waveform I). The switching point in the signal is now *before* horizontal blanking.

Head-Switch Pulse Generator

Gate Q10 (Fig. 5-33) is enabled by the record bus whenever the machine is in any mode other than record. At those times, the gate passes 480-Hz pulses from the 480-Hz multivibrator (Q1, Q2). Each transition of the 480-Hz signal triggers the monostable multivibrator (Q11, Q12), and the multivibrator generates seven-microsecond pulses at a 960-Hz rate. This is now the head-switching pulse output, the leading edge of which coincides with the video-channel switch point. During input or noise test conditions, the post-emphasis module utilizes the head-switch pulse to clamp out switching disturbances in the demodulated video signal.

5-10. MODERN DEMODULATION CIRCUITRY

Demodulation circuitry, since it is now strictly solid-state, has changed considerably from that described earlier in this chapter. But, if you understand pulse-width demodulation (described earlier), you also understand the basic action of modern demodulators. Essentially, this process depends on the fact that as the carrier frequency increases, the pulses grow closer together, and as the carrier frequency decreases, the pulses grow farther apart. A frequency change therefore results in a dc change (dc pulsing), which a discriminator can convert to video information.

After switching and equalization, the signal-to-noise ratio is improved in the fm filter module. This module reduces noise without affecting the signal to be demodulated by redistributing the sideband information and by attenuating noise. Balance in the sidebands is restored in the limiter stages of the viedo-channel demodulator which follows.

In addition to restoring the sideband balance, the limiters in the video-channel demodulator module also serve to remove amplitude variations caused by variations in head-to-tape contact and differences in tape content level (e.g. scratches or similar disturbances). After substantial limiting, the signal is supplied to a discriminator that converts frequency variations in the fm signal to a varying-amplitude signal.

Demodulated video supplied from the video-channel demodulator contains carrier and modulation components that must be removed in order to return the signal to characteristics similar to those of the record signal prior to modulation. The video filter module removes these undesired components and supplies a low-level video signal to the post-emphasis module.

The video-channel signal is amplified and clamped in the post-emphasis module. The high-frequency boost (pre-emphasis) that had been added in the video input module is now removed, and the video is restored to its original form. A separate section in the module is used to process the sync-channel signal similarly, so that both channels maintain separate characteristics as their signals are supplied to the video processing system (next chapter) and the monitors.

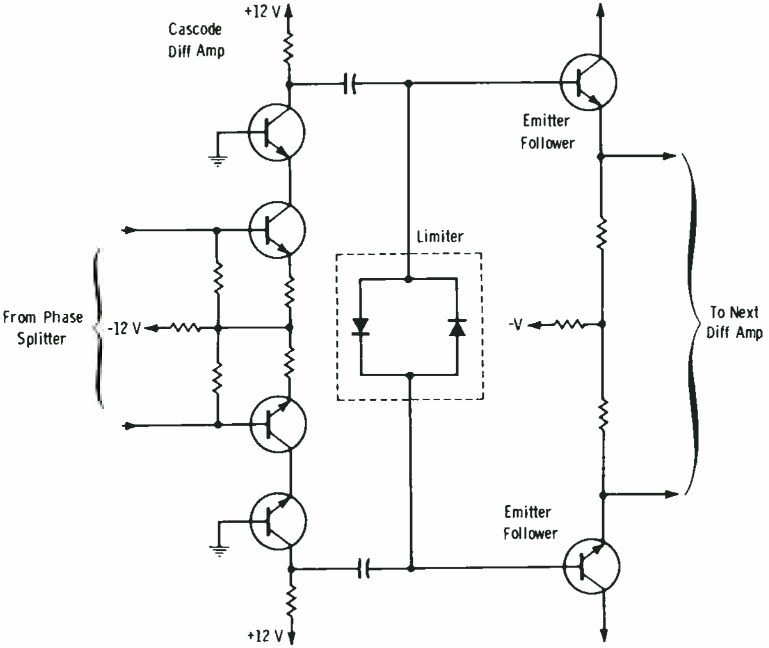
Sync-channel demodulation (Fig. 5-1) is performed with the sync-channel demodulator module (used by RCA), which is identical in construction to the video-channel demodulator module. Using a separate channel for sync demodulation provides a desirable enhancement of picture quality and sync stability. This is accomplished by having sync-channel switching occur during fm overlay corresponding to the picture interval. Thus, timing errors are not introduced, and switching disturbances do not occur during the demodulated sync interval. Conversely, the video-channel switching is accomplished during sync-interval fm overlap, leaving the active picture interval undisturbed. The disturbance to the sync pulse caused by switching is overcome by completely replacing the sync pulse with a clean pulse derived form sync demodulation in the processing amplifier (Chapter 6).

> NOTE: In the Ampex system, the processing amplifier derives and provides switching pulses which cause video head switching to take place on the front porch of sync, thus avoiding any ambiguity in the timing edge of horizontal sync.

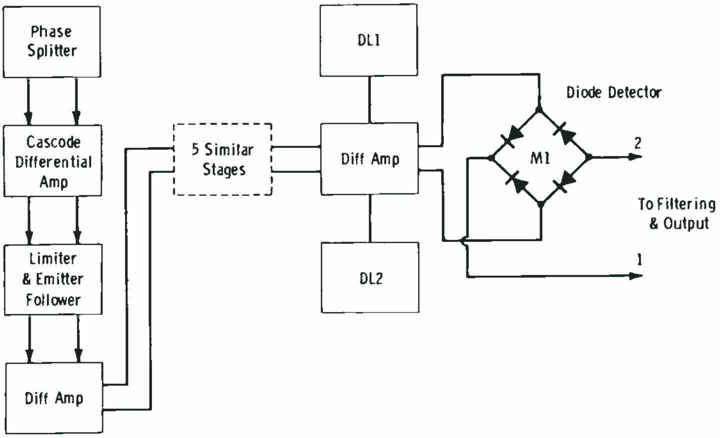
See Fig. 5-41. In the video-channel demodulator, the signal is split in phase and processed in a push-pull manner through the module. Limiter stages clip the signal to remove variations in level, and push-pull fm is supplied to the discriminator stage.

Conversion of frequency variations to amplitude variations is initiated in the discriminator circuit where constant-width pulses are generated at a repetition rate corresponding to the instantaneous carrier frequency. The effective video level from the discriminator is very low compared to the carrier level. However, the filter following the discriminator partially removes those carrier components that may cause cross talk, and it supplies the push-pull video to an amplifier stage to provide the module output.

Push-pull output from the demodulator module is supplied to the video filter module, where selection is made for the proper Bode-type filter according to the operating standard of the machine. The Bode filters present a characteristic that passes video and attenuates fm. The constant-width pulses from the demodulator discriminator are integrated, forming video that passes relatively undisturbed through the passband region; however, in the stopband region, the phase is caused to lag by 90° in one half of the filter and lead by 90° in the opposite half of the filter. This lag and lead condition occurs at higher frequencies, which is where fm cancellation is required.



(*A*) *Partial simplified schematic.*



(*B*) *Block diagram.*

Fig. 5-41. Basics of solid-state demodulator circuitry.

Let us now study Fig. 5-41 in more detail. Fm supplied to either the video-channel demodulator or sync-channel demodulator is fed to a phase splitter, from which outputs of opposite phase are supplied to a dual-channel cascode differential amplifier.

The cascode differential amplifier supplies its outputs to the first of five limiter stages. Each stage operates in push-pull with an associated differential amplifier and emitter follower for each channel. The opposite phases of the fm signal are balanced, amplified, and symmetrically clipped prior to combination of the phases for demodulation.

Output from the fourth limiter stage is supplied to a differential amplifier as well as to the following fifth limiter stage. This differential amplifier then feeds an output from the module through a relay (not shown) when the rf-copy mode of operation is selected. This output, which is still in fm form, is supplied from the machine as the rf-copy signal and is sometimes used directly for rerecording when a copy tape is to be made.

The output of the fifth limiter stage is coupled through emitter followers to the delay-line drivers. Reflections from delay lines DL1 and DL2 produce narrow pulses as a result of the square-wave current pulses that enter the delay lines (Fig. 5-42). Each half of the push-pull circuit generates a positive or negative pulse at each corresponding input square-wave transition. The pulse repetition rate is therefore twice the instantaneous fm carrier frequency.

The quad diodes in M1 (Fig. 5-41B) are connected as a bridge rectifier that gates the push-pull positive and negative pulses from the delay lines to the proper inputs of the filter drivers. The bridge supplies only negative pulses to point 2 and only positive pulses to point 1.

Each delay line (DL1 and DL2) consists of a precisely cut 84-inch length of 75-ohm foam coaxial cable that is shorted at its outer end. The input network of each line provides an accurate impedance match through the frequency band of 1 MHz to above 100 MHz. This is necessary because the pulses present include frequency components in this frequency range. The first reflection of each square-wave current pulse that enters the delay line is a 17-nanosecond pulse; the second and third reflections are cancelled out. (The second reflection is less than 4 percent of the first; the third reflection is less than 2 percent of the second.)

With time and amplitude balance of the 17-nanosecond positive and negative pulses established, the only remaining variable is frequency, which is directly related to the interval between pulses. The action of the bridge detector doubles the number of positive and negative pulses that are present. The frequency at which there is no interval between pulses occurs at approximately

$$\frac{1}{2(17 \times 10^{-9}\,\text{sec})} = 29\,\text{MHz}$$

The voltage at the output of the bridge detector rises linearly with propor-

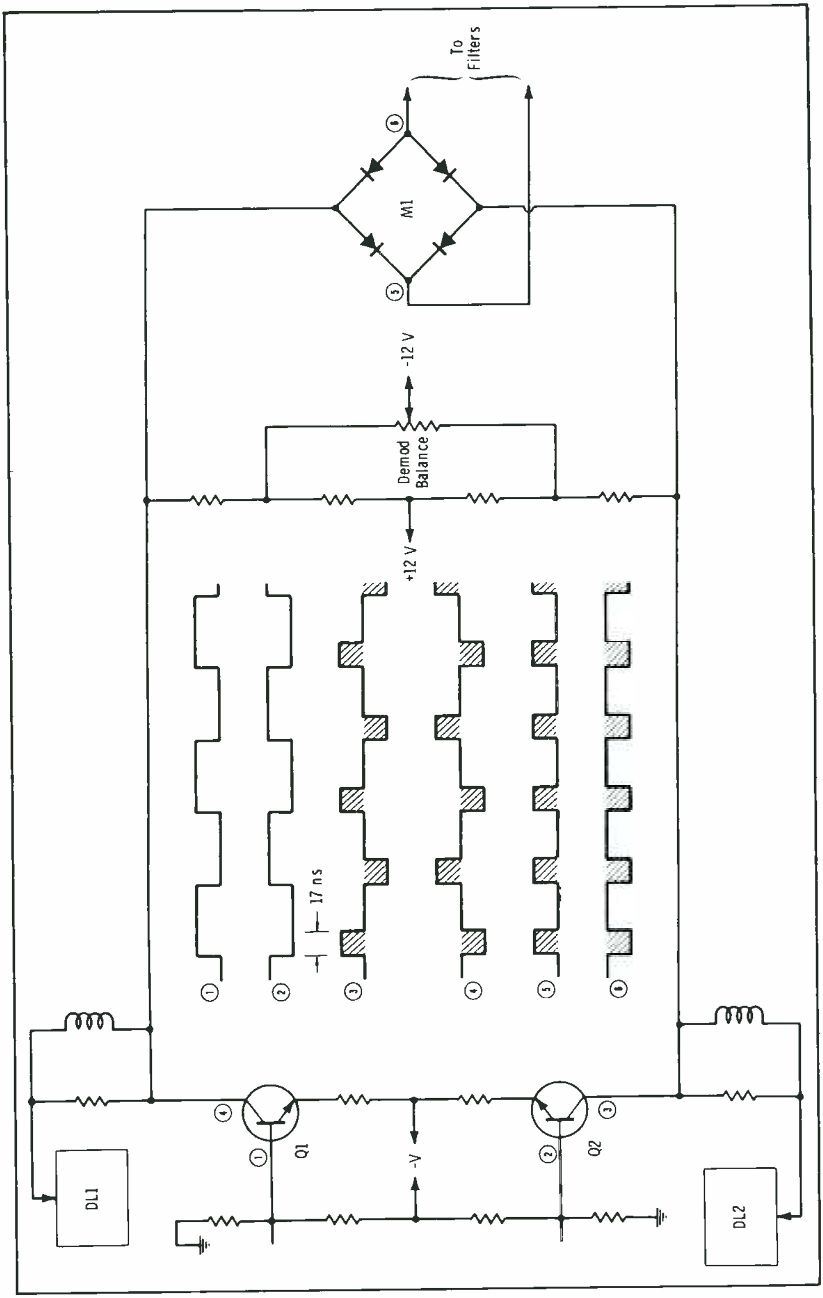


Fig. 5-42. Simplified schematic of delay-line drivers and diode detector.

tional increases of frequency from zero to the maximum at approximately 29 MHz.

Integration (through filtering) of the constant-width pulses from the bridge rectifier develops a voltage with an amplitude that is dependent on only the pulse repetition rate. Thus, in the push-pull phase with positive pulses, the higher the pulse repetition rate becomes, the more positive will be the output voltage. A similar situation exists in the negative phase of the push-pull circuit, where a negative output voltage is developed.

NOTE: This chapter has not discussed the recovered video signals following demodulation. The remainder of the video system includes special processing of the signal components, and is more appropriately studied in Chapter 6.

EXERCISES

Q5-1. Under what circumstances could electronic "quadrature correctors" be eliminated in both the record and playback functions?

Q5-2. What is the fm bandwidth of (A) older tape systems and (B) later-model combination high-band, low-band systems?

Q5-3. Give the corresponding frequency for each of the following:
(A) Low-band sync-tip level (monochrome)
(B) Low-band blanking level (monochrome)
(C) Low-band peak white (monochrome)
(D) Low-band color sync-tip level
(E) Low-band color blanking level
(F) Low-band color peak white
(G) High-band sync-tip level
(H) High-band blanking level
(I) High-band peak white

Q5-4. Define "dropouts."

Q5-5. Approximately how much rf voltage exists at the headwheel brushes in (A) the record mode and (B) the playback mode?

Q5-6. What is the primary signal that supplies switching information to the electronic channel switcher?

Q5-7. Where does the input signal to the demodulator come from in (A) the record mode and (B) the playback mode?

Q5-8. Why is fm amplitude limiting used in the demodulator?

Q5-9. Why must timing information from separated sync be fed to the electronic switcher?

Q5-10. Is head-resonance compensation used for fm equalization?

CHAPTER 6

The Video Processing System

Fig. 6-1 presents basic block diagrams of the circuitry to be studied in this chapter. In Fig. 6-1A, MATC means Monochrome Automatic Time Correction, and CATC means Color Automatic Time Correction. Fig. 6-1B is the Ampex equivalent of the upper row in Fig. 6-1A, indicating differences in arrangement and nomenclature from RCA.

The video paths of Fig. 6-1 are being observed on the system output monitoring equipment during the E-E or record mode of operation. During the play mode, this video path is being continuously corrected by various error signals to be described. The connected groups of blocks in Fig. 6-1A are interconnected in various ways by internal harnessing. External lines in and out of the individual blocks are indicated on the drawing.

6-1. FUNCTIONAL DESCRIPTION

The basic terminology for and functions of the blocks shown in Fig. 6-1A are as follows:

Tape Sync Processor: This unit separates tape sync from the sync-channel video and provides optimum noise immunity and transient gating for all sync functions.

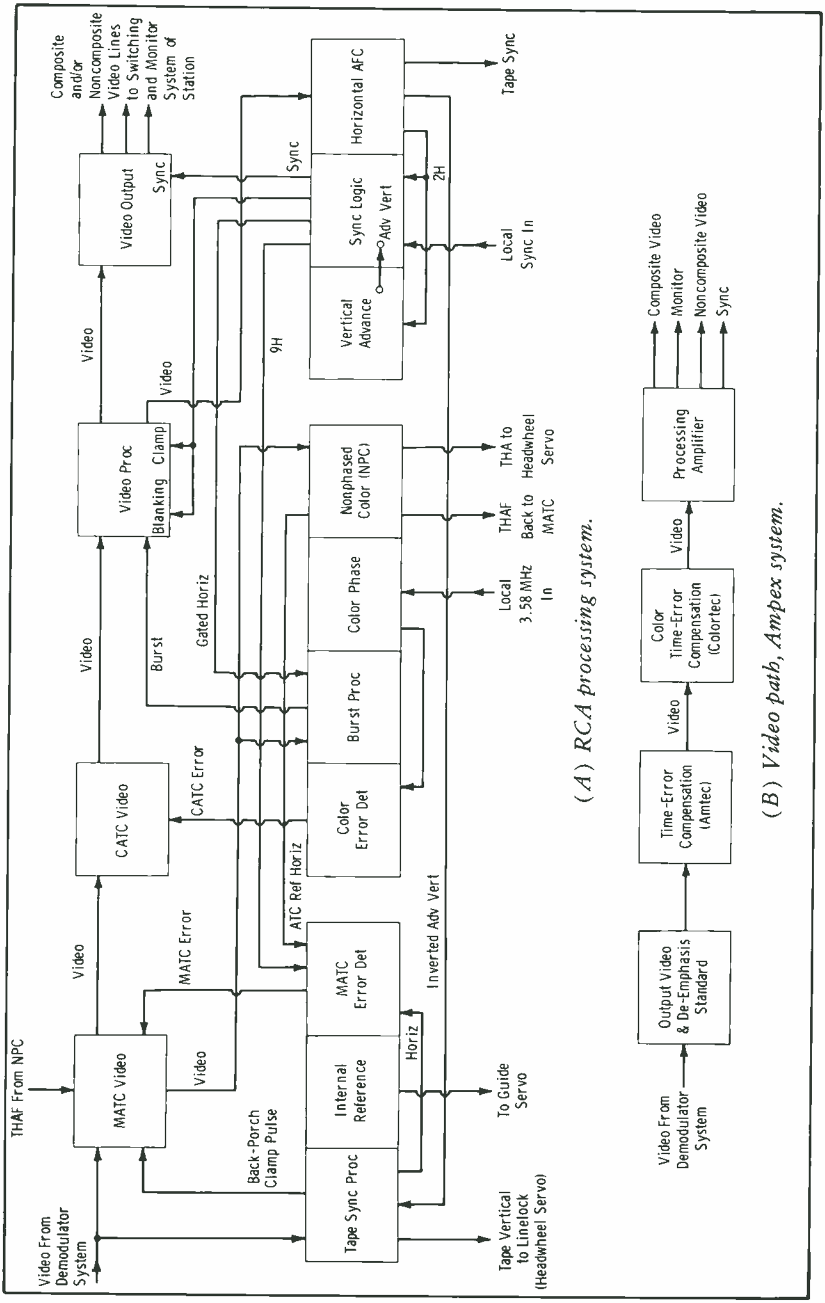
MATC Error Detector: The time-base error of the separated tape sync is measured and converted to the necessary control signal for MATC.

MATC Video: This section contains the variable delay line and driver circuits for the MATC function.

CATC Video: This section contains the variable delay line and driver circuits for the Color ATC function.

Color Error Detector: Color time-base errors are detected to provide the control signal for Color ATC.

Burst Processor: This unit provides separation of the burst from the tape signal for the color error detector. It also includes circuits for shaping the new burst from the local subcarrier.



(A) RCA processing system.

(B) Video path, Ampex system.

Fig. 6-1. Video processing systems.

Color Phase: This circuit provides adjustment of regenerated burst phase and system subcarrier phase.

Nonphased Color: This section provides necessary pulse circuits for control of the nonphased color mode (sometimes termed NIC, or noninterlaced color).

Internal Reference: This part of the system provides afc locked to the tape horizontal sync to provide precise timing of all switching, transient suppression, sync gating, and ATC pulses.

Vertical Advance: Special circuitry counts the number of pulses in a field to determine accurately the position for regenerated vertical blanking.

Sync Logic: This unit generates horizontal and vertical blanking and combines them into composite blanking. It combines tape sync and regenerated horizontal sync into composite regenerated sync, and it generates a start pulse which phases the counting of the vertical advance circuitry.

Horizontal AFC: Sync separated from the color-corrected video signal is used to control the frequency and phase of a multivibrator. This, in combination with other circuits, generates new horizontal sync, front porch, and blanking.

6-2. BASIC PRINCIPLES OF ATC

The Ampex terminology is Time Error Compensation (Amtec) for monochrome and Color Time Error Correction (Colortec) for color. The RCA terminology is Automatic Time Correction (ATC or MATC) for monochrome and Color Automatic Time Correction (Color ATC or CATC) for color.

One action of ATC circuitry is to control the speed and phase of the headwheel, in addition to the control exerted by the servo system. Therefore, the servo systems are mentioned in this study, and Table 6-1 spells out the differences in terminology used by Ampex and RCA for the specified modes of servo operation. (Servo systems are covered in detail in Chapter 7.)

The operation of ATC is based on application of an error signal to an electronically variable delay line inserted between the video output of the demodulator section and the input of the signal-processing amplifier. The error signal is obtained by comparing the timing of horizontal sync in the composite video playback signal at the demodulator output with the timing of reference sync. Since geometric distortion is an error in time, it can be corrected by a variable delay line of opposite time function.

The ATC circuits operate in either of two modes, *internal* or *external*. The internal mode is used only when the headwheel servo is in nonsynchronous operation, and the external mode is used only when the headwheel servo is in synchronous operation. The circuits sense whether the system is in tonewheel (Ampex normal) or Pixlock (Ampex automatic) operation and automatically switch to the internal or external mode.

In the internal mode, ATC corrects geometric distortion but does not synchronize vertical- or horizontal-sync pulses from the tape recorder with the corresponding sync pulses from the local sync generator. To accomplish this type of correction, the reference sync is timed by deriving an average from a long-time-constant afc loop locked to tape sync. A dc error signal is obtained by making a phase comparison between a sample pulse derived from the trailing edge of tape sync and a trapezoid waveform generated from reference sync. The trapezoid timing is steady enough to eliminate geometric distortion but changes sufficiently with the average timing of tape sync to prevent slow drifts from causing the error signal to exceed the correction range of the delay line.

Table 6-1. Servo Terminology

Mode No.	Ampex	RCA	Servo Mode
1.	Normal	Tonewheel	Tachometer signal referenced to local 60 Hz, but no feedback to servos from demodulated tape sync. Nonsynchronous mode of operation.
2.	Vertical	Switchlock	Same as mode 1, but phase comparison of local 60 Hz with demodulated tape 60 Hz "frames" tape playback with local signal. Provides "no-roll" switching, or vertical-synchronous operating mode.
3.	Horizontal	Linelock	Phase comparison of local horizontal rate and demodulated tape horizontal rate locks tape playback to local horizontal rate. Not necessarily "framed" but synchronous (in time) to local horizontal.
4.	Automatic	Pixlock	Phase comparison of demodulated tape signal horizontal and vertical rates to local horizontal and vertical rates provides "genlocked" operation of tape system. Fully synchronous (time and phase) to allow lap-dissolves, supers, special effects, etc.

Note 1: Operating mode 3 or 4 is required for color tape playback.
Note 2: The Ampex AVR-1 video output is always fully synchronous in any mode of operation. Time-base error is corrected so that the off-tape video signal will be in sync with the system input reference signals. At the output, reference sync, blanking, and burst signals are added to the time-corrected video signal. Thus the recorder-output composite video signal is synchronous (except for delay of cabling outputs) with all other video signals that are connected to the same sync generator.

In the external mode, essentially the same circuits are used, but the afc loop is locked to local sync instead of tape sync. Since the local sync signal is fixed in timing, the error signal derived by comparing it with tape sync contains information to correct both jitter and geometric distortion. As a result, the ATC greatly reduces residual Pixlock (automatic) jitter and provides an extremely stable output.

In either of the two modes, the error signal is amplified and applied to the delay line. As the demodulated composite video signal passes through the delay line, the length of the line is modulated by the error signal every 63.5 microseconds, or once per tv line.

Full correction range is maintained automatically by a tha (tape horizontal alignment) feedback circuit. This circuit adjusts the relative phasing between the ATC sample pulse and the ATC trapezoid so that the average error signal is in the center of the delay-line range. In the internal mode, the tha signal controls a variable delay in the internal reference afc loop. In the external mode, the tha signal causes the Pixlock servo to advance the phasing of tape sync with respect to local sync by controlling the headwheel motor speed.

Geometric distortion includes various segmentation errors which result in picture distortions such as jogs, scallops, and quadrature-error indentations (Chapter 2). Segmentation errors are sufficiently minimized for monochrome picture reproduction by the monochrome ATC system; however, optimum color reproduction requires a considerably greater error reduction. A comparison of segmentation error effects between monochrome and color reproduction may be made by observing the fact that a picture displacement from line to line of 0.03 microsecond (30 nanoseconds) is not visible in a monochrome picture but represents a 38° color-subcarrier phase shift, which in turn produces a serious hue shift in the color picture.

Time-base jitter, inherent in all quadruplex recording processes, is caused by nonuniformities in the mechanical motions of the machine. When the machine is in the tightest mode of servo operation (Pixlock or Linelock for RCA, automatic or horizontal for Ampex), the servo system is capable of reducing the residual jitter to a value of approximately 0.1 microsecond, which is entirely satisfactory for monochrome operation but which represents a 125° color-subcarrier phase shift and is, therefore, intolerable for color operation. (The foregoing statement is true because 0.8 nanosecond of error represents one degree at the color-subcarrier frequency of 3.58 MHz, as derived in Chapter 3. Since 0.1 $\mu s = 100$ ns, then $100/0.8 = 125°$.)

ATC completely corrects steps (such as the errors resulting from improper head quadrature) because the time error remains constant throughout each individual line. The same is true for jogs (skewing) because the timing error from jogs (improper tip penetration), although increasing throughout the line, increases at a constant rate and is the same for corresponding points on successive lines.

Errors resulting from scalloping cannot be removed completely by an ATC system, because the timing error at the right-hand side of the picture is not the same for successive lines. The difference in timing errors for successive lines will be seen in the ATC output as a small skew-like effect in vertical lines at the right-hand side of the picture only. It is, therefore, essential that the manual scalloping adjustment on the headwheel panel be performed carefully.

Practical field experience with quadruplex television tape recorders has shown that it is reasonably easy to maintain the total time-base error below one microsecond peak to peak. Therefore, an automatic timing corrector must have a correction range of about one microsecond to permit noncritical operation of the recorder. This range is achieved by the use of electronically variable delay lines.

> NOTE: It is imperative that the reader be familiar with two basic circuit functions very common in ATC circuitry, or any circuitry which involves error detection. These are (1) boxcar pulse generators (delayed and undelayed) and (2) sampling-pulse (sample and hold) circuitry. These are covered in Chapters 9 and 12, respectively, of *Workshop in Solid State* by Harold E. Ennes, (Indianapolis: Howard W. Sams & Co., Inc., 1970). In addition, the application of voltage-variable-capacitance diodes in voltage-controlled delay lines must be understood. This is covered in Chapter 2 of the same reference.

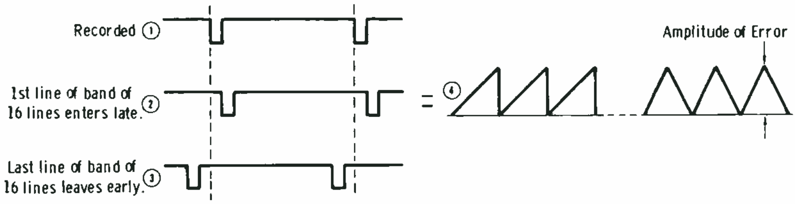
Time-base error correction is inserted between the demodulated video output and the input to the video processing amplifiers (Fig. 6-2). Assume the errors of Fig. 6-2A. (This is the condition of Fig. 2-14, Chapter 2.) Waveform 1 is the sync time recorded, and waveforms 2 and 3 show the playback sync timing for the first and last lines of a complete band of 16 lines. Waveform 4 shows that this results in a series of linearly progressing errors across each band of 16 lines, or the duration of one head pass.

Now go to Fig. 6-2B. Since errors must be sampled (measured) before a correction is made, a fixed delay of 2 to 3 μs is employed, as shown, prior to application of the corrector voltage to the voltage-controlled video delay line.

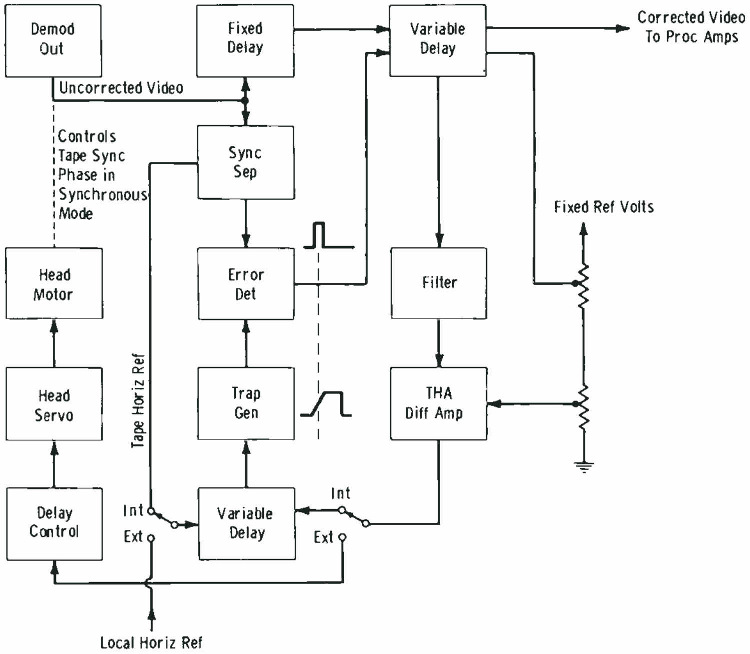
Reference sync changes with the mode of operation. For nonsynchronous operation, this reference is separated horizontal sync from the video signal after demodulation. For synchronous operation of the servos, the reference becomes local horizontal sync from the station sync generator. The terminology here is "internal" for nonsynchronous modes and "external" for synchronous modes.

In the internal mode, tape sync supplies both the sampling pulse and the trapezoid. The trapezoid is obtained by applying tape sync to a long-time-constant afc loop. This mode provides a relatively large range of control, since the trapezoid changes sufficiently with average timing of tape sync to prevent drifts from exceeding the characteristic impedance (Z_0) of the variable delay line.

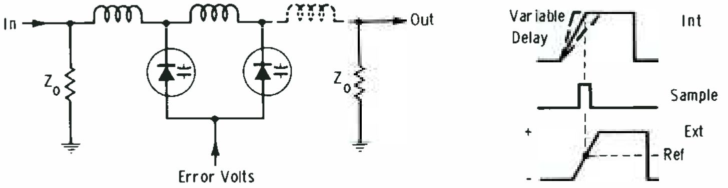
When the voltage-controlled variable delay line is modulated away from its center of operation, Z_0 becomes increasingly mismatched (misterminated). When a given range of correction (delay) is exceeded, reflections from mistermination occur and upset the servos. The maximum of all errors in the time base should not exceed 1 μs.



(A) Time-base error.



(B) Correction circuitry.



(C) Variable delay. (D) Error waveforms.

Fig. 6-2. Time-base error correction.

In the external mode (synchronous mode), station sync is used, and the head servo, in turn, is locked to this sync. This naturally imposes a tighter restriction on the amplitude of tolerable errors from the head-to-tape contact, as well as all other errors in servo and signal processing.

When color time-base correction is used, the station color standard becomes the reference for that unit. Old burst is gated out and a new burst, referenced to the stable subcarrier standard, is gated on. The error between the old burst and the reference color standard is fed back to the monochrome time-correction differential amplifier. Hence, in turn, the head servo (Chapter 7) is tightened to its maximum capability. It is now being controlled to correct to the color-subcarrier time base. This total correction will result in well under 5° of jitter at the color-subcarrier rate of 3.58 MHz.

6-3. MONOCHROME ATC

Since a large timing shift may occur when the recorder switches from one head to another during playback, it is essential that timing errors be measured after switching so that the proper amount of corrective delay is provided for the next line. In older systems, switching took place during the horizontal-sync pulse, and the trailing edge of tape sync was used for deriving the timing-error signal. In the latest systems, switching takes place at a predetermined time ahead of the leading edge of sync, and the leading edge of tape sync is used for deriving the timing-error signal.

Operation of the electronically variable delay line depends on the fact that the capacitance of a reverse-biased silicon diode (varicap diode) changes with applied bias. A variable delay line could be constructed simply by connecting a number of inductors in series, connecting one diode from each junction of the coils to a common bus, and applying a variable dc voltage between one end of the series inductors and the common bus. However, this design would not be satisfactory because the varying bias used to change the line length would appear in the output signal. To overcome this, a second set of diodes is used, and each diode of this set is connected from one of the junction points to a second bus (Fig. 6-3). A fixed negative dc voltage is applied to the center (inductive) portion of the line. A variable positive voltage is applied to the common bus of one set of diodes, and a variable negative voltage is applied to the common bus of the other set. The bus supplying the positive voltage is called the positive error bus (PEB), and the bus supplying the negative voltage is the negative error bus (NEB). The dc levels of the PEB and NEB signals are fixed to equal amounts above and below the voltage applied to the center, and ac components are equal but oppositely phased. The video input is applied between one end of the coil series and ground, and the delayed video output appears between the other end of the series and ground.

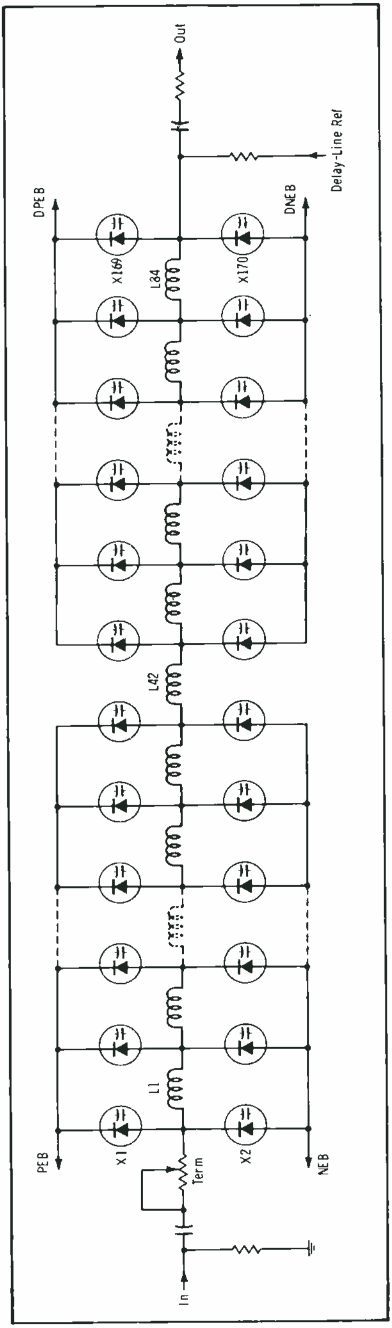


Fig. 6-3. Electronically variable delay line.

The electronically variable delay line used in a monochrome ATC system consists of two halves connected in series. The PEB and NEB signals are applied to the first half, and a pair of error signals delayed 1.5 microseconds behind the first pair are applied to the second half. The delayed signals are called the delayed positive error bus (DPEB) and delayed negative error bus (DNEB) signals.

The following description involves both Fig. 6-2 and the timing diagram of Fig. 6-4 in explaining the basics of monochrome ATC. Tape sync from the demodulator output (Fig. 6-4, waveform 2) is obtained by use of a clamped sync separator designed to prevent introduction of any timing errors by the separation process. Sync is then applied to a circuit which generates a sampling pulse, approximately 2 microseconds wide, from the leading edge of tape sync. The leading edge of this pulse (waveform 3) coincides with the leading edge of sync. The sample pulse is applied to an error detector which compares the timing, or phase, of the sample pulse with a reference trapezoid waveform (waveform 4). In the internal mode of ATC, the trapezoid is obtained by applying tape sync to a long-time constant afc loop; in the external mode, local sync is used instead of tape sync. Note also (Fig. 6-2) that in the external mode the headwheel servo system is controlled.

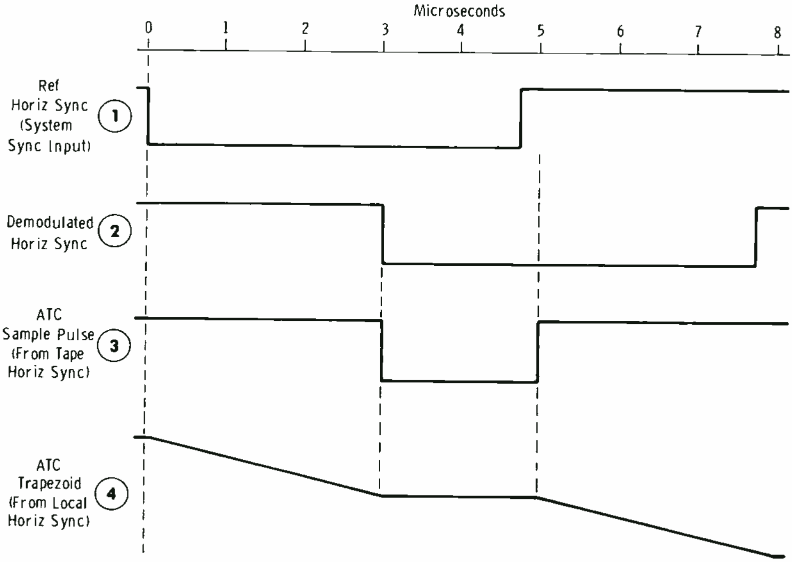
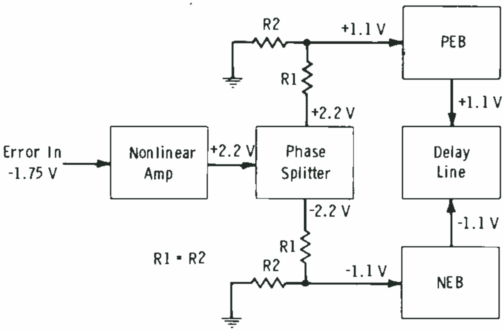


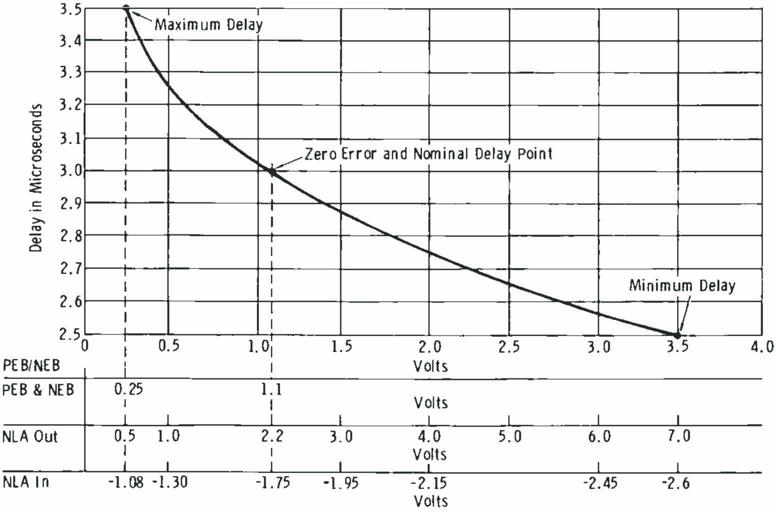
Fig. 6-4. Basic MATC timing diagram.

The error detector provides an output voltage which changes linearly with the difference in phase between the sample pulse and the trapezoid.

Since the delay line has a nonlinear relationship between the voltage applied and the time delay, a linear signal cannot be used to drive the delay line directly. To overcome this difficulty, the error signal is applied to an amplifier whose output varies nonlinearly with the input signal (Fig. 6-5A). The amplifier is carefully designed to match the delay-line characteristic so that the overall relationship is linear. The output of the nonlinear amplifier is applied to a phase splitter which provides the PEB and NEB signals, and through a fixed delay line to another phase splitter which produces the DPEB and DNEB signals. Each of the four error signals is applied through an individual complementary-symmetry emitter-follower stage to the variable delay line. Circuits of this type are used because they



(*A*) *Circuit arrangement.*



(*B*) *Delay versus voltages.*

Fig. 6-5. Delay-line drive in RCA TR-70 tape system.

provide low output source impedance on both positive-going and negative-going signals to the error buses.

To recapitulate, the picture-channel video from the demodulator is fed to the monochrome ATC video module. The video is amplified, clamped, and applied to an electronically variable delay line. The video signal is either delayed or advanced from the nominal error delay of 3.05 microseconds ± 0.05 microsecond (Fig. 6-5B). The delay line is controlled by the positive error bus and negative error bus (PEB and NEB) signals, which are developed from a phase comparison of the tape sync and the reference sync in the ATC error detector module. The output of the MATC video module is fed to the Color ATC video module where further error correction takes place. Essentially, this is the most important function of the MATC system. All of the other circuits in the system only contribute to the detection of an error between tape sync and reference sync and the controlling of these auxiliary circuits.

When the tape recorder is operating in the tonewheel servo mode, the tha error signal is fed to the ATC trapezoid circuit in the ATC error detector module, where it shifts the phase of the ATC trapezoid waveform with respect to the ATC sample pulse. The tha loop is stabilized when the PEB voltage is equal to the tha reference voltage of +1.1 volts. Under these conditions, the dc average of the error signal keeps the electronically variable delay line in the center of its range. It should be noted that this condition is necessary to obtain maximum correction range (Fig. 6-5).

When the tape recorder is operating in the synchronous servo mode, the tha error signal is fed to the Linelock module, where it causes the headwheel motor to shift the phase of the video signal from the tape. In turn, this results in equal shifts in phase of tape sync and the ATC sample pulse with respect to the ATC trapezoid waveform. The resulting change in the PEB voltage increases or decreases the tha error signal. As in the tonewheel mode, the loop is stabilized when the PEB level is equal to +1.1 volts.

6-4. COLOR ATC

The preceding paragraphs contain a discussion of basic considerations for an ATC system which operates effectively with monochrome signals. For color operation, additional considerations must be taken into account. One of these is noise. When horizontal sync is used in video-signal timing measurements, only one sample per line is provided, and a relatively wide bandwidth is required to pass the signal; therefore, timing measurements are affected by random noise which is added by the tape recording process. This effect is known as *positional noise.* Positional noise occurs at or below the threshold of visibility during monochrome operation and is not critical; however, during color operation, positional noise represents a substantial phase jitter which results in phase instability. Color ATC systems reduce the effect of positional noise because of the availability of a greater number of samples per line due to the presence of approximately eight cycles of subcarrier in the burst, and because of the possible use of a narrower bandwidth.

A second factor which prohibits the use of horizontal-sync phase comparison in color operation is that there is no specified phase relationship between the edge of sync and the color subcarrier. In addition, it is possible that time modulation may be introduced between horizontal sync and the color subcarrier; therefore, horizontal sync cannot be used in controlling the absolute phase of a subcarrier. It is essential that the final color timing correction be accomplished by comparing the phase of burst with a fixed reference.

The MATC open-loop system is capable of maintaining an error-reduction factor of at least 25 to 1, which is sufficient for monochrome reproduction but may leave enough residual error to disrupt color performance if large errors are to be corrected. Because of the cascading effect of the CATC process, residual error theoretically can be reduced by another factor of 25 to 1, and any error remaining is then negligible, even for color operation.

Color ATC systems employ the same open-loop control described above for monochrome signals; however, in color systems, the error detector uses burst instead of horizontal sync. Also, CATC systems require a delay range of only 360° at the subcarrier frequency (0.28 microsecond at a subcarrier frequency of 3.58 Mhz); therefore, the delay line is shorter than that utilized in the MATC systems and need not be split to contain the delay-change transient within the horizontal-sync interval. The CATC nonlinear amplifier, fixed delay line, and driver circuits are identical to those of MATC systems.

In CATC systems, it is necessary that the phase-error detector have the equivalent of a linear delay range of 360° at the subcarrier frequency. Design limitations prevent the detector from functioning effectively over an entire 360° delay range; therefore, the detector is operated at half-frequency, and the required 360° delay range appears to the detector as a 180° range. Multivibrators divide both the burst and reference subcarrier signals; the divided burst is used to form narrow sampling pulses, and the reference signals form a sawtooth waveform. A special inhibit circuit in the burst path insures that the narrow sampling pulses always occur on the center half of the sawtooth slope.

The control signal for CATC variable delay lines is formed in the color phase-detector circuit by the measurement of burst phase error. The function of the control signal is to correct phase errors in composite color signals and stabilize signal timing in order to provide excellent color reproduction. However, color signals must still be passed through processing-amplifier circuitry to clean up blanking and sync and insert a new color burst that is free of noise. This requires special circuits which do not distort the color components of a signal.

The system used in processing color signals consists of splitting a composite signal into high-pass and low-pass components. Low-pass components do not contain color information and can be passed through standard monochrome processing-amplifier circuits in order to clean up blanking and sync. High-pass signals contain all chroma information and are processed by special circuits in the CATC system to clean up the blanking interval and insert regenerated burst. High-pass signals are then added back to the low-pass signals just ahead of the output amplifier in the processing-amplifier circuits.

Color ATC provides time-base corrections in tape playback signals to a residual error level of a few nanoseconds with respect to the subcarrier reference signal. This allows color tape recording with essentially no bandwidth or color-response limitations; thus, a machine equipped with CATC can record and play back color program material which is indistinguishable from original live signals.

The color fixed delay line (Fig. 6-6) inserts an additional 2.5 microseconds of delay into the video signal path, and the output of the fixed delay line is fed to the electronically variable delay line in the color delay module. The variable delay line is controlled by the color PEB and NEB potentials, which, in turn, are developed through a phase comparison of the tape burst and reference subcarrier signals in the color error detector module (Fig. 6-1). The phase-comparison process results in transients which appear on the error buses. However, since tape burst information from which the sample pulses are derived is obtained before the video signal has been delayed by the color fixed delay line, transients applied to the variable delay line advance 2.5 microseconds with respect to the video signal applied to the line. Transients occur during the horizontal sync pulse interval and do not affect burst or video information in a composite signal. The output of the variable delay line is a composite video signal which is stabilized in time with respect to the reference subcarrier. This signal is fed to the color processing system.

Circuits of the color processor separate low-frequency and high-frequency components of a delayed video signal so that they can be processed independently before recombination. The separated high-frequency chroma signal is fed to special processing circuits in the color processor module. Special processing circuits for the high-frequency signal are required because the monochrome processing-amplifier circuits clamp out the burst signal, and the black clipper removes all signal components below black level. The low-frequency signal is fed to the MATC reference module (Fig. 6-6). Circuits in the MATC reference module separate sync from the low-pass signal, and the separated sync is used to develop regenerated sync in the sync logic module (Fig. 6-1). Regenerated sync is fed to the video output module where it is combined with the low-pass and high-pass portions of the video signal (processed in the video control and color processor modules, respectively) to form the video output signal.

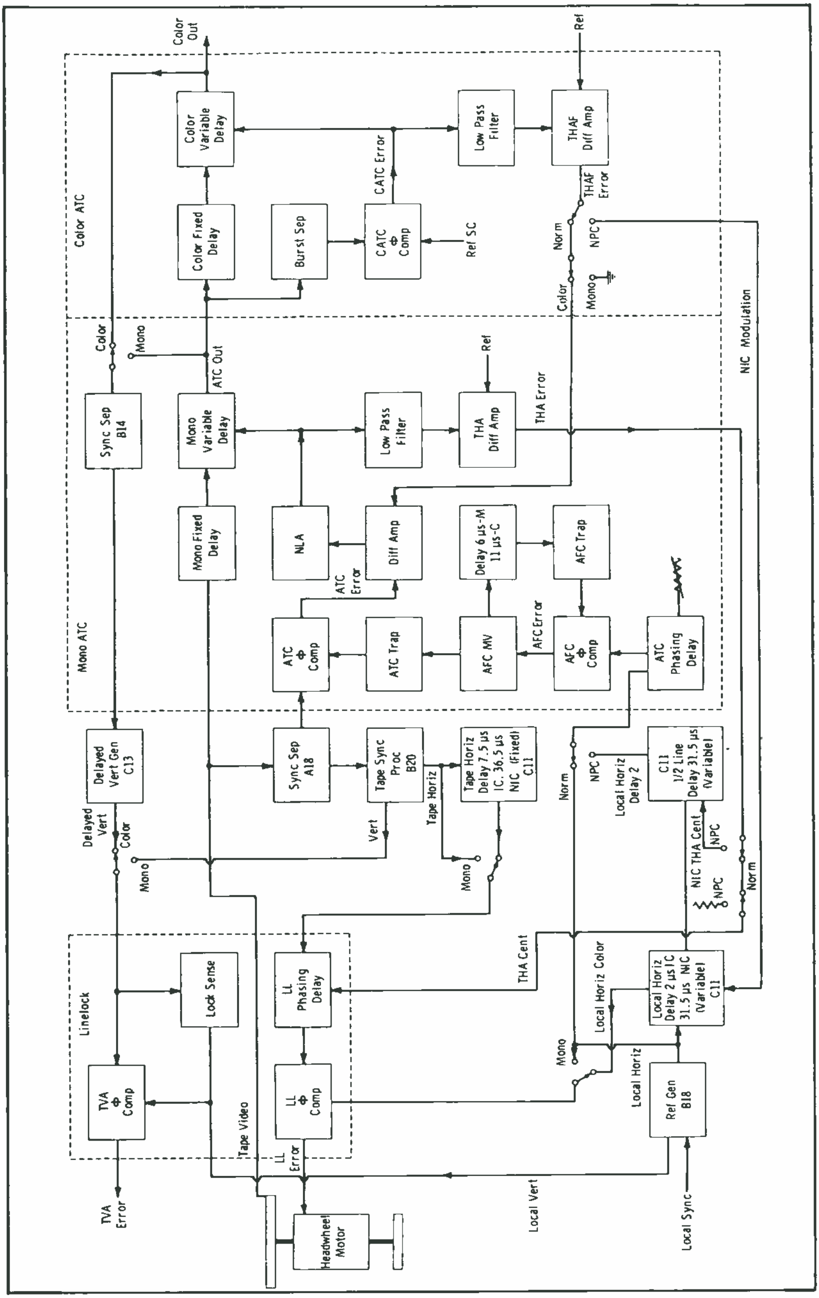


Fig. 6-6. Synchronous-mode servo with MATC and CATC.

As shown in Fig. 6-1, the reference 3.58-MHz subcarrier signal is fed to the color phase module, which contains two electronically variable delay lines. The first variable delay line is controlled by the SYSTEM PHASE control and can be varied over a nominal range of 0.3 microsecond (i.e., a delay equivalent to a subcarrier phase shift in excess of 360°). Following this delay, the reference subcarrier signal is fed simultaneously to the second variable delay line in the color phase module and to the color error detector module. The second variable delay line is controlled by the BURST PHASE control, and the delay range available is also nominally 0.3 microsecond. The reference subcarrier delayed by the second variable delay line is designated the burst subcarrier and is fed to the color processor module. The reference subcarrier fed directly to the color error detector module is designated the system subcarrier.

Tape burst, separated from the video signal in the burst processor module, is also fed to the color error detector module. In the color error detector module, the system subcarrier signal is used in generating a reference sawtooth waveform; the tape burst signal is used in developing a sample pulse. The sample pulse and sawtooth waveform are fed to a phase-comparator circuit where the sample pulse falls higher or lower on the sawtooth waveform slope, depending on the relative phase between the reference-subcarrier and tape-burst signals. The output from the phase-comparator circuit is an error signal, the magnitude of which reflects the difference in phase between the system (reference) subcarrier and tape-burst signals. Logic circuits insure that sampling occurs only over the linear portion of the sawtooth waveform slope; therefore, the gain of the error detector is linear. If the sample pulse falls near either extreme of the range on the sawtooth waveform slope, it is possible to obtain a cracking effect (i.e., successive pulses sampling at alternate extremes of the slope, which causes conflicting error information). To prevent this effect during normal tape playback in the CATC mode, a portion of the phase-error signal is used in controlling the thaf (tape horizontal alignment, fine) signal in the CATC system; the thaf signal in turn adjusts the video delay slightly so that the sample falls near the center of the sawtooth slope.

The burst logic circuit, which controls the sampling process, is in turn controlled by the narrow burst-gating pulse developed in the burst processor module. The width of this pulse is variable; however, the width is nominally set at that value which allows approximately five samplings during each line. The output error signal fed to the Color ATC module is a fluctuating series of dc potentials. To eliminate the possibility of an erratic output signal such as could occur if tape burst were suddenly lost, a clamping circuit provides a steady dc output signal which corresponds to zero error if the tape burst signal is absent. The clamping circuit is controlled by the burst-lock sense potential which in turn is determined by a logic circuit in the color processor module. The phase-error signal fed to the CATC module is compared with a fixed reference in a differential amplifier circuit, and the resulting output is developed into the PEB and NEB potentials which control the variable delay line.

The PEB and NEB potentials which control the electronically variable video delay line are developed from the phase-error signal of the color error detector. The phase-error signal is an indication of the relationship between the reference-subcarrier and tape-burst signals and varies linearly with the phase difference between these signals. However, the characteristics of the video delay line are such that the delay varies nonlinearly in response to a linearly varying control potential impressed across it. It is desired that the delay vary linearly; therefore, it is necessary to convert the linearly varying phase-error signal to a nonlinear potential having gain characteristics which match the delay characteristics of the video delay line. The nonlinear conversion is accomplished by a differential amplifier circuit that incorporates a gamma network containing resistors with values calculated to produce a nonlinear output which compensates for the nonlinearity of the video delay line.

The nonlinear error signal is split in phase, and signals of opposite polarity drive complementary-symmetry emitter followers which produce PEB and NEB potentials. It is important that the PEB and NEB potentials be equal in amplitude and opposite in polarity with respect to the voltage to which the video signal in the delay line is referred, over the entire range of the phase error signal. Therefore, potentiometers are provided as a means of adjusting the PEB and NEB potentials to insure that a change in one is accompanied by an equal and opposite change in the other. Potentiometers are also provided as a means of adjusting the transient behavior of the PEB and NEB potentials so that the rise times are as nearly equal and opposite as possible in response to a step of error such as occurs at switching when a vacuum-guide error is present.

Fig. 6-6 shows the tha and thaf closed feedback loops to the headwheel servo. The block diagram shows the functions of the headwheel servo, MATC system, and CATC system that operate in conjunction with the tha and thaf closed loops. In general, the principle function of the tha loop is to adjust automatically the phase of the headwheel servo to maintain the average sampling of the MATC in the center of the error detector slope. This point, in turn, is set by internal adjustments to correspond to the PEB potential for the center delay of the monochrome variable delay line.

The principal function of the thaf loop in the CATC system, during playback in the normal CATC mode, is to adjust automatically the phase of the MATC output signal to maintain the average sampling of the CATC in the center of the error detector slope. The center of the error detector slope in the thaf loop is also set up by internal adjustment to correspond to the PEB voltage representing the center delay of the color variable delay line. The actual operation is accomplished in several steps. First, the thaf error signal is generated by comparing the PEB potential to a reference voltage. The resulting error signal is applied, through a low-pass filter, to the reference side of the input differential amplifier in the monochrome nonlinear amplifier circuit. Therefore, a change in thaf error signal generates a change in the potentials of the MATC error buses, PEB, NEB, DPEB, and DNEB, which are applied to the monochrome variable delay line. The change in error-bus potential causes the delay of the monochrome variable delay line to change in such a direction as to correct the average phase of the signal applied to the CATC system.

In correcting the average phase of the signal applied to the CATC system, the average delay of the monochrome variable delay line shifts from the nominal center value of the PEB potential. The tha differential amplifier in the MATC system measures this change in PEB potential and generates its own error signal which feeds back to the phasing delay in the Linelock module. A change in the Linelock phasing delay causes the headwheel to advance or retard so that the monochrome variable delay line is restored to operation in the center of the delay range.

The net result of the closed-loop servo, during playback in the normal CATC mode, is that the headwheel is changed in phase to supply the correction demanded by the CATC system, the monochrome variable delay line is still operating in the center of the delay range, but the MATC error detector is slightly shifted from operation in the center of its slope. It should be noted that the bandwidth of the thaf loop is somewhat greater than that of the tha loop. Therefore, changes in the average thaf voltage occurring at a frequency greater than the tha loop bandwidth are corrected by changing the delay of the monochrome variable delay line rather than by changing the phase of the headwheel.

There are several fixed delays shown in Fig. 6-6 which are not basic to the operation of the thaf loop during playback in the normal CATC mode. The 7.5-microsecond tape horizontal delay and the 2-microsecond reference horizontal delay are inserted into the tape horizontal and reference horizontal paths, respectively. The net difference in the two delays represents a 5.5-microsecond delay in series with the Linelock phasing delay. The purpose of this net delay is to maintain the operation of the variable Linelock phasing delay at nominally the same value during playback in the normal CATC mode as it is during playback in the MATC mode. At the same time, this net delay increases the total delay to that value which advances the headwheel by an amount equivalent to the delay inserted into the signal path by the color fixed delay line and the color variable delay line. Note: The arrangement of the fixed and variable delay lines in ATC systems varies with the manufacturer and model of the equipment.

A fixed delay is also inserted into the path of the tape vertical signal applied to the tva (tape vertical alignment) and lock-sense circuits of the Linelock module. If the output signal from the machine is to be aligned with reference sync as it normally is, the output from the demodulator must be advanced considerably because of delays presented by the monochrome fixed and variable delay lines and the color fixed and variable delay lines. When the output is not in coincidence with reference vertical, the vertical coincidence circuit will drop out and thereby throw the servo out of the Pixlock mode. To prevent the machine from falling out of the Pixlock servo mode during color tape playback, tape vertical is timed to the output signal by the fixed delay inserted into the tape vertical path.

In the nonphased color (npc) mode of tape playback, requirements are somewhat different than in the normal CATC mode. The principal function of the npc mode is to allow playback of noninterlaced color (nic) tapes. Noninterlaced color tapes are produced by dubbing a playback from a heterodyne color system. Inherent in the heterodyne color system is an output signal in which the phases of the monochrome and chroma portions of the signal are displaced by an amount equal to the jitter of the tonewheel servo in the machine that made the original recording, with the result that they no longer have a fixed relationship. The Linelock and the MATC circuits, which are attempting to correct the video-signal time base by comparing tape sync to reference sync, and the CATC system, which is attempting to correct the video-signal time base by comparing tape burst to reference subcarrier, are apparently presenting conflicting information. However, the presentation of conflicting information is avoided by causing the CATC system to assume control.

As the relative phase between the tape burst and reference subcarrier attempts to change, the thaf differential amplifier senses this condition and generates a signal which modulates a delay in the path of the reference sync fed to the Linelock and MATC circuits. The headwheel servo and MATC systems follow this change in phase of reference sync in such a manner that the phase of the tape burst does not change with respect to the reference subcarrier. The bandwidth of the thaf loop during color tape playback in the npc mode must be greater than that of the tonewheel servo used in recording the original tape. The net result is that the output signal from the machine varies in phase in such a manner that the chroma signal bears a fixed phase relationship to reference subcarrier. That is, the output signal is noninterlaced color, but it is as satisfactory as the original noninterlaced color playback.

To accomplish modulation of the reference horizontal delay with as great a range as possible, it is necessary to provide a nominal delay of approximately one-half line. The nominal delay can then be modulated ± 20 microseconds, if necessary, to follow the jitter of a very loose servo. A similar fixed delay of approximately one-half line is inserted into the tape horizontal path, so that the undelayed tape signal retains approximately the same phase relationship to the undelayed reference sync during playback in the npc mode that it does during playback in the normal CATC mode. This allows the headwheel servo to operate in the Pixlock mode during color tape playback in the npc mode, since vertical alignment is maintained.

Even though the tape signal is varying in time in response to modulation of the reference horizontal delay, if its nominal position is centered with respect to reference vertical, the excursions do not exceed the range of the lock-sense circuit. In tape recorders equipped for the Linelock-only (LLO) servo mode, it is advantageous to operate in that mode during npc playback when vertical coincidence is not required. Since exact horizontal phasing is not predictable in playback of a noninterlaced color tape (nor is it precisely adjustable in playback of an interlaced color tape in the npc mode), there is no possibility of mixing, fading, or incorporating special effects, etc. The prime purpose of the normal CATC mode is to provide these possibilities during playback in the Pixlock servo mode.

Delayed reference horizontal, with the same modulation, must also be fed to the MATC system. If the MATC system were operating from a fixed horizontal reference, it would attempt to correct the timing modulation which has been inserted into the tape signal by the headwheel servo. However, the delayed reference horizontal is delayed by nominally one-half line, whereas the tape signal is nominally aligned to undelayed reference horizontal. It is necessary to insert another half-line delay in the reference-horizontal path to the MATC system to insure that the trapezoid waveform is properly timed so that the sample pulse falls on its slope. This nominal half-line delay is automatically adjusted to be precisely the correct amount to cause average sampling at the center of the slope by the tha error signal. It should be noted that the tha loop is relatively limited in bandwidth so that the ATC is still performing a normal function of removing timing errors such as quadrature error, jogs, etc. It should also be noted that the thaf loop, during npc playback, is also bandwidth-limited so that it does not respond to the normal line-by-line correction of phasing errors by the CATC system.

There is one further refinement of MATC operation required for color tape playback in the npc mode. This refinement consists of bypassing the afc loop to form the ATC trapezoid directly from the delayed reference horizontal. The afc loop performs no useful function in the external mode of MATC operation; it is actually detrimental during color tape playback in the npc mode, because it provides undesired bandwidth limiting and an additional phase shift which makes the high-gain thaf loop very difficult to stabilize. During color tape playback in the normal CATC mode, however, the afc loop provides a required timing advance which is not required during npc operation because a delay of one full tv line is provided.

The remaining circuitry of Fig. 6-1 associated with the ATC system prior to video processing—the tape sync processor and internal reference—will be examined in the following two sections.

6-5. THE TAPE SYNC PROCESSOR

The tape sync processor uses sync obtained during tape playback to derive (1) afc tape horizontal sync, (2) ATC tape horizontal sync, (3) vertical sync, (4) a tape frame pulse, (5) a back-porch clamp pulse,

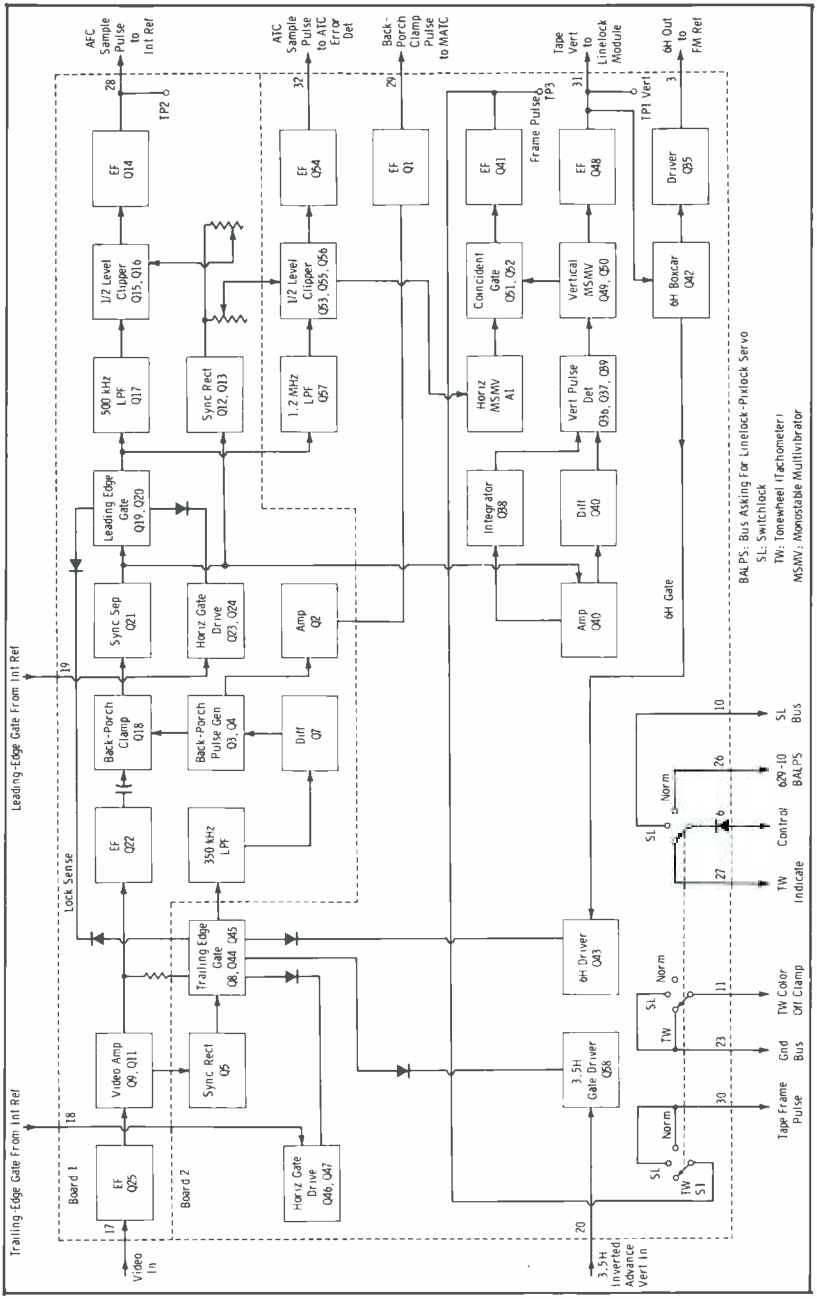


Fig. 6-7. Tape sync processor, RCA TR-70 system.

and (6) a 6H pulse. The tape sync processor module also derives horizontal and vertical sync signals during back-to-back (E-E) operation.

As illustrated in Fig. 6-7, tape horizontal sync is stripped from the incoming video signal and is gated, at the horizontal rate of the system, to two outputs by the leading-edge gate. One output is sent to the internal reference module for use in the afc loop timing; the other is sent to the ATC error detector module for use in MATC timing. Tape vertical sync is stripped from the incoming video signal and is sent at the vertical (field) rate of the system to the Linelock module, where it is used in the tva and tm vertical circuits (Chapter 7). The tape frame pulse is generated by gating the tape horizontal and tape vertical sync pulses and sending the resultant, at the frame rate (one-half the field rate) to (1) the capstan phase module, where it is used in the capstan servo operation, and (2) the splice logic module, where it is used for Switchlock detection (Chapter 10).

The back-porch clamp pulse is derived from the trailing edge of the incoming composite-video sync signal and is sent, at the horizontal rate of the system, to the MATC video module, where it is used to establish the average picture level (APL), and to the composite trailing-edge-gate pulse generator to reset the flip-flop. The 6H pulse output, at the vertical rate of the system, is fed to the fm reference module, where it is used to control the white insert function (Chapter 5).

The tape sync processing circuitry for both Ampex and RCA systems is described further in Chapter 7 under Servo Functions.

6-6. THE INTERNAL REFERENCE CIRCUITRY

The internal reference module provides gating pulses to the tape sync processor module, to the tonewheel modulator module, to the fm switcher module, to the ATC error detector module, and to the burst processor module. In addition, the internal reference module also provides guide error to the guide servo module, a lock-sense level to the ATC error detector module, and a sync fault level to the horizontal AFC module. Refer to Fig. 6-8.

The afc sample pulse generator is triggered by gated afc tape horizontal sync from the tape sync processor module when the tape recorder is locked (or proper phasing is attained between tape sync and the internal oscillator). At nearly the same time, a trapezoid is generated by the output of the horizontal-rate multivibrator (oscillator). Comparison is made at the first sampling quad, and a dc error voltage is produced.

A second sampling occurs approximately four microseconds after the first sampling. The second sampling is provided to ensure that transients do not correct the oscillator erroneously. For this reason, the sync-fault circuit is permitted to function during the 600 nanoseconds before the second-sampling circuits start to operate. If it turns out that a sync fault has been detected, then the second sampling does not occur, and the oscil-

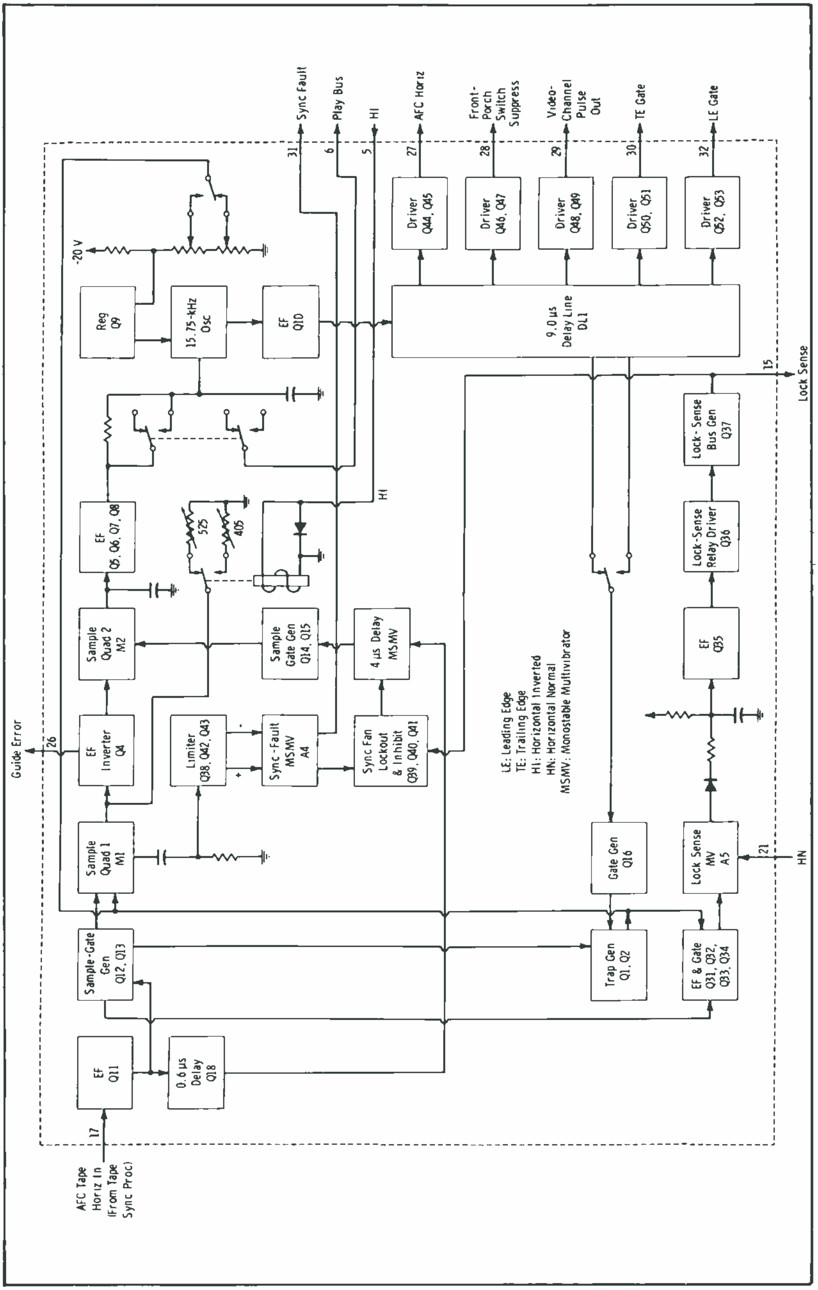


Fig. 6-8. Simplified diagram of internal reference, RCA TR-70 system.

lator remains undisturbed. If a sync fault is not detected, then approximately five microseconds after the afc tape horizontal pulse arrives, the second sample pulse is generated. This pulse opens the second sample quad and permits the dc error voltage to be transferred to the oscillator correction circuits.

The lock-sense circuit determines the phase relationship between the afc tape horizontal signal and the output signal of the horizontal-rate oscillator. If the two signals are not in phase, the lock-sense circuit produces a control signal which disables the sync-lockout circuit and enables the error clamp circuit in the ATC error detector.

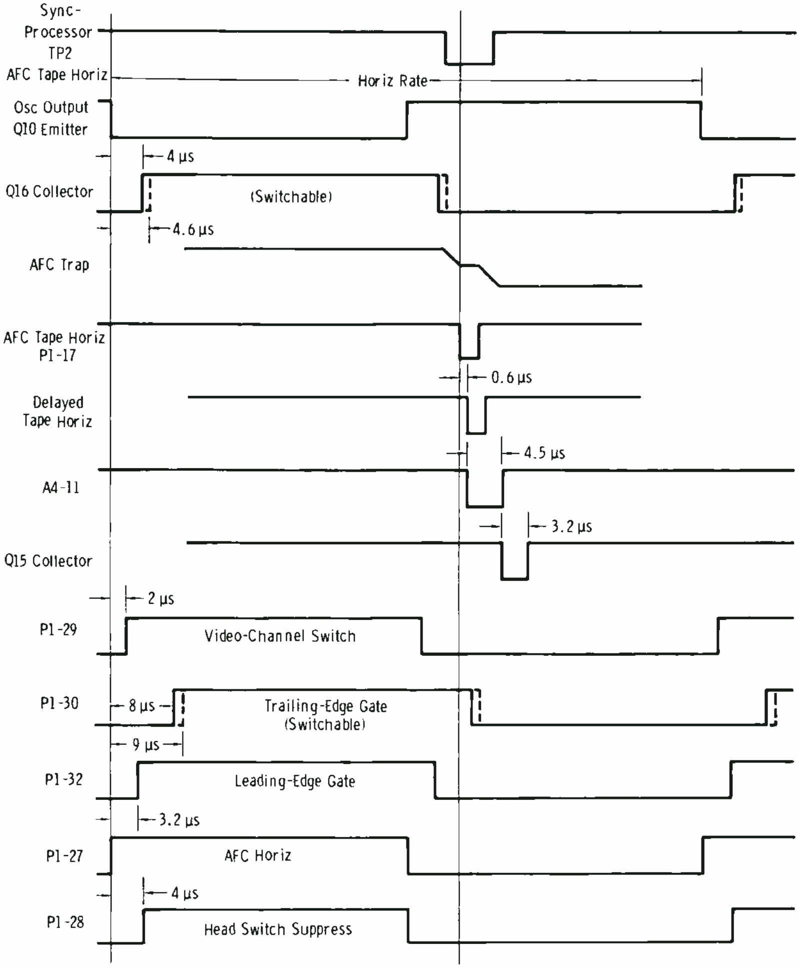


Fig. 6-9. Timing diagram for internal reference module.

The output pulses are delayed from the input horizontal-sync pulse by various amounts determined by their functions. Refer to the timing diagram in Fig. 6-9.

Internal reference functions in both Ampex and RCA systems are discussed further in Chapter 7 under Servo Systems.

6-7. SIGNAL PROCESSING

The output of the demodulator unit of a tv-tape system can produce satisfactory pictures on local monitors, but it is not suitable for distribution to transmitting facilities without further processing. The function of the signal-processing system is to restore all components of the video signal to ensure that the output signal meets industry standards and is suitable for transmission.

The signal-processing system in the RCA TR-70 system (Fig. 6-10) consists of the following modules:

Video processor module (432)
Video output module (433)
Vertical advance module (532)
Sync logic module (533)
Horizontal afc module (534)

When the composite video signal enters the signal-processing modules, the sync pulses may be deformed with noise spikes and switching transients during the blanking interval. The output of the signal-processing modules is a composite video signal that includes regenerated horizontal and vertical sync pulses, regenerated color burst (phased with the chroma signal), and a clean and adjustable black level. The clean horizontal interval eliminates misclamping in stabilizing and transmitter amplifiers, which tends to occur due to the noise in the area below the black level. Monochrome and chroma balance are established so that proper proportions of each are maintained to produce a good color signal at the output.

As illustrated in the simplified block diagram of Fig. 6-10, only three signals (excluding control and standards buses)are fed to the system. These are (1) the composite video signal from the CATC video module (620), where automatic timing correction has taken place; (2) regenerated color burst from the burst processor module (632); and (3) house sync from the local station sync generator. The output signals from the signal-processing system include three composite video signals ready for transmission and two video signals used within the tape recorder for monitoring purposes.

The signal-processing system consists of five modules and is further separated into two subsystems, the pulse-processing and video-processing subsystems illustrated in Figs. 6-11 and 6-12. These diagrams show, in simplified form, the general function of the modules.

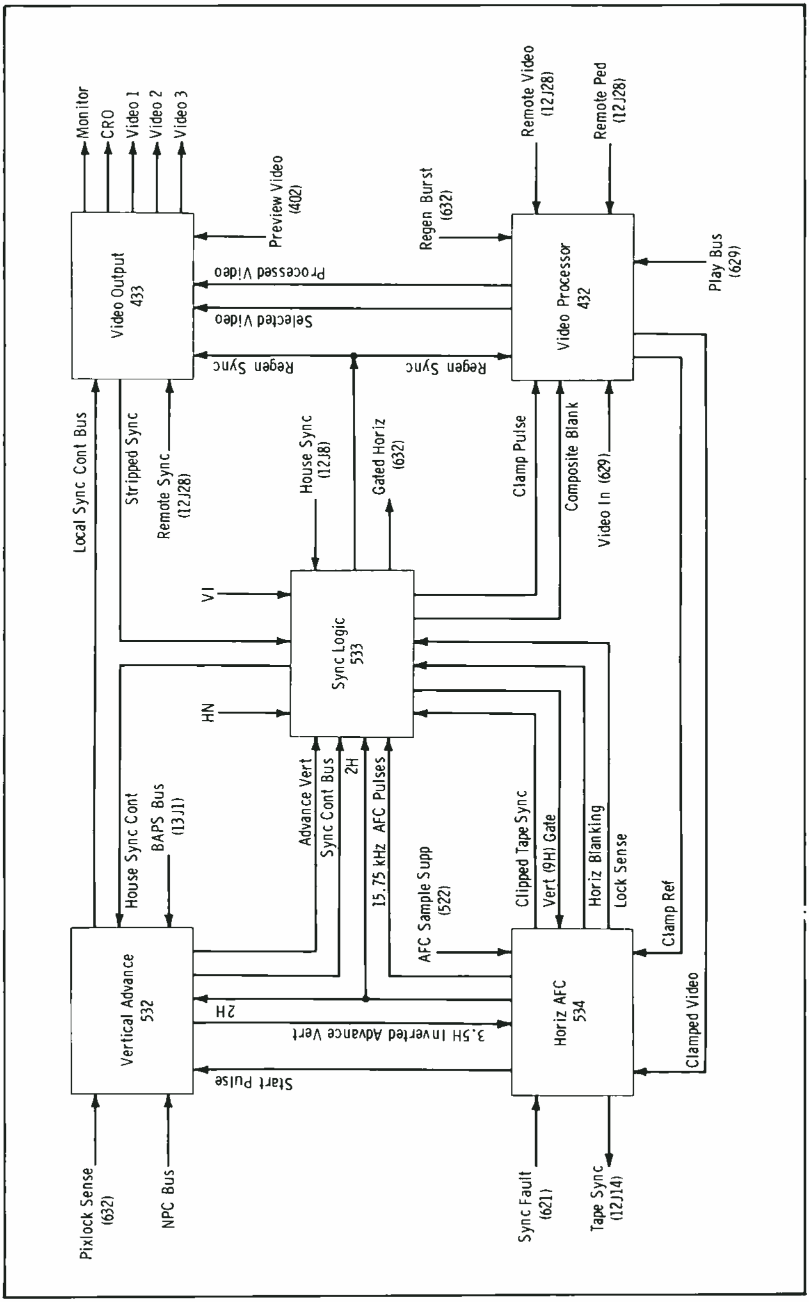


Fig. 6-10. Block diagram of signal processing system.

Pulse Processing

The three pulse-forming modules that carry out the sync timing and regeneration functions (Fig. 6-11) are the horizontal afc module (534), the sync logic module (533), and the vertical advance module (532). These three modules are closely interlinked functionally and physically to produce composite blanking, gated horizontal sync, and regenerated (output) sync. It is important to note that the blanking pulses needed for both monochrome and color tape-recording systems must be regenerated from the tape sync pulse and hence must be advanced in time relative to the leading edge of sync.

Start Pulse

Clamped composite video from the video processor module is fed to the horizontal afc module. Vertical sync is separated from the composite video and integrated. The integrator circuit has a long time constant and only functions during the vertical-sync interval. The output of the integrator produces a start pulse which is coincident with the leading edge of the second vertical-sync pulse. The start pulse is fed to the vertical advance module, where it starts the field-rate counter. This circuit counts pulses from the master oscillator in the horizontal afc module. These pulses occur at a rate of twice the horizontal line frequency ($2 \times 15{,}750 = 31{,}500$) and therefore with a separation of one-half the tv line time ($63.5/2 = 31.5$ microseconds).

Gated Sync Separator

The same clamped composite video that is used in the start-pulse circuit is used in the gated sync-separator circuit. Gating is performed by the 3.5H pulse from the vertical advance module, the 9H pulse from the sync logic module, and the horizontal-blanking pulse generated within the horizontal afc module. This gating of sync performs noise immunity, thus reducing the chance of transients in the sync-regeneration system. The output of the gated sync separator is composite sync which is fed to the sync logic module and used as tape sync in the sync-selector circuits. Another output from the gated sync separator is fed to a horizontal-rate multivibrator that removes the double-rate pulses during the vertical interval. These pulses are fed to a sample-pulse generator. Sample pulses of opposite polarity open and close the switch circuit in the afc loop.

AFC Loop

The purpose of the afc loop is to reference the afc sync pulses, or more specifically, the output of the master oscillator, to the tape sync pulses. The master oscillator is a free-running astable multivibrator and is controlled by a dc error voltage which results from sampling the slope of a trapezoidal voltage waveform. A trapezoidal waveform permits tighter con-

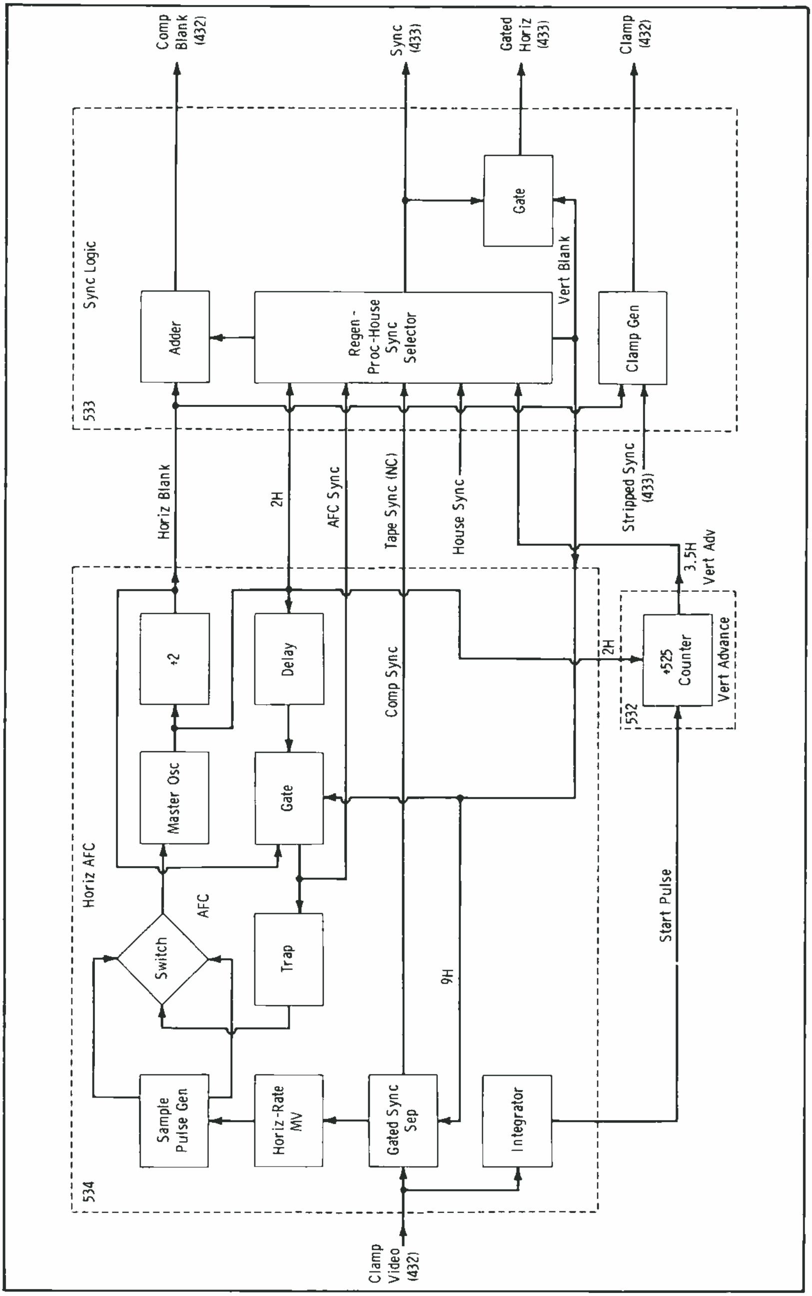


Fig. 6-11. Simplified block diagram of pulse processing.

trol, since for a small change in time a large change in voltage is produced. The trapezoidal waveform is produced by gating the master oscillator and horizontal-blanking pulses and feeding this pulse to a trapezoid generator. The sample pulse is produced by the separated composite tape sync.

The sampling medium is a diode quad which acts like a normally open switch that is closed by the sample pulse. During the pulse time, the closed switch applies a voltage determined by the height of the trapezoid slope at that instant to a long-time-constant RC circuit. This RC circuit smooths out rapid timing variations so that the oscillator is not constantly shocked by quick changes. During times when the tape sync and afc sync pulses are not locked, the time constant is much faster, and the master oscillator responds to changes more rapidly. This permits a faster lock-up of the afc loop.

AFC Sync Pulses

The afc sync pulses result from gating the delayed output of the master oscillator with the horizontal-blanking pulses. When the sync-selector switch on the sync logic module is in the Regen position, the afc sync pulses are in phase with the tape sync pulses and are used to produce new or regenerated sync. When the sync-selector switch is in the Proc position, the afc pulses trail the tape sync pulses. Tape sync pulses in this case are used for the primary sync source, and the delayed afc sync pulses are used in case of tape-sync dropout.

If the afc loop is not locked, the afc pulses are not produced, and tape sync is the sole source of sync. All afc pulses that are coincident with the video switching point are gated out by the afc-sample suppressor pulse generated in the fm switcher module. Thus, timing errors in the afc loop due to mistiming of the leading edge of sync during switching are eliminated.

Blanking

Composite blanking is made up of horizontal blanking from the horizontal afc module and vertical blanking from the sync logic module. Composite blanking is applied to the video processor module so that old sync may be removed from the composite video signal and new sync added later in the video output module. The horizontal-blanking pulse is used internally in the horizontal afc module to gate the delayed afc sync pulses.

Sync Selection

Three sources of composite sync from the sync logic module are available to be added to the video output. They are (1) regenerated sync, which is new sync made from the leading edges of the afc sync pulses from the horizontal afc module, (2) processed sync, which is made from the leading edges of tape sync pulses, and (3) house sync, obtained directly from the local station sync generator.

Sync selection is made by a three-position rotary switch on the front panel of the sync logic module. In any selected sync mode (Regen, Proc, or House), automatic switching and detection takes place so that if the primary source of sync should fail, a back-up source fills in the gap.

In order to use house sync for the primary sync source, the house sync and incoming tape sync must be in phase. This condition prevails whenever the tape-recorder servo system has achieved Pixlock operation and the phase is set by the horizontal-position control on the play panel.

Automatic sync switching is accomplished by an electronic switching circuit in the sync logic module. Automatic vertical-advance detection is accomplished by multivibrator action. If the vertical-advance detector fails to detect the vertical-advance pulse (3.5H), tape sync is selected as the composite sync source, and composite blanking, gated horizontal sync, and the clamp pulse to the video processor module are inhibited.

Clamp Pulse

Stripped tape sync, from the video output module, and horizontal blanking, from the horizontal afc module, are fed to the clamp-pulse generator. The output of the generator is fed to the video processor module where it clamps the video circuits.

Video Processing

The two video processing modules that form the video adder and sync adder functions are the video processor module (432) and the video output module (433) shown in Fig. 6-12. These two modules are closely located physically so that the video signals are not affected by external noise.

Processed Video

Composite video from the CATC video module is applied to the video processing module, where it is amplified. The gain of the amplifier is controlled either on the front panel of the video processor module or on a remote panel.

The amplified composite video is split into a monochrome channel and a chroma channel. The clamp pulse generated in the sync logic module is applied to the back porch of the horizontal interval in the monochrome channel and clamps it to −10 volts. At this point, composite blanking is added, and the old blanking and sync are removed. A new pedestal level is added; it also is variable from a remote panel, if selected.

Meanwhile, the chroma portion of the video signal is applied to a clamp circuit which removes the old burst signal only when the tape recorder is in the play mode. Chroma gain is adjustable only at the local location on the front panel of the video output module.

The monochrome and chroma channels, along with the regenerated color-burst signal, are combined in the video adder. The output of the video adder (at this point video without composite sync) is applied to the video

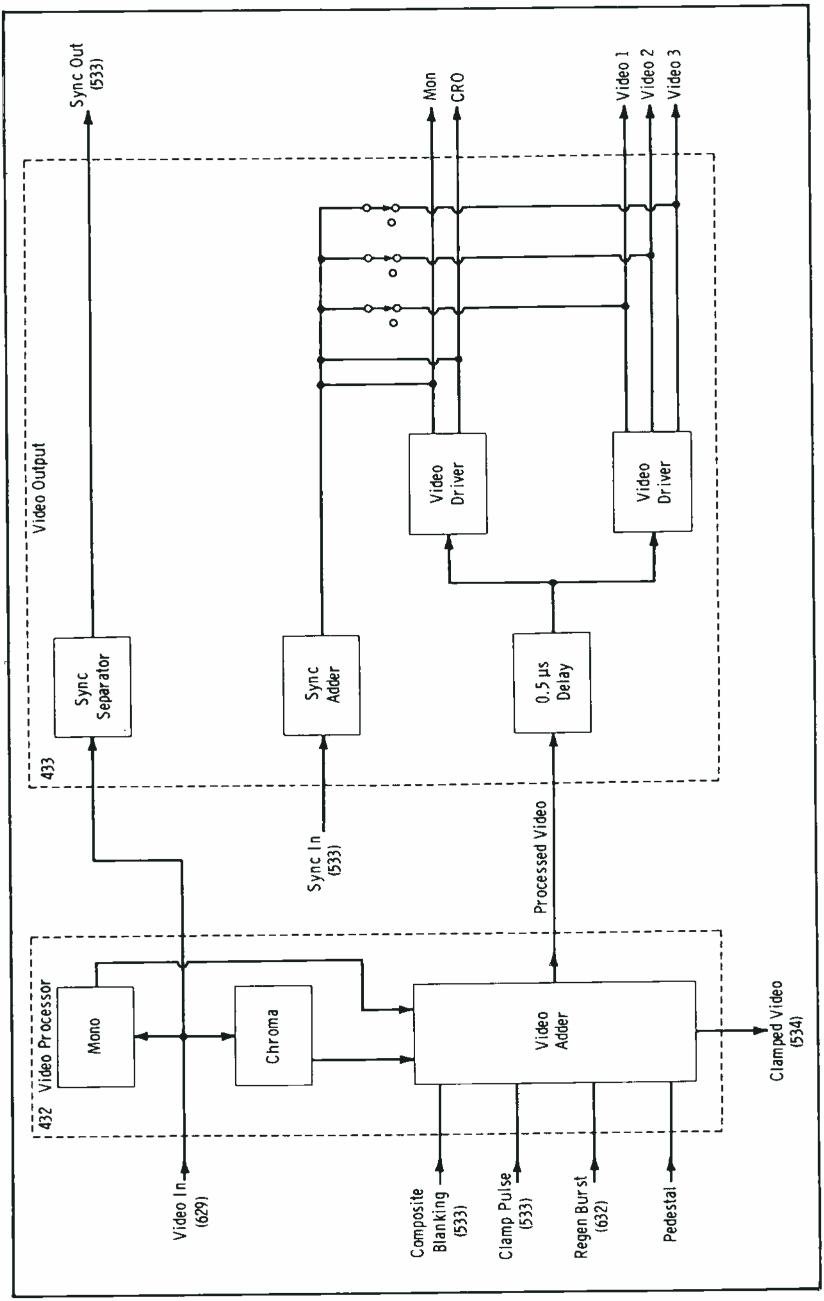


Fig. 6-12. Simplified block diagram of video processing.

output module. In the E-E mode, the new burst is not generated; therefore, a burst-notch circuit is provided so that the old burst is not eliminated by the clamp in the chroma channel. The video at this point is called "processed video," and it is delayed by 0.5 microsecond in order to match the delays imposed by the sync channel. The chroma portion of the video signal is fed through a high-frequency boost circuit which compensates for any loss that results from signal handling.

Sync Adder

Composite sync from the sync logic module is applied to the sync adder circuits. Sync is added to the processed video at the output of the video line drivers. Sync gain may be varied either locally on the front panel of the vertical advance module or from a remote panel. The composite video signal is supplied to the picture monitor and waveform monitor (cro). Composite sync may be removed from the composite video signal in one or all video output channels (1, 2, or 3) by opening the sync switches, which are located in the video output module.

International Standards

Most of the circuitry in the three pulse-forming modules consists of simple time-constant changes in order to obtain the correct pulse widths needed for the different tv line standards. The verical advance module contains the circuitry necessary to change the timing of the advance vertical pulse (3.5H) so that it is compatible with 405- and 625-line standards. This circuitry includes an additional transistor stage, a miscount amplifier for driving the first counter when on 625-line standards.

The switch used in selecting the different tv line standards is located directly beneath the picture monitor. For operation on 625-line standards, the center frequency of the bandpass filter in the chroma channel and the band-rejection filter is changed from 3.58 megahertz to 4.43 megahertz by the action of the line standard switch.

In machines equipped with PAL, when 625-line high-band color operation is selected, the regenerated burst switches between 0 and 90° every other line. The regenerated burst moves back and forth with the meandering vertical interval according to the PAL-system specifications.

6-8. REMOTE VIDEO GAIN

Remote control of various signal amplitudes has been mentioned several times. A description of the remote video gain control for the Ampex VR-2000 will serve to illustrate the principles involved.

Etched board 18 (Fig. 6-13) provides remote control of video gain by the use of dc voltages instead of by running long video lines to the remote control point. Thus, the effects of external disturbances on long video lines in the control circuit are eliminated.

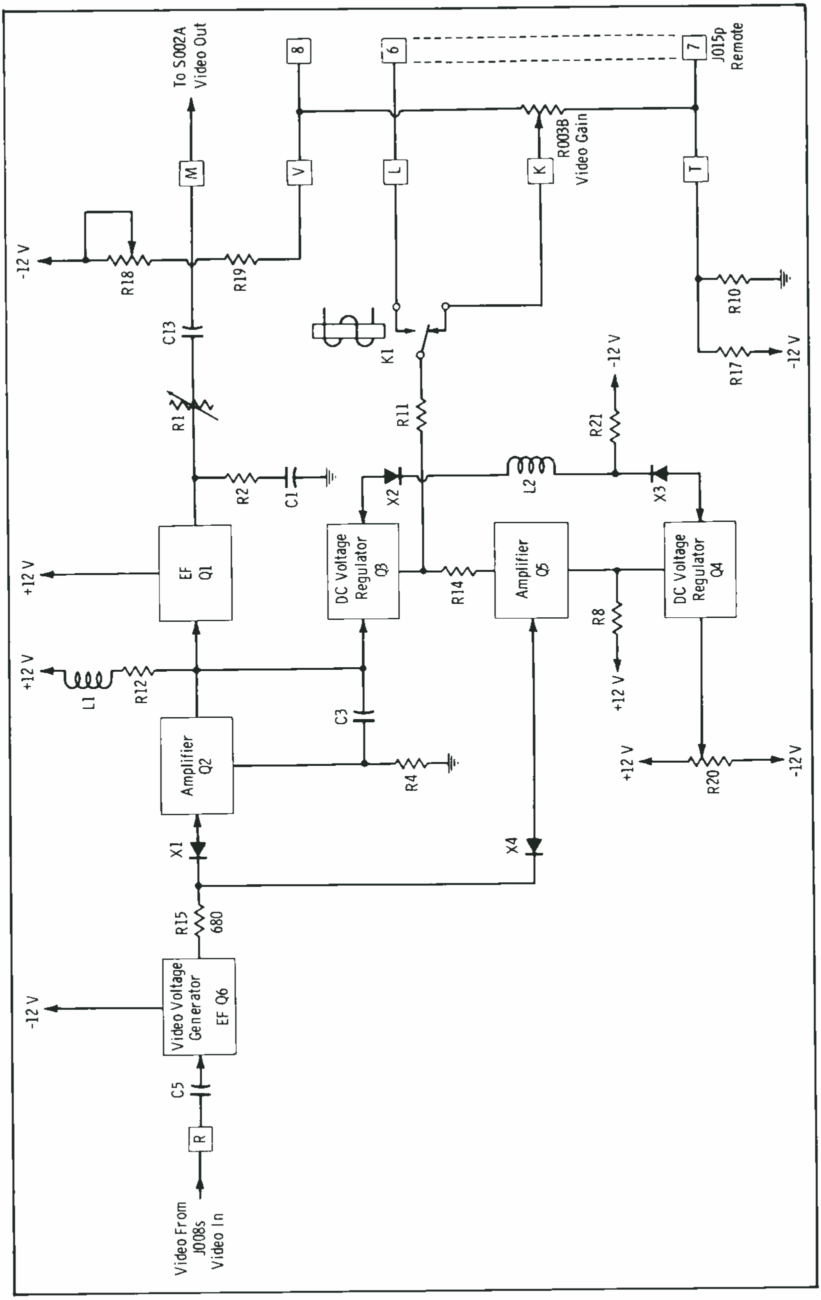


Fig. 6-13. Remote-video-gain etched board 18.

The incoming video signal from J008s enters the circuit board at pin R and is coupled by emitter follower Q6 through resistor R15 to the junction of diodes X1 and X4. The anodes of these diodes are connected to the emitters of Q2 and Q5, respectively.

The input impedances of diodes X1 and X4 and transistors Q2 and Q5 are the key to the remote control of video gain. The dynamic impedance of any semiconductor device is a function of the dc current through it. The resistive component of the diode impedance is approximately 25 divided by the dc current in milliamperes. Thus if the dc current is 1 mA, the resistive component is 25 ohms; if the current is 5 mA, the resistive component is 5 ohms.

The impedance at the junction of R15 with the cathodes of X1 and X4 is very low (i.e., of the order of 10 to 20 ohms). The resistance of R15 (680 ohms) is considerably larger than the junction impedance. It thus establishes a constant-current source that is relatively independent of any current changes that occur in later circuitry. Fig. 6-14 is a simplified diagram that illustrates the mechanism involved. At the junction of R15 with diodes X1 and X4 there is a variable resistance to the left and a variable resistance to the right. The constant current from Q6 divides between the two grounded-base amplifiers (Q2 and Q5) in the inverse ratio of their dynamic impedances.

The output of the circuit of Q2 and Q5 is taken from the collector of Q2. When Q2 saturates, Q5 cuts off, and all the dc current through R15 passes through Q2 and R12. This is the condition for maximum gain. When Q2 cuts off, all the current through R15 passes through Q5 and R8. This is the no-signal condition.

If transistors Q2 and Q5 were used by themselves and their conductions varied differentially, the dc voltage at the collector of Q2 (the output) would follow the changing dc level, causing an unwanted "bounce" in the resulting gain. Such a sudden change of dc level would seriously disturb subsequent clamp circuits in the processing amplifier. Transistors Q3 and Q4 provide a dc current change which is (ideally) equal and opposite

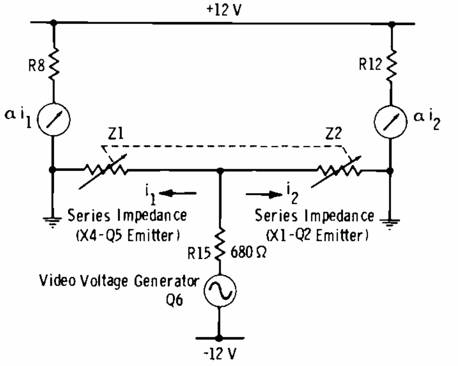


Fig. 6-14. Simplified diagram of remote control of video gain.

to the "bounce" current that appears in R12. The dc current through R12 remains nearly constant throughout the range of video gain. The bases of Q3 and Q5 are connected through R14; the collectors of Q4 and Q5 are common. Thus Q3 and Q4 act to cancel the dc current and tend to hold the collector of Q2 at a constant dc voltage. (Neither Q3 nor Q4 is concerned with the video signal.) The network consisting of R4 and C3 (Fig. 6-13) provides dc feedback to further reduce the unwanted gain "bounce."

When relay K1 is de-energized, panel control R003B (VIDEO GAIN) controls the dc bias of Q1 and Q3; when K1 is energized, an identical potentiometer on the remote control panel replaces R003B.

The range (or calibration) of R003B is set by R18. Control R20 adjusts the base bias of Q4 to balance the currents through Q3 and Q4, and to equalize their currents with the currents through Q2 and Q5. An RC network that includes R14 reduces differential phase and differential gain and maintains the frequency response through etched board 18. Inductor L1 peaks the frequency response of the collector output of Q2. Inductor L2 isolates feedthrough of the video signal appearing at the collectors of Q2 and Q3. This is done to prevent high-frequency loading of the signal by the emitter of Q4.

The output of Q2 is coupled by emitter follower Q1 through response-equilizing control R1 to pin M, from which it is routed to the remote position of switch S2002A (VIDEO OUT). The network composed of R1, R2, and C1 compensates for the capacitance presented by the unterminated cable that is connected to pin M.

The connections between the remote video gain panel and etched board 18 are made through a 10-conductor cable to J015p (REMOTE). This cable carries only dc control currents and voltages, and it may have any reasonable length.

EXERCISES

Q6-1. What is the basic signal error in the playback of a tape when the guide positioning is not identical to that used for recording?

Q6-2. What is the basic element in any quadruplex-tape ATC system?

Q6-3. How is the element of Q6-2 basically used for time-error correction?

Q6-4. With the tape system in the nonsynchronous mode of playback, what are the basic signals used for comparison to generate an error signal?

Q6-5. With the tape system in the synchronous playback mode, what are the basic signals used for comparison to generate an error signal?

Q6-6. What is the normal correction range (in nanoseconds) for automatic time correction circuitry?

Q6-7. Are the varicaps in an electronically variable delay line forward or reverse biased?

Q6-8. What signals are used for comparison to generate an error signal in color ATC systems?

CHAPTER 7

The Servo System

The servo constitutes the *synchronizing section* of the television-tape system, as contrasted to the *video section.* The television-tape servo system is electromechanical in nature; the input is an electronic signal, and the output device is an electric motor with a mechanical load. Three basic servo systems are involved: The rotating-head–motor servo, the capstan-motor servo, and the vacuum-guide–motor servo.

NOTE: The entire combined headwheel (drum) and capstan servo that makes it possible to lock one or more recorders to any external sync source or to each other is termed the *Intersync* section of Ampex recorders. This is equivalent to RCA's Linelock or Pixlock sections. See Table 6-1 (Chapter 6) for the correlation of terminology.

7-1. RELATIONSHIPS

The basic synchronizing function of the tv-tape system will be clear if the following basic relationships are clearly visualized:

1. Relationship of the head timing pulse (tachometer) to the video head recording vertical sync.
2. Phasing of the control-track signal being recorded with the video tracks being recorded, as timed from the 60-Hz reference pulse from which the 30-Hz frame (edit) pulse is derived.
3. Relationship of the tracking control to the video head playing back vertical sync.

Fig. 7-1 illustrates the factor that determines which of the four video heads records the vertical sync. Since the 240-Hz signal derived from the rotating-head shaft is compared in phase with the 240-Hz signal derived from vertical sync (reference pulse), the particular head in contact with the tape at the leading edge of this pulse is the one that will be recording vertical sync. Thus, the physical orientation of the timing ring of the tone-

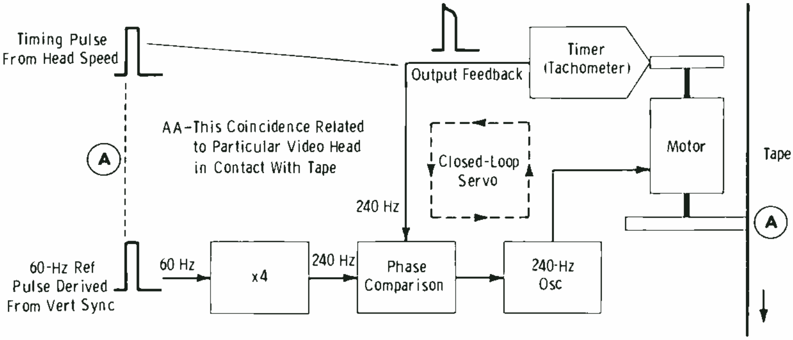


Fig. 7-1. Relationship of tachometer signal to head in contact with tape.

wheel notch relative to the head assembly determines which of the four heads will record vertical sync.

The notch in the RCA tonewheel is directly over the tonewheel head when video head No. 1 is in the approximate center of the tape. Thus video head No. 1 records vertical sync in the RCA machine. The orientation of the Ampex tachometer is such that the leading-edge reference occurs when head No. 4 is in the approximate center of the tape. Thus, head No. 4 records vertical sync in the Ampex machine.

The A-scope (which monitors the playback channels) on the Ampex control panel is a driven type, with the horizontal sweep being triggered from a derivative of the timing tachometer. The output of the four video heads during one revolution of the head drum is displayed on one horizontal sweep of the oscilloscope. With the tracking control centered (same head playing back vertical sync as recorded it), the presentation is as shown in Fig. 7-2. Since vertical sync occurs at the approximate center of the channel-4 track, the retrace is triggered at this time, and channel 4 continues a short distance on the left section of the trace.

NOTE: It should be understood that any existing difference with respect to which video head records vertical sync does not affect compatibility or interchangeability of tapes between any two systems. When a recorded

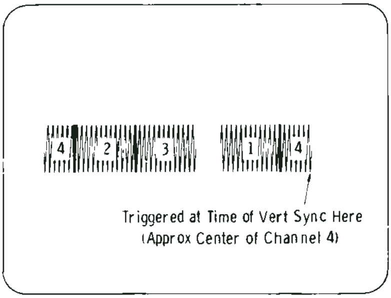


Fig. 7-2. A-scope presentation of Ampex head switching.

tape is played back on a different head than that used for recording, the tracking control is adjusted to obtain the best match of head-to-tape response.

The phasing of the control-track signal, recording of the video tracks, and frame (edit) pulse is illustrated in Fig. 7-3. (Since the control-track signal is used to provide a timing reference during playback for the capstan servo, it is sometimes called the *tracking-control recording.*)

The 240-Hz sine wave on the control track represents the current in the control-track head during recording, and hence the degree (and polarity) of magnetization on the tape. The current nodes (zero magnetization) occur in phase with alternate video-track guard bands. Thus, current nodes and current maximums occur in phase with alternate video-track guard bands. The control-track sine-wave current is so phased that the edit pulse (30-Hz frame pulse derived from the 60-Hz reference pulse and occurring every 33 video tracks) occurs at the point of maximum current in the guard band between the second and third tracks following the track that contains vertical sync. This is between tracks 3 and 4 if track 1 contains the vertical sync, as shown in Fig. 7-3.

It is important to note that proper phasing of the control-track signal with the edit pulse (and hence the reference pulse) automatically establishes a standard phasing relative to the video tracks being recorded; this is most important for interspliceability. If a tape is spliced onto another segment which does not have identically the same phasing between video tracks and control tracks, the tracking control must be manually readjusted immediately after passage of the splice.

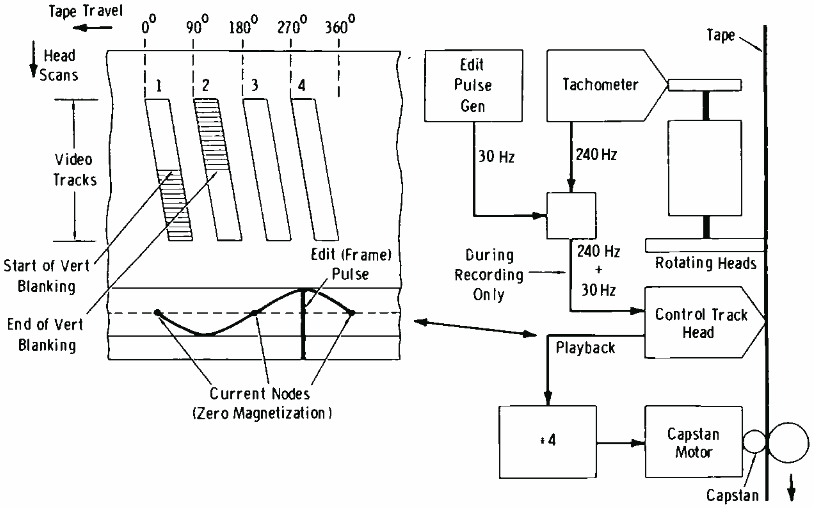


Fig. 7-3. Phasing of video tracks, control-track signal, and edit pulse.

Fig. 7-4 shows the relationship of the tracking control to the video head playing back vertical sync. As shown, either the control-track signal or the head-tachometer signal may be shifted in phase so that any one of the four video heads will track on vertical sync. Ampex machines track by means of the control-track signal, and older RCA machines track by means of the tone-wheel signal. All older RCA systems modified for synchronous operation and all later-model RCA recorders also use the control-track signal path for tracking control.

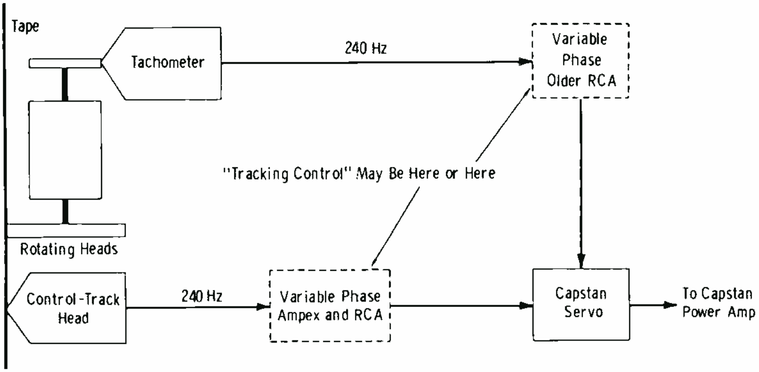


Fig. 7-4. Tracking control of video head playing vertical sync.

7-2. BASICS OF THE AMPEX INTERSYNC SERVO SYSTEM

The magnetic-tape recording and reproduction of television signals involves the scanning of a moving tape by four video heads that are mounted in precise quadrature on the periphery of a rapidly rotating head drum. The longitudinal movement of the tape is synchronized with the rotation of the head drum by the action of two mutually synchronized electronic servos. In the basic system, tape speed is controlled by the action of the capstan servo system; head-drum rotation is governed by the head-drum servo.

A better understanding of the Intersync servo functions and circuitry will be gained by a brief review of the standards of the television industry and how they relate to problems accompanying the achievement of a high degree of servo synchronization and timing stability. The discussion which follows deals with the:

1. Elements of the television signal
2. Limitation of timing errors
3. Servo record-mode functions
4. Servo play-mode functions
5. Servo control modes

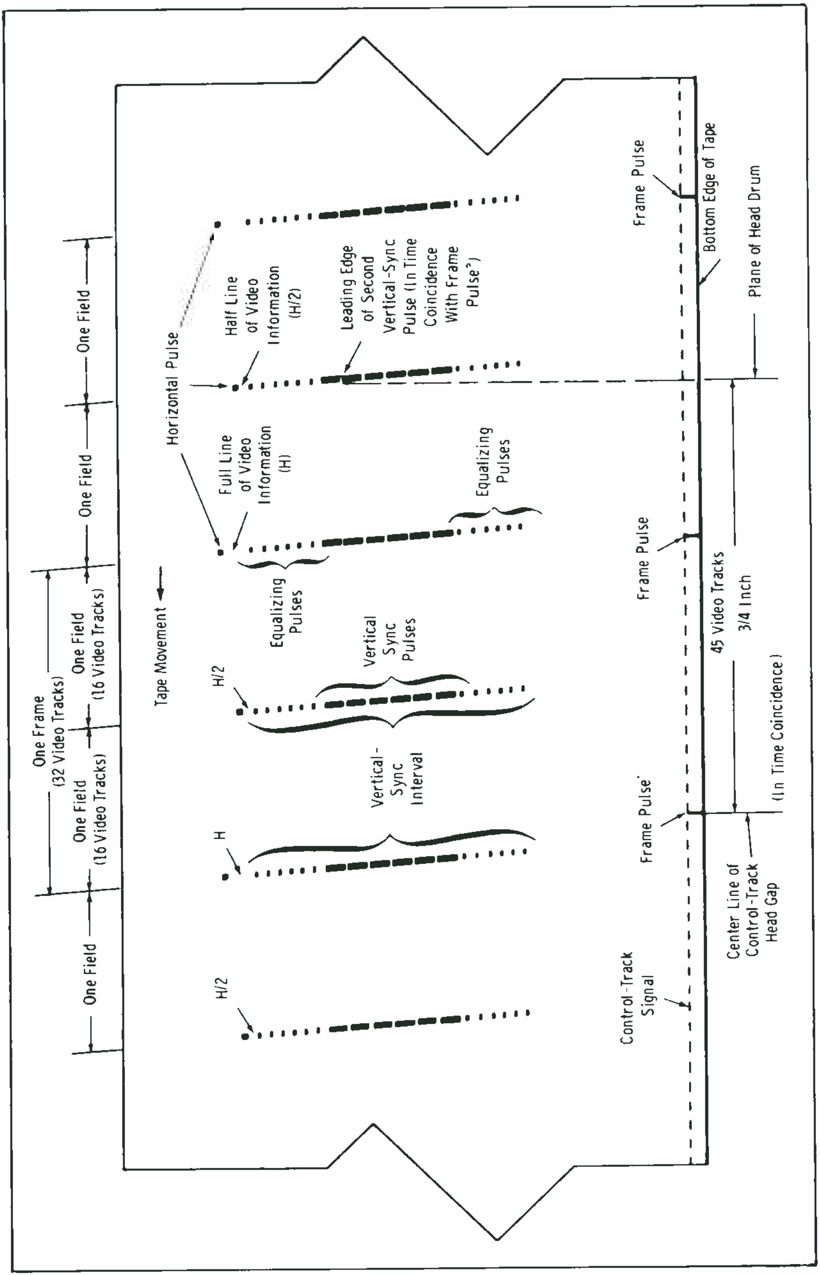
Elements of the Television Signal

To produce a complete frame of a television picture, the raster is completely scanned twice by the electron beams in the camera and the picture tube. Each scan starts at the top of the picture and ends at the bottom and is composed of a series of closely spaced horizontal lines; the horizontal paths traced by the electron beam on the second scan are interlaced midway between those traced on the first scan.

The television standard in use in the United States is 525 lines per frame and 30 frames per second, which requires 60 scans per second. When each scan is completed, the scanning beam is blanked out and returned to the top of the raster by a synchronizing pulse occurring at the vertical rate, which is 60 times per second. These vertical-synchronizing pulses are recorded on the tape midway across the area occupied by the video information, and they recur on every sixteenth path of recorded video information. The vertical pulses that initiate the first scan of a frame coincide in time with a 30-pps frame pulse that is recorded simultaneously on the longitudinal control track at the lower edge of the tape. The frame pulse recorded on the control track always appears on the tape in the same relative position with respect to the corresponding vertical-sync information recorded as a part of the composite video signal.

The 525/30 television standard uses 525 horizontal traverses of the raster by the electron beam for each complete frame. There are therefore 15,750 such traverses per second, requiring 15,750 horizontal pulses per second. This is known as the horizontal rate. When video information is present during the recording, the space following each horizontal pulse, with one exception, contains video information corresponding to a full horizontal line in the picture.

The vertical-synchronizing information that initiates a new frame is always preceded by a half-line of video information; the vertical-synchronizing information that appears on the sixteenth path following completes the frame and is always preceded by a full line of video information. Thus, complete frames are presented 30 times per second. Fig. 7-5 shows the vertical-synchronizing information which appears at the middle of every sixteenth transverse path. This information may be seen to include (in sequence) six equalizing pulses, six vertical-sync pulses, and six equalizing pulses. The recorded 240-Hz control-track signal and the superimposed 30-pps control-track frame pulses appear at the bottom edge of the tape. Fig. 7-5 also shows that the stationary control-track record/reproduce head, which is mounted on the video head assembly, is located ¾ inch "downstream" from the plane of the video heads. The control-track head records and reproduces the 30-pps frame pulses in addition to the 240-Hz control-track signal. Because of the "downstream" location of this head, the vertical-sync information associated with each frame pulse is 45 video tracks "upstream" from it.



Courtesy Ampex Corp.

Fig. 7-5. Positional relationship of video and sync on coated surface of tape.

Limitation of Timing Errors

There is a minimum degree of inherent timing error in the record/reproduce process. Because of this, any recording will contain a normal amount of timing errors to which the playback process will add more. Timing errors originate from a variety of causes, of which the following are the more frequently encountered:

1. Momentary changes of head-drum velocity caused by variations of head-drum loading.
2. Momentary phase transients in either the reference signal or the video signal.
3. Momentary loss of horizontal or vertical sync.
4. Instability of the reference signal caused by a malfunction of the afc circuitry in the sync generator.

The principal function of the Intersync servo unit is the maintenance of synchronization between the reproduced video signal and other video sources to a degree that permits program switching between these sources without interruption of picture continuity. The Intersync servo unit accomplishes this by locking the reproduced signal to the sync reference to which the other video signals are locked, and by holding the timing errors in the reproduced signal within very narrow limits. Fig. 7-6 shows a simplified block diagram of the Intersync servo system.

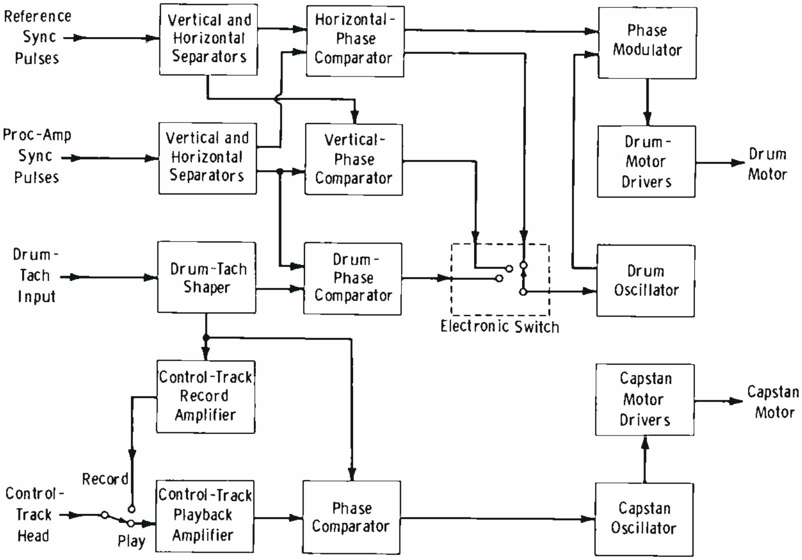


Fig. 7-6. Simplified diagram of Ampex Intersync servo system.

Servo Record-Mode Functions

During the record mode, the Intersync servo unit provides two closed servo loops that control head-drum rotation and maintain maximum timing stability of the recorded signal. The positional loop (Fig. 7-7) determines the average rotational rate of the head drum and the instantaneous angular position (or phase) of the video heads with respect to the reference signal. Its gain and bandwidth are designed to provide a "soft" servo control that resists the reaction of the head drum to high-rate-of-change disturbances that may appear in the video or reference signal. Control is maintained by the phase (i.e., time) comparison of the tachometer signal (representative of head-drum phase) with the sync components of the incoming video signal. The resulting measure of timing error is represented by a proportional voltage that controls the frequency of the drum-oscillator output. This action places video head 4 in position to record the vertical-sync information at the precise center of the tape width.

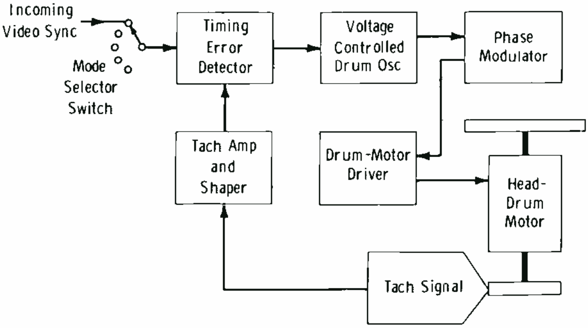


Fig. 7-7. Block diagram of positional loop.

If a program transition to a nonsynchronous video signal source is required during the making of a recording, the positional servo must correct the angular position of the head drum at a controlled rate, in order to minimize a corresponding instability that will occur during the subsequent reproduction. In the event of severe interruptions of the video sync component, the Intersync servo unit may be switched to the power-line or external reference position.

The second loop (Fig. 7-8) provides damping and is used during all modes of operation. Its damping action minimizes high-rate-of-change disturbances that affect the instantaneous frequency of head-drum rotation. Such disturbances include those resulting from the natural tendency of the drum motor to "hunt" at a rate of 7 to 10 Hz, or from momentary changes of head-to-tape pressure (drum loading) caused by the passing of a tape splice. The minimizing of these disturbances establishes a flat frequency characteristic within the bandpass of the servo system.

In the damping loop, a frequency-sensitive detector derives a signal voltage that is proportional to any instantaneous changes in the frequency of the tachometer signal. This signal voltage is applied to a phase modulator which also receives the drum-oscillator signal. The oscillator signal is modulated in terms of corresponding momentary phase shifts to counteract the disturbance, and then it is routed to the drum-motor driver.

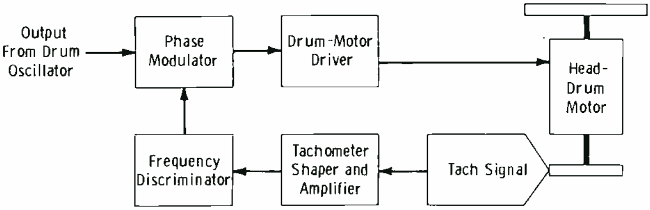


Fig. 7-8. Block diagram of damping loop.

During the record mode, the capstan servo system maintains constant velocity of the tape in its movement past the rotating video head drum. The frequency of the capstan drive signal is 60 Hz (U.S. system) derived from an oscillator and locked to the drum-tachometer signal. The capstan synchronous motor is thus caused to drive the tape at a nominal rate of 15 inches per second (U.S. system) but is electronically locked to the rotation of the video head drum.

Derivation of the capstan drive signal in this manner, rather than directly from the power line, prevents power-line phase transients from having an effect because of the "soft-lock" characteristic of the drum servo loop. In addition, if the head drum changes speed momentarily to rephase, the capstan changes speed proportionally and thus maintains a constant interval between the recorded transverse tracks across the width of the tape.

Servo Play-Mode Functions

During the making of a recording, the tape moves longitudinally at the nominal rate of 15 inches per second, while the video heads rotate at the rate of 14,400 rpm (US system). The carefully controlled positional relationship between vertical-sync information and the 30-pps frame pulse is established at this time, during which the tachometer scans the rotation of the video head drum and generates one complete cycle of a square wave during each revolution.

Because the drum turns at 240 rps, the square wave produced by the tachometer has a frequency of 240 Hz and is in exact phase with the drum position. The tachometer signal is recorded on the control track at normal level together with the 30-pps frame pulse, which is recorded at the level of tape saturation. The considerable difference between the recorded levels of the frame pulse and the control track permits positive identification of both reproduced signals.

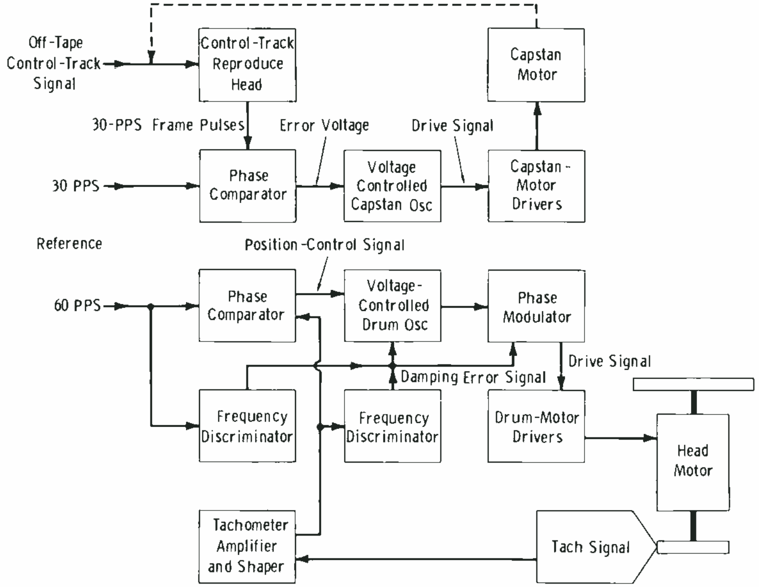
Reproduction of the recorded composite video signal requires accurate servo controls that will position the tape longitudinally and phase the video heads transversely to re-establish the positional relationship existing during the recording process. The tape is positioned longitudinally by the capstan, which is controlled by comparison of the reproduced control-track signal with a reference signal. Simultaneously, the phase of the video head drum is precisely indicated by the phase of the tachometer signal, which is compared with that of the reference signal. An error in the longitudinal position of the tape or in the phase of the head drum results in a correction voltage that acts on the appropriate servo system to cancel the error.

Servo Control Modes

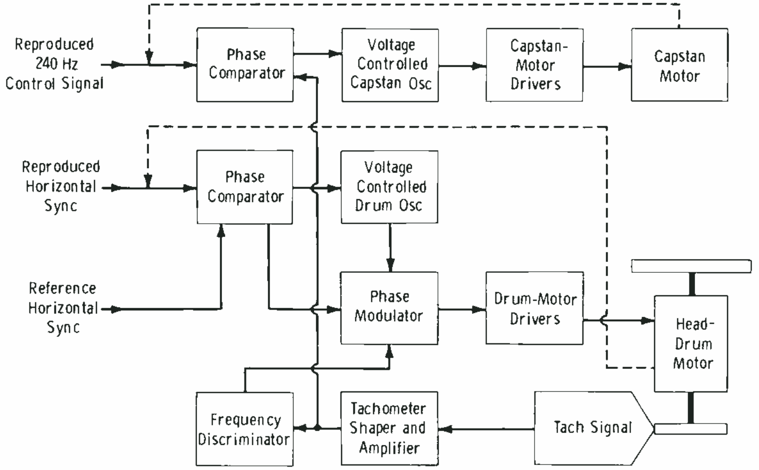
The Intersync servo unit allows manual selection of five operating modes, as follows:

1. Automatic: In record, this mode locks the recorder to the incoming video vertical-sync signals. In play, it permits full Intersync operation which tightly locks the recorder to reference horizontal and vertical sync.
2. Vertical: This mode locks the recorder to the video vertical-sync signal in record and to reference vertical sync in play; it maintains accurate frame lock when no-roll switching is desired.
3. Horizontal: This mode locks the recorder to the video vertical-sync signal in record and tightly locks to external reference horizontal sync in play. Use of the horizontal mode minimizes any effects from signal discontinuity and permits high quality when playing back spliced color and monochrome tapes. Properly made splices are not visible on the screen. The reproduced video will not necessarily be vertically framed with respect to reference sync.
4. Normal: For monochrome use, this mode locks the recorder to the signal vertical sync in record and to the power line in play.
5. Preset: In this mode, the Intersync servo unit may be set to any desired record or reproduce reference. This mode is similar to the normal mode, except that the timing reference source is selected by the chassis switches labeled PRESET REFERENCE SELECTORS. The preset mode is used for checking various circuits and to meet unusual requirements of the user.

Automatic Mode—The Intersync servo unit performs its major function during the recovery of signal information from a tape recording. To do this, in the automatic mode it provides servo controls that identify the particular transverse track in which a frame begins, positions the tape to cause the video heads to scan the exact center of each transverse track, and phases the head-drum rotation to cause one particular video head (number 4) to scan the identified track when switched to track 1. Other heads may be selected to scan the identified track. Fig. 7-9A shows a block diagram of the



(*A*) *Initial condition.*



(*B*) *Final condition.*

Fig. 7-9. Block diagrams of automatic mode.

automatic mode, initial condition, and Fig. 7-9B shows a block diagram of the automatic mode, final condition.

Track identification is derived from the 30-pps frame pulse recorded on the control track, which controls capstan rotation to position the tape longitudinally. During this period, head-drum rotation is locked to a reference signal (e.g., station reference sync), but the video heads are not yet in contact with the tape. Thus the longitudinal positioning of the tape is accomplished by relatively large changes of tape speed during a period when recorded vertical- and horizontal-sync information is not being reproduced. Because the control-track record/reproduce head is in contact with the tape at all times, frame pulses are reproduced as soon as tape movement begins. It should be remembered that each frame pulse coincides in time with the vertical-sync information that initiates a new frame (Fig. 7-10), and that the frame pulse is recorded on the control track, whereas the vertical-sync information is recorded on a transverse video track.

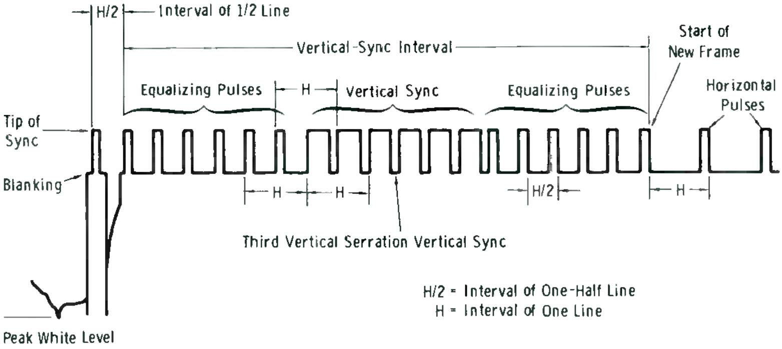


Fig. 7-10. Vertical-interval waveform at end of frame.

After 1 or 3.8 seconds, depending on the type of start-up used, and after capstan rotation has stabilized or nearly stabilized the longitudinal position of the tape, the vacuum tape guide brings the tape into contact with the video heads; the heads then begin reproduction of the recorded video information. If for any reason the control-track frame pulses are not present and framing is not accomplished as described above, duplicate framing information derived from the reproduce video tracks controls the capstan in the same manner as the control-track frame pulses. When framing is completed and video is being satisfactorily reproduced, the capstan servo and head-drum servo change to the same condition as the horizontal-mode final condition.

Horizontal Mode—In this mode, capstan rotation is controlled by phase comparison of the reproduced control-track signal with the tachometer signal. There is no other correction of the longitudinal position of the tape. Fig. 7-11 describes the horizontal mode in the initial condition; Fig. 7-9B describes the horizontal mode in the final condition (same as the automatic mode in the final condition).

During the few seconds after the reproduced control-track signal appears and before the vacuum guide engages the tape with the video heads, head-drum rotation is stabilized by phase comparison of the tachometer signal with reference vertical sync. At the conclusion of this interval, if reproduced sync pulses are being received, the control of head-drum phase is transferred to the output of the horizontal comparator. It remains under this control unless the tachometer phase comparison shows a slipping condition of the tachometer phase with respect to reference vertical sync or unless the reproduced sync completely disappears.

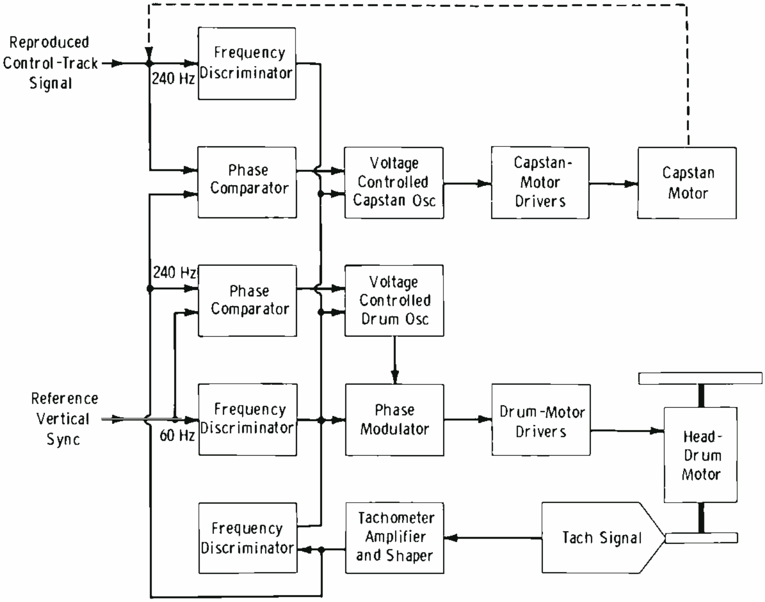


Fig. 7-11. Horizontal mode, initial condition.

Whenever resynchronization is required by the appearance of momentary phase transients, or by the momentary loss of reproduced horizontal sync, it is accomplished by again locking the reproduced horizontal sync to the nearest reference horizontal-sync pulse.

The horizontal mode is particularly designed for use with Colortec, which is the Ampex direct color process. Because this mode provides rapid recovery of lock-in, the interval during which timing errors in the reproduced signal exceed the Colortec correction range is minimized. However, the horizontal mode does not provide frame or field synchronization either initially or in the restoration of lock-in following momentary loss of sync.

Consequently, program switching between reproduced video and other video sources will produce brief disturbances in the picture presentation.

Vertical Mode—Frame synchronism within ± 10 microseconds of the reference is achieved rapidly in two sequential operations. Initially, the capstan positions the tape to place the beginning of a recorded frame in line with the head drum coincidentally with the beginning of a frame of information in the reference signal. This is accomplished by phase comparison of a reproduced frame pulse with a reference frame pulse and is normally completed within 3 to 4 seconds following the appearance of the reproduced control-track information. During this period, head-drum phase is corrected, by phase comparison of the tachometer signal, to place video head 4 at the center of the tape width coincidentally with the occurrence of reference vertical sync. The block diagram of the vertical mode in the initial condition is the same as that shown in Fig. 7-9A.

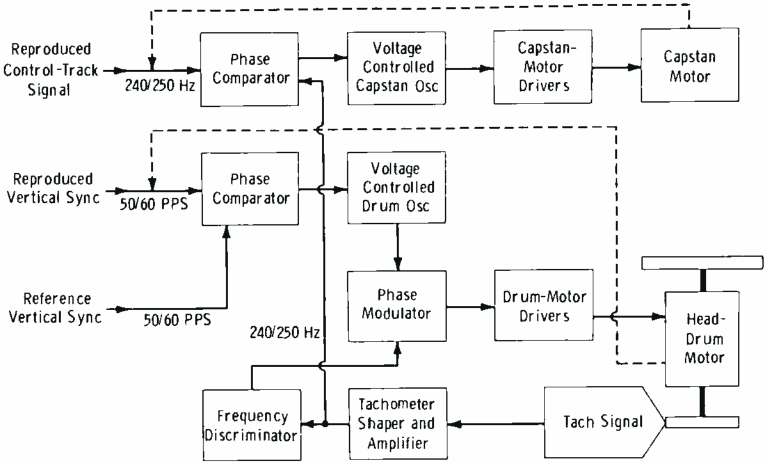


Fig. 7-12. Vertical mode, final condition.

At the conclusion of this period, capstan control is transferred to a voltage derived by phase comparison of the reproduced control-track signal with the tachometer signal. Tape movement is then locked to head-drum rotation. Control of head-drum rotation is transferred to a voltage derived by phase comparison of the reproduced vertical sync with reference vertical sync. The occurrence of a phase transient or an imperfect tape splice may cause loss of lock. If this occurs, the capstan will again accomplish framing as described above, provided the REFRAMING switch on module 14 is set to the Cap position. If the REFRAMING switch is set to the drum position, the drum advances or retards as many rotations as necessary to restore frame lock without loss of tracking. Fig. 7-12 describes the vertical mode in the final condition.

The TRACKING control on the main control panel has the "home" track setting marked on its dial. At this setting, video head 4 will reproduce the transverse video tracks that contain the vertical-sync information.

While a given video head assembly is in service, the TRACKING control should be kept at the "home" track setting during the recording and reproduction of a given tape. This will assure the best possible reproduction of that tape because the reproduce conditions recreate those present during the making of the recording.

By altering the setting of the TRACKING control, any one of the other video heads may be selected to reproduce the tracks that contain the vertical-sync information. During the reproduction of a recording made by a different video head assembly (or a different system), there may be an occasional subjective improvement of reproduced picture quality when head 1, 2, or 3 is selected to reproduce these particular tracks.

Normal Mode—The normal mode is recommended for monochrome reproduction when the recording is known to contain sync-timing discontinuities such as those that occur when a tape is improperly spliced. Reproduced video is "soft-locked" to the power-line frequency. However, reproduced sync timing is totally ambiguous with respect to the station sync-generator reference. Tape reproduction results without regard to framing and is based on phase comparison of the 240-Hz control-track signal with the drum-tachometer signal, which in turn is phase locked to the power line. Fig. 7-13 describes the Intersync servo when operated in the normal mode.

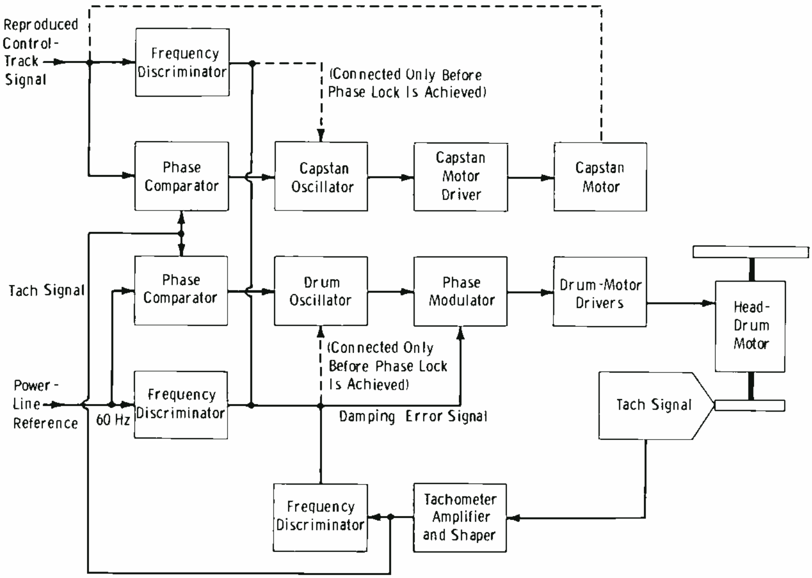


Fig. 7-13. Block diagram of normal mode.

Preset Mode—In the preset mode, the controls of the Intersync servo unit may be set to any desired record and/or reproduce reference. This mode is used mainly for checking various areas of the circuitry and to meet unusual requirements of the user. The preset mode is similar to the normal mode except that its timing reference source is chosen by means of two chassis-mounted selector switches labeled PRESET REFERENCE SELECTORS.

7-3. THE RCA HEADWHEEL SERVO

The headwheel servo system (Fig. 7-14) provides servo-controlled three-phase power to the headwheel motor in both the record and play modes of the RCA TR-70 tape machine. In the record mode, the headwheel servo tightly locks the motor velocity and phase to vertical sync. This relation ensures that vertical sync will be recorded by video head 1 at a precisely determined spot near the center of the tape width and that exactly the required number of video tracks will be recorded per tv field. On domestic (525-line) standards, the headwheel rotates at four times the 60-Hz field rate (240 revolutions per second), and, therefore, since each revolution produces four tracks, sixteen tracks are recorded in each field period. On international (405- and 625-line) standards, however, the headwheel rotates at five times the 50-Hz field rate (250 revolutions per second), and 20 tracks are recorded per field.

If, during recording, the headwheel motor velocity were fixed, without reference to vertical sync, the recorded vertical-sync pulses would drift across the video tracks, and the recorded edit pulses (see Section 7-4) would drift on the control track. Although a tape recorded under these conditions could be played back successfully on the same machine if no splices were made after recording, it would not be interchangeable with tapes made on a different machine.

During playback, the primary function of the headwheel and capstan servo systems is to control the respective motors so that a stable picture, with accurate sync and video frequencies, will be produced. Different requirements, however, such as roll-free switching, special effects, and monochrome or color ATC, demand a choice in the tightness of control and in the phasing between tape and external (local) sync. Therefore, during playback any of four different modes of servo operation may be selected: tonewheel, Switchlock, Linelock, or Pixlock. These modes are discussed in the system functional description below.

In both the record and play modes, the headwheel servo functions basically as a closed feedback loop in which error signals regulate the power supplied to the motor. These error signals are derived by periodically measuring the angular velocity and phase of the magnetic tonewheel (on the headwheel motor shaft) against standard references. During playback in the Pixlock or Linelock mode of servo operation, however, the system is expanded into a compound loop containing additional feedback from

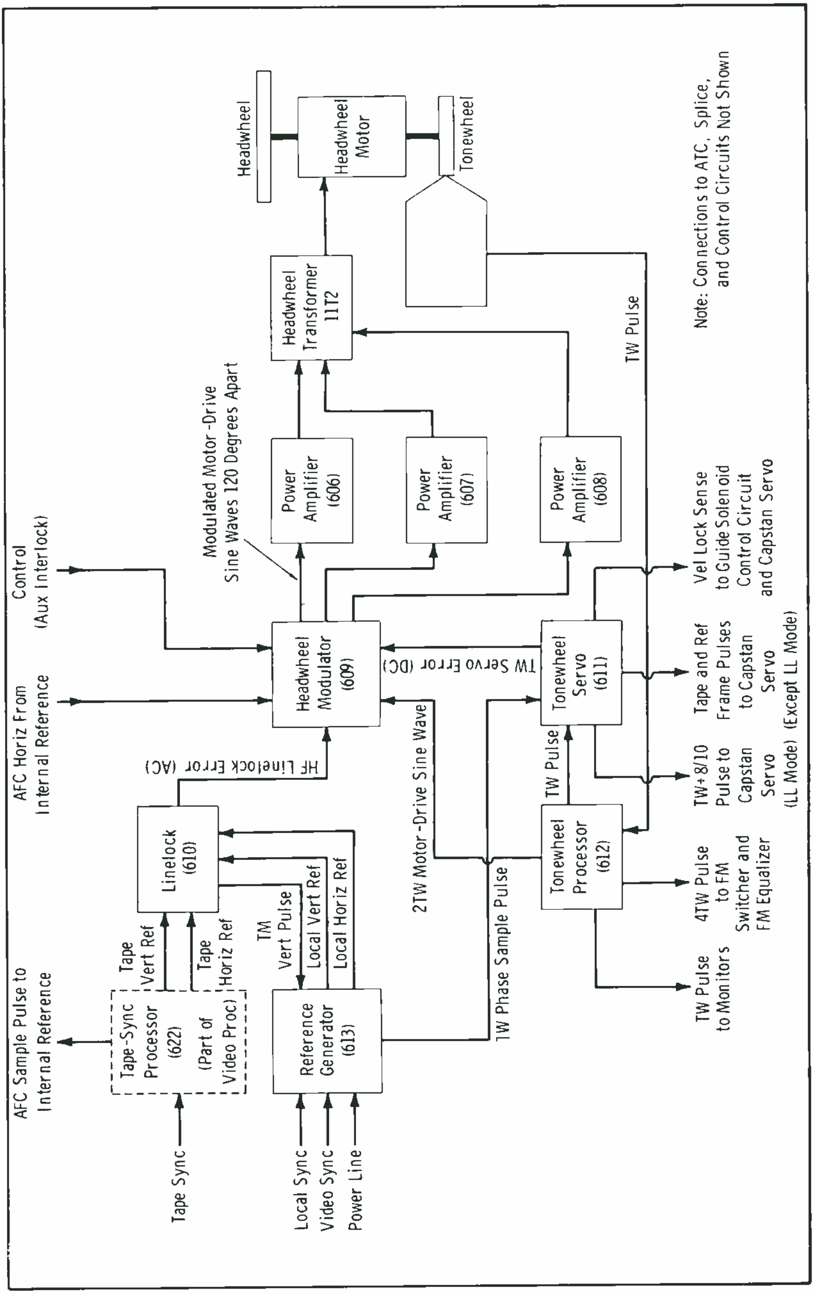


Fig. 7-14. Simplified block diagram of headwheel servo system.

tape sync and the error buses of the monochrome or color ATC system (Chapter 6).

The headwheel servo system consists of the following components:

1. Timing and signal processing
   A. Reference generator (613)
   B. Tonewheel processor (612)
2. Modulation and motor drive
   A. Headwheel modulator (609)
   B. Power amplifiers (606, 607, 608)
3. Error detection
   A. Tonewheel servo (611)
   B. Linelock (610)

The following sections describe the overall operation of the headwheel servo system during recording and playback.

Record Mode

In the record mode, an afc circuit in the tonewheel processor module, locked to the pulses from the magnetic tonewheel attached to the headwheel motor shaft, produces a sine wave at twice the tonewheel frequency. This sine wave serves as the basic motor drive signal (see Fig. 7-15). Networks in the headwheel modulator module split this signal into three sine waves which are 120° apart in phase. Chopper circuits controlled by a dc error signal from the tonewheel servo module then pulse-width modulate the three sine waves at a line-frequency (horizontal) rate. The amplitude and polarity of the dc error signal control the modulating pulse width, and, since the drive-signal amplitude is zero during the pulse interval, the pulse width determines the energy remaining in each cycle of the sinusoidal signal after modulation. For example, a negative error signal of maximum amplitude reduces the pulse width to zero and leaves the sine wave in the unmodulated, or maximum-energy, condition. Conversely, a positive error signal of maximum amplitude increases the pulse width to a full horizontal line period, thereby leaving zero energy. Filters in the modulator output remove the line-rate information and leave three sine waves, separated in phase by 120°, with amplitudes depending on the energy in the pulse-modulated signals. Separate power amplifiers (modules 606, 607, and 608) are driven by each of the three headwheel-modulator output signals and provide just enough power to drive the three-phase synchronous motor at one-half the synchronous speed.

As the headwheel rotates, the tonewheel pickup head provides one pulse per headwheel revolution. These pulses provide feedback to a velocity-error detector and a phase-error detector in the tonewheel servo module. The velocity-error detector compares the period of the tonewheel pulses with an independent fixed reference, which is the combined period of two free-running multivibrators. The total multivibrator period is one-quarter of

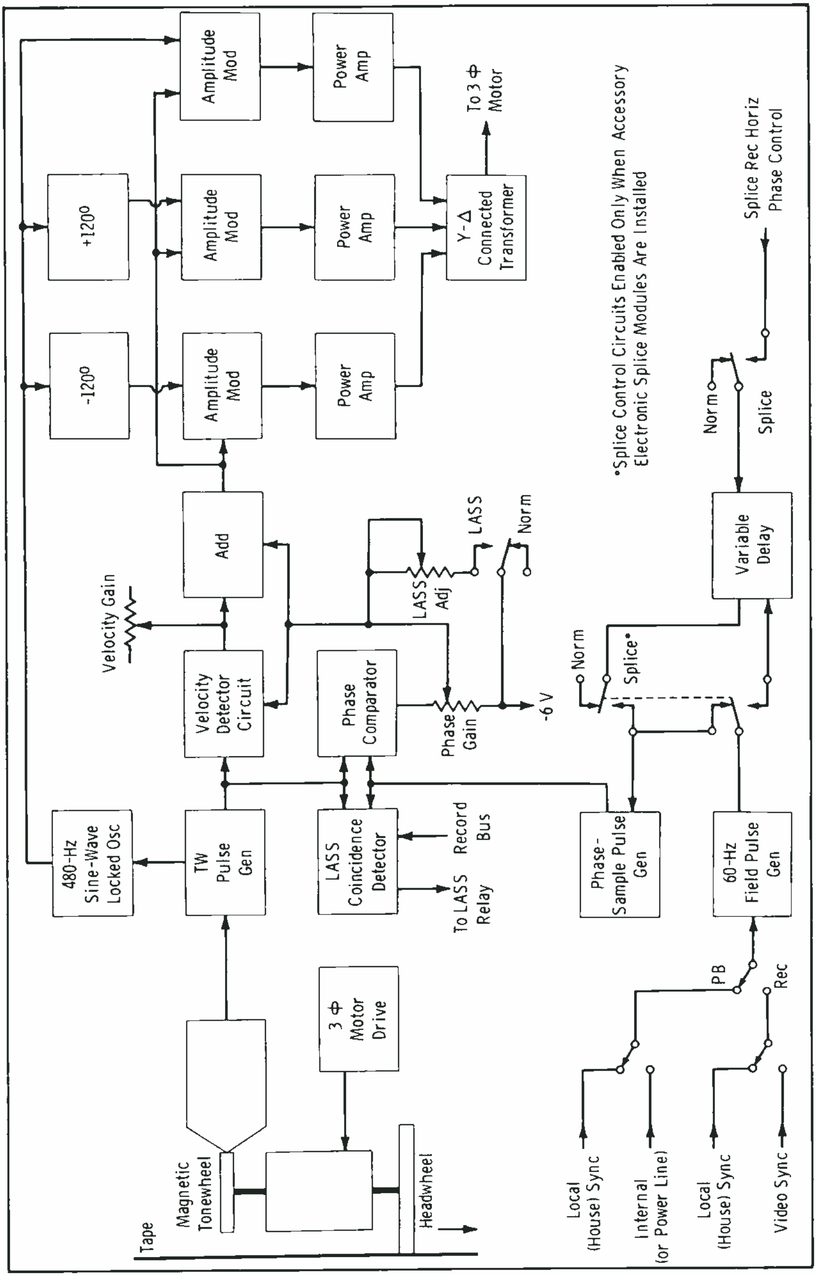


Fig. 7-15. Headwheel servo system during recording mode and tonewheel or Switchlock playback mode.

the tv field period (1/240 second) on domestic standards, or one-fifth of the field period (1/250 second) on international standards. Therefore the velocity-error signal depends on the difference between the tonewheel velocity and 240 (or 250) revolutions per second. The phase-error detector compares the phase of the tonewheel pulses with the phase of a reference vertical (field-rate) signal provided by the reference generator module. In the record mode, a switch on the reference generator module permits the selection of either external (house) sync or sync separated from the incoming video signal as the source from which the reference vertical signal is derived.

The velocity- and phase-error signals are combined in a manner which causes the velocity signal to predominate when large errors occur and the phase signal to predominate when small errors occur. Consequently, when the headwheel motor starts from rest, the velocity-error signal causes application of full power to the motor. The motor then accelerates rapidly toward the synchronous speed of 480 (or 500) revolutions per second, but as the tonewheel pulse period approaches the multivibrator period, the velocity-error signal reduces the power until the speed stabilizes at 240 (or 250) revolutions per second. At this time, the phase-error detector assumes tight control and corrects normal variations in headwheel-motor speed.

During manufacture of the headwheel panel, the tonewheel is attached to the motor shaft at a predetermined angle of rotation with respect to the headwheel; therefore, a precise phase relationship exists between the timing of the tonewheel pulses and the positions of the video heads on the tape. This relationship causes vertical sync to be recorded by video head 1 at a precise spot near the center of the tape width. Slight differences in the headwheel-to-tonewheel phasing between different machines, or between different headwheel panels, normally have little effect. When, however, an electronic splice is made (Chapter 10), a difference in headwheel-to-tonewheel phasing between the machine used for the original recording and the machine used for the splice recording will produce a horizontal "lurch" in the reproduced picture. Therefore, special splice circuits are provided in the headwheel-servo and electronic-splice systems to permit matching the headwheel-to-tonewheel phasing. When the machine is in the splice-play or splice-record mode, these circuits allow the operator to switch a variable delay into the path of the vertical reference pulse used for tonewheel phase-error detection. A potentiometer in the splice system then permits matching the phasing by adjusting the delay while observing the video signal during playback of the original recording. Adjustment of the potentiometer has the same electrical effect as changing the angle between the tonewheel and the headwheel.

Minimization of recorded drift or jitter requires fast servo response to error voltage and therefore high gains in the velocity and phase loops; however, after a nonsynchronous switch in the incoming video signal. a high gain in the tonewheel phase loop will cause the headwheel to rephase itself too rapidly for the capstan servo. Therefore, to permit a smooth transition, a special circuit designated the Lazy Servo Simulator (LASS) temporarily reduces the phase gain after a nonsynchronous switch (see Fig. 7-15). The LASS circuit, actuated only when a nonsynchronous switch occurs during recording, detects coincidence between the tonewheel pulse and the reference vertical signal. When actuated, the LASS circuit switches in a potentiometer previously set to provide the required gain reduction and then, after coincidence is restored, returns the circuit to normal.

Play Mode

During tape playback, the mode of servo operation is selected by a rotary switch on the tape-sync processor module in conjunction with a push-button switch on the play control panel. Playback in the tonewheel or Switchlock mode of servo operation is attained by rotating the switch on the tape-sync processor module to the TW or SL position, respectively. Playback in the Linelock or Pixlock mode of servo operation is attained by rotating the switch on the tape-sync processor module to the normal position and then selecting the desired mode by means of either the LINELOCK or PIXLOCK push-button switch on the play panel.

Now before going ahead, let us clarify a rather unfortunate situation in terminology. When RCA first made synchronous operation available, they called it "Pixlock." Instruction books referred to this function as either "Pixlock" or "Linelock" (since it is in actuality line-to-line lock), and either term applied to the same function. For fully synchronous operation (to be able to use mix and special effects of other local signals with the tape output), there must be vertical and horizontal coincidence of the tape output signal with other local signals. At the same time, for playback of a color tape, the tape system must be locked to local sync for proper control of the time base. This is necessary even if it is not required to use mix or special effects with other local sources. The main drawback of fully synchronous operation is that tape disturbances such as dropouts (particularly during the vertical interval) or faulty splices require a complete relocking process of the servos. Recovery of vertical alignment must come first. Due to the flywheel (inertia) effect of the frame rate, this can take from 3 to 4 seconds in the best of servos. Since the use of local mixing and special effects involving other local sources with tape playback is limited, another method of "synchronous lock" has been devised. This method involves locking to the local sync generator in timing only, dropping the requirement for exact vertical (framing) alignment. In the RCA system, the latter mode is termed "Linelock." Then the fully synchronous mode (timed *and* phased to local vertical sync for use of local mixing) is termed "Pixlock." So the two terms now cover different functions and are *no longer interchangeable.*

Tonewheel—In the tonewheel mode of servo operation, the tonewheel servo loop controls the headwheel motor as in the record mode, except that either external (house) sync or a special internal-generator or power-line signal may be selected for timing the vertical reference pulse. (The timing signal is obtained by utilizing a switch on the reference generator module and, if a power-line signal is desired, by changing a jumper internally.) This mode of servo operation will produce a satisfactory picture, but tape and reference sync will not necessarily be aligned because of the absence of feedback from the demodulated (tape) video signal to the headwheel or capstan servo.

Switchlock—When Switchlock is selected, the headwheel operates in the tonewheel mode of servo operation, but the capstan servo controls the tape motion so that the headwheel is on the track containing recorded vertical sync at the end of a frame when the corresponding vertical interval of reference (local) sync occurs. This coarse framing brings tape and reference vertical sync close enough to permit roll-free switching between the recorded output and other video sources, or to permit electronic splicing; however, it does not correct for errors in placement of the recorded vertical sync on the tracks.

NOTE: Before an electronic-splice recording can be made, the servo selector switch on the tape sync processor module must be in the SL position, and the machine must be actually playing back tape in the Switchlock mode of servo operation. If this condition is not met, the splice control circuit automatically prevents entry into the splice record mode.

As explained in the discussion of the capstan servo system, coarse vertical framing is attained in two stages. In the first stage (fast lock-up capstan), Switchlock is achieved before a tape playback signal is available by utilizing the edit pulses recorded on the control track to reset binary dividers in the capstan servo. In the second stage, which starts after four seconds from the moment of entry into the play mode, relays substitute tape frame pulses for the less reliable edit pulses. If no edit pulses were recorded on the tape, or if they were of poor quality, the capstan servo would go immediately to the second stage.

Pixlock—In the Pixlock mode of servo operation, the capstan servo provides coarse vertical framing, as in Switchlock. However, the headwheel servo additionally imposes both a tighter phase relationship between tape and reference vertical sync (tape vertical alignment, or tva) and a lock between tape and reference (local) horizontal sync (Linelock). This combined vertical and horizontal lock permits adjusting the tape horizontal phasing to obtain coincidence between sync in the video output of the machine and reference sync, so that lap dissolves, special effects, and similar transitions between the tape signal and other television signals may be used. In addition, the higher sampling rate used in maintaining Linelock reduces jitter to a low level.

NOTE: Since Pixlock performance depends partly on *recorded* jitter, best results in Pixlock playback are obtained with tapes recorded with a low-jitter servo.

Pixlock operation differs from Switchlock only in the use of error information from the Linelock module in addition to the velocity and phase information provided by the tonewheel servo module. The combined operation of the capstan and headwheel servos in establishing Pixlock occurs in two main phases: the tonewheel-tva phase and the Linelock phase.

At the moment the servo mode-selector push-button switch on the play panel is pressed for Pixlock operation, the machine enters the tonewheel-tva phase (Fig. 7-16). In this phase, a variable delay generator (time-modulated vertical circuit) in the Linelock module is switched into the path of reference vertical sync before the phase comparison circuit in the tonewheel servo module. A dc control voltage from the tape alignment (tva) error detector in the Linelock module is fed to the delay generator. The delay, nominally equal to the period between tonewheel pulses (4166 microseconds on domestic standards or 4000 microseconds on international standards), is modulated by the tva error signal. This signal is a measurement of the phase difference between tape vertical sync and unmodulated reference vertical sync.

At the start of the Pixlock operation, the tonewheel servo accelerates the headwheel motor in the same manner as in Switchlock. While the motor is accelerating, the tva signal has little effect because either the tape signal is not yet available or the vertical framing error is beyond the range of the tva error detector. When, however, the tonewheel velocity loop "locks in" and the capstan servo achieves coarse framing, the tva voltage assumes control of the tonewheel servo phase loop. If tape vertical sync occurs late with respect to reference vertical sync, the tva error decreases the vertical delay. The time-modulated vertical pulse then occurs earlier than normal with respect to the tonewheel pulse and produces the same effect as a later-than-normal tonewheel pulse. The dc tonewheel-servo error signal therefore becomes more negative. In response to the negative increment, the headwheel modulator then provides more power to the headwheel motor, causing an increase in speed. Conversely, if tape vertical sync is early with respect to reference vertical sync, the delay increases, the tonewheel-servo error signal becomes more positive, the motor power decreases, and the motor slows down.

The preceding actions rapidly bring the combined tonewheel-tva loop to an equilibrium condition in which time-modulated reference vertical sync has the same phasing, with respect to the tonewheel pulse, as the unmodulated reference vertical sync in the tonewheel mode. The time-modulated delay is then at a value which brings tape vertical sync very close to exact coincidence with reference vertical sync. The remaining error in tape vertical alignment has a fixed and a varying component, both small (within a few microseconds) because the tva gain is relatively large. The variable error is due directly to the low sampling rate (60 samples per second). Further reduction in the fixed error would require an even larger gain not attainable at this low sampling rate. While tape and refer-

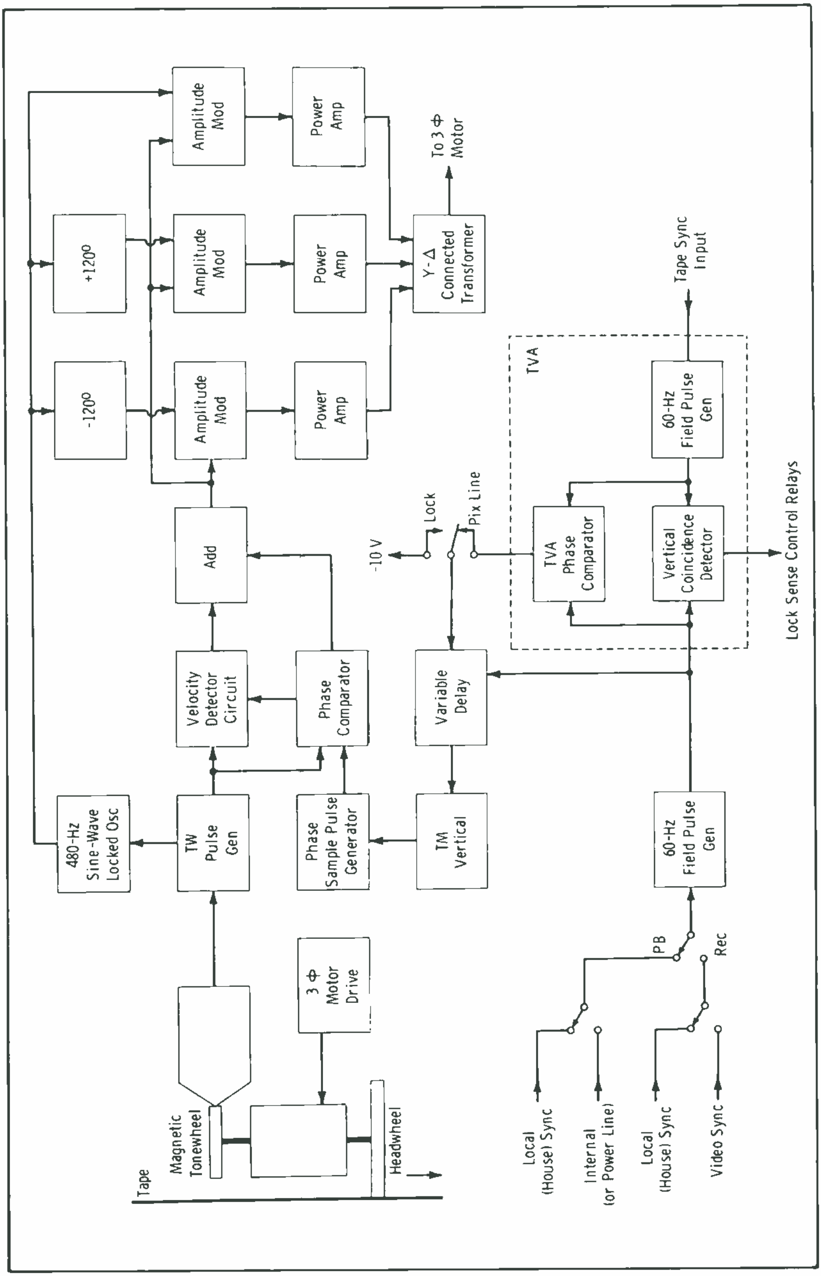


Fig. 7-16. Headwheel servo system in tonewheel-tva phase of Pixlock or Linelock mode of operation.

ence vertical signals are being brought into alignment, a coincidence detector and lock sense circuit in the Linelock module, independent of the tva circuit, compare the tape and reference vertical phasing. When vertical coincidence is established, this circuit energizes a bus (lock bus) which causes relays to switch the headwheel servo to the Pixlock mode.

At the moment the system is switched to the Pixlock mode of operation, the tva error signal is disconnected, and the Linelock error-detector circuitry is enabled (refer to Fig. 7-17). The Linelock error detector compares an output derived from tape horizontal sync at the video demodulator output with a reference derived from local (house) horizontal sync, to produce an error signal sampled at the line rate. Filters and amplifiers separate this signal into a high-frequency, or velocity, ac component and a low-frequency, or phase, dc component. The high- and low-frequency error-signal paths have separate antihunt and stabilizing networks. A gain control in the low-frequency error-signal path permits obtaining optimum loop gain and phase characteristics. In addition, each output amplifier provides special dynamic characteristics which compensate for the mechanical response of the headwheel motor to sudden disturbances.

The low-frequency Linelock error component is fed to the time-modulated vertical circuit in place of the tva error, and the high-frequency Linelock error component is fed, through a separate path, directly to the headwheel modulator. When the Linelock error-detector circuit is enabled, a time-delay circuit gradually increases the gain to prevent transients from supplying false information. As the gain increases, the low-frequency error component assumes control of the time-modulated vertical circuit; thereby it adjusts the delay previously established by the tva error signal to a value which causes the tonewheel servo to align tape horizontal with reference horizontal. Simultaneously, the high-frequency Linelock error signal provides velocity information to the modulator which locks the frequency of tape horizontal sync to that of reference horizontal sync.

Completion of all phases of Pixlock operation requires less than five seconds from the moment of entry into the play mode. When the Linelock phase is completed, only the mechanical capabilities of the motor drive system limit the tightness of control. The high gain and rapid response of the combined tonewheel and Linelock system reduce the maximum phase error between tape and reference sync to less than ±0.07 microsecond for a tape recorded on a machine having the same type of servo system.

As a distinguishing characteristic of Pixlock operation, the vertical-coincidence circuit continues to check the phase relationship between tape and reference vertical sync after the machine enters the Linelock phase. Therefore, if dropouts or similar disturbances cause loss of vertical coincidence, the lock-sense circuit will temporarily switch the headwheel servo back to the tonewheel-tva phase until the tva circuit re-establishes coinci-

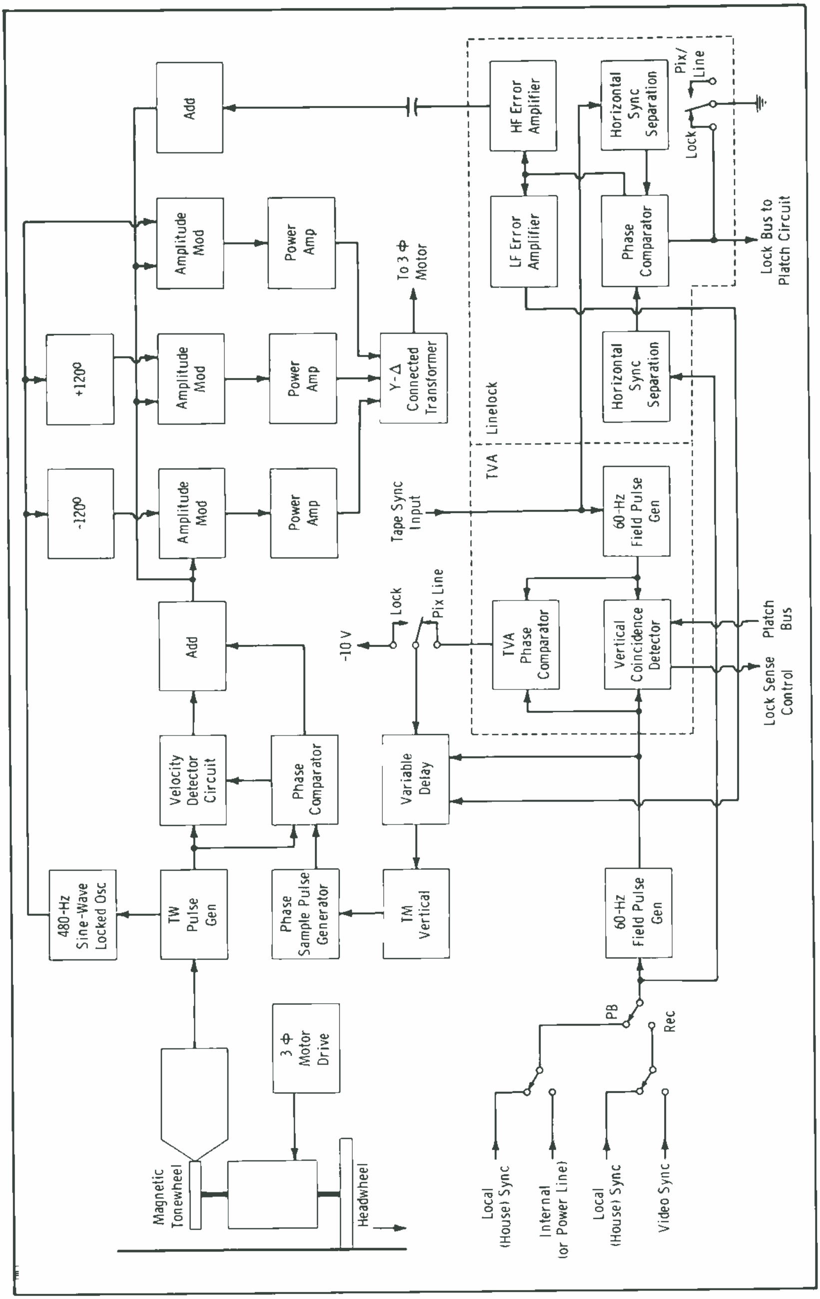


Fig. 7-17. Headwheel servo system in lock phase of Pixlock or Linelock.

dence. Resynchronization will normally occur within a time interval of three seconds.

To permit obtaining the different phase relationships between tape and reference (local) sync required for operation without ATC or in the various ATC modes, delays not previously mentioned are inserted into the paths of tape and reference horizontal sync before the actual phase comparisons are made in the Linelock and tva circuits. The Linelock circuit itself contains a fixed delay in the reference horizontal-sync path and a variable delay in the tape horizontal-sync path. Additional delays required only for ATC operation are inserted by the ATC systems before the reference signals are fed to the Linelock module.

Linelock—Initially, the Linelock mode of servo operation is similar to the Pixlock mode of operation. However, in Linelock, once the switch to the lock phase occurs, both the vertical-coincidence and Switchlock requirements are eliminated. Rapid recovery from tape disturbances such as dropouts or faulty splices is thus ensured, since the headwheel can immediately lock to any horizontal line without waiting for reframing. The Linelock mode is primarily useful in normal Color ATC or npc (nonphased color) playback, where vertical coincidence is not a requirement. (It should be noted that lack of vertical framing prevents the use of special effects.)

When the servo mode-selector switch on the play panel is pressed for Linelock operation (selector switch on tape sync processor module in Normal position) and the PLAY push button is pressed, operation of the headwheel and capstan servos is, initially, similar to Pixlock operation except that an eight-second time-delay section of a special control circuit (Pixlock Achieved, or Platch, circuit) is energized. If Pixlock is achieved within the initial eight seconds, the Platch circuit energizes a control bus one second after the switch to the lock phase occurs (Fig. 7-18). The

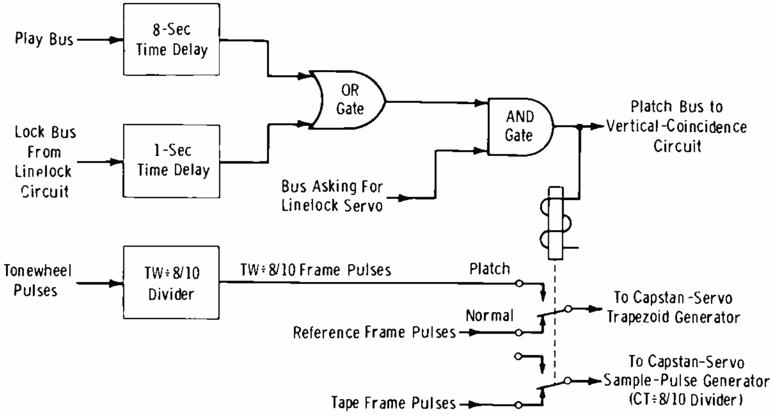


Fig. 7-18. Pixlock Achieved (Platch) circuit.

Platch bus then disables the vertical-coincidence circuit of the headwheel servo, and a relay switches the capstan-servo reference from the local frame pulse to a frame pulse derived from the tonewheel. However, if Pixlock is not achieved within eight seconds, the Platch circuit is automatically energized, and the Platch bus disables the vertical-coincidence circuit. The lock-sense circuit then switches the system to the lock phase.

The Platch bus thereafter remains energized throughout the playback period. The Linelock circuitry then functions exactly as described above under Pixlock, except that a loss of vertical framing does not cause reversion to the tonewheel-tva phase. After a disturbance, the Linelock circuitry, by rephasing the headwheel, locks the nearest horizontal line of tape video to reference (local) sync, and the capstan servo, referenced to the tonewheel, maintains tracking by adjusting tape motion.

7-4. THE RCA CAPSTAN SERVO

The purpose of the capstan servo system is to control the speed of the capstan motor and thus the speed at which the tape runs through the machine. In addition to the normal tape speed of 15 inches per second (15.625 in/s on 405/625-line international standards), the tape may be pulled through the machine at half-speed (7½ in/s). The primary advantage of running the tape at half-speed is that twice as much recording time can be obtained from a given length of tape as would be obtained from the same length of tape running at 15 in/s. The increase in recording time results in advantages such as reduction of tape costs, saving on tape storage space, and reduction in tape distribution expense. Although the tape speed is nominally 15 or 7½ in/s, during tape playback it is necessary that the capstan-motor speed be tightly controlled by the capstan servo system to ensure that exactly four video tracks are pulled past the rotating headwheel assembly during each rotation of the headwheel.

The capstan servo system in the TR-70 consists of the following modules in addition to the capstan motor itself:

1. Control-track record/playback (617)
2. Capstan phase (616)
3. Capstan error (615)
4. Capstan oscillator (614)
5. Capstan power amplifier (605)

The following discussion of the capstan servo system presents a brief overall description of the system operation during tape recording and playback. In the discussion, all timing references pertain to machine operation on domestic (525-line) standards. If the machine is operated on international standards, the appropriate timing differences must be taken into consideration (i.e., substitute 50 Hz for 60 Hz, 250 Hz for 240 Hz, etc.).

Also, throughout the discussion of the capstan servo system, the term "frame pulse" is used frequently. In the tape recording and playback processes, there are actually several distinct types of pulses occurring at a frame rate (30 Hz on domestic standards or 25 Hz on international standards). One type, designated the *reference* frame pulse, is obtained by comparing *station* (reference) horizontal- and vertical-sync signals in a coincidence gate circuit. During playback, this pulse is used directly as a reference for the capstan servo. During recording, the pulse is superimposed on the control-track signal, and the combined signal is recorded on the tape as specified by the SMPTE recommended practices. The frame-pulse portion of this combined control-track signal is referred to either as an *edit* pulse or as a *control-track* frame pulse. During tape editing, this pulse serves as a frame marker on the tape to permit making roll-free mechanical splices. Also, during the first four seconds of playback, the edit pulse is separated from the combined signal picked up by the control-track head and used in the fast lock-up circuit of the capstan servo.

In addition to the reference and control-track frame pulses, a *tape* frame pulse is used during playback in the Switchlock and Pixlock modes of servo operation. This pulse is generated by feeding *tape* horizontal and vertical sync (separated, after demodulation, from the signal picked up by the video heads) to a coincidence detector. The tape frame pulse, therefore, occurs at a definite time during the vertical-blanking interval at the end of each frame of the tape video signal.

Normal Record Mode

In order to maintain a definite timing relationship between tape movement and video-head scanning during the recording process, the capstan motor speed is "locked" to that of the headwheel motor. To accomplish this, a chain of binary counters is used to divide the frequency of the 240-Hz tonewheel pulses by four, and the resulting 60-Hz signal is used to drive the single-phase, hysteresis synchronous capstan motor. Because the tonewheel is physically attached to the headwheel motor shaft, both the tonewheel and the headwheel rotate at the same speed. Therefore, since the frequency of the signal driving the capstan motor will follow that of the tonewheel pulses, a "lock" is established between the capstan and headwheel motors. This method of controlling the capstan motor speed ensures that the tracks laid down on the tape during recording follow a standard geometrical pattern (e.g., that specified by the SMPTE or CCIR), thus facilitating interchangeability of tapes.

NOTE: In the record mode, the headwheel motor must lock in at its correct speed before the tonewheel pulse is applied to the first binary counter. Therefore, until a headwheel lock has been obtained, the counter is driven by the 240-Hz local oscillator used during tape playback. This arrangement protects against excessive motor and power-amplifier currents during start-up.

The binary counters produce a 60-Hz square-wave signal which is converted into a sinusoidal signal and fed to a power amplifier. The power amplifier then provides the power required to drive the capstan motor (Fig. 7-19).

To provide a continuous, accurate record of the capstan motor speed during recording, a 240-Hz sinusoidal control-track signal is recorded along the lower edge of the tape by the control-track head located on the headwheel panel. (The control track is utilized in controlling tape motion during playback and is analogous to the sprocket holes in motion-picture film.) The control-track signal is derived from the tonewheel pulse signal, which passes through a variable delay circuit before being formed into a sinusoidal waveform, and thus bears a definite phase relationship to the video heads. (It should be noted that when the recorded control-track signal is played back, it will not appear to be sinusoidal; because a direct recording process instead of a linear recording process is used, the signal will exhibit a characteristic double-humped pattern. This is clarified in Section 7-5.)

Superimposed on the control-track signal is a stable timing reference pulse designated the control-track frame pulse. This pulse is produced by a coincidence gate circuit which compares reference vertical- and reference horizontal-sync signals. The pulse occurs at a 30-Hz rate (25-Hz rate in international machines), and thus there will be one control-track frame pulse for every eight cycles of control-track signal (every ten cycles in international machines). To meet SMPTE standards with regard to relative phasing between the control-track signal and the control-track frame pulse, a variable delay is incorporated into the circuit which generates the control-track signal. Thus, by maintaining a specific phase relationship, the control-track frame pulses provide physical locations on the tape (approximately every half inch) at which the tape may be cut and spliced without danger of picture rollover (loss of vertical sync) during tape playback. Since the control-track frame pulse may be utilized as a guide for cutting the tape during tape editing, this pulse is sometimes referred to as an "edit" pulse.

The level of the combined control-track signal and control-track frame pulse fed to the control-track head is fairly critical. Therefore, the simultaneous playback head is provided as a means of playing back the combined signal immediately after it has been recorded, so that the signal level may be observed on the cro monitor and corrected if necessary. The combined signal may also be observed directly on the monitor as it is being recorded. This allows the operator to position the control-track signal relative to the control-track frame pulse precisely and to obtain the correct pulse amplitude. In addition to these presentations on the cro monitor, provision is made for observation of the motor drive signal as a means of checking the normal output which drives the capstan power amplifier during the recording process.

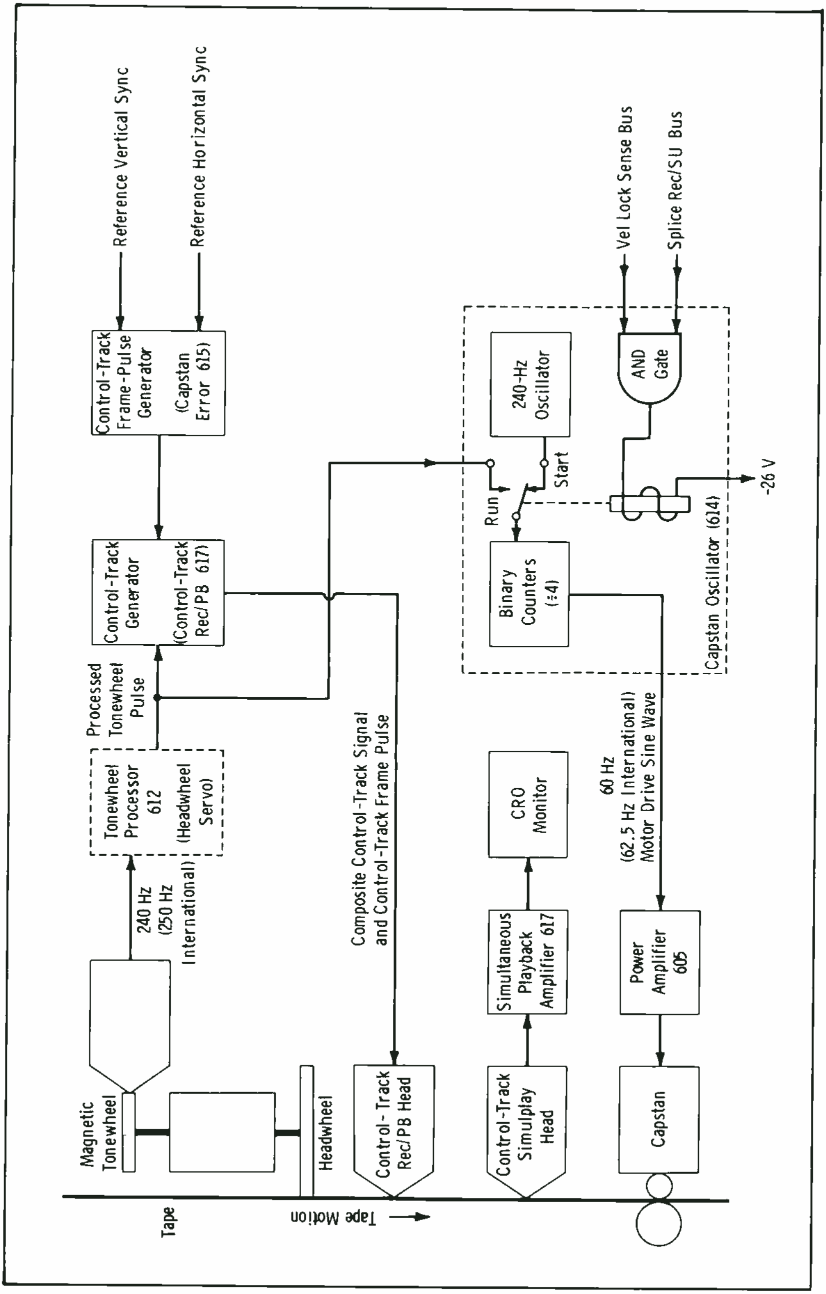


Fig. 7-19. Capstan servo system in record mode.

Playback Operation

During playback, several modes of operation are possible. These are described as follows.

Tonewheel—During tape playback in the tonewheel mode of servo operation, the capstan servo controls the longitudinal tape speed and phasing so that the video heads track properly on the recorded video tracks. In playback operation, the capstan motor speed is controlled by a local oscillator rather than by the tonewheel pulse as it is during the recording process. (See Fig. 7-20.) The oscillator is "free-running" at a frequency of 240 Hz; however, if the tape moves too slowly or too rapidly, an error signal is developed which increases or decreases the oscillator frequency (and thus the capstan motor speed) to correct the tape speed. The 240-Hz output signal from the oscillator is divided by four by the binary counters and formed into a 60-Hz capstan-motor drive signal, in exactly the same manner as is the tonewheel pulse during recording.

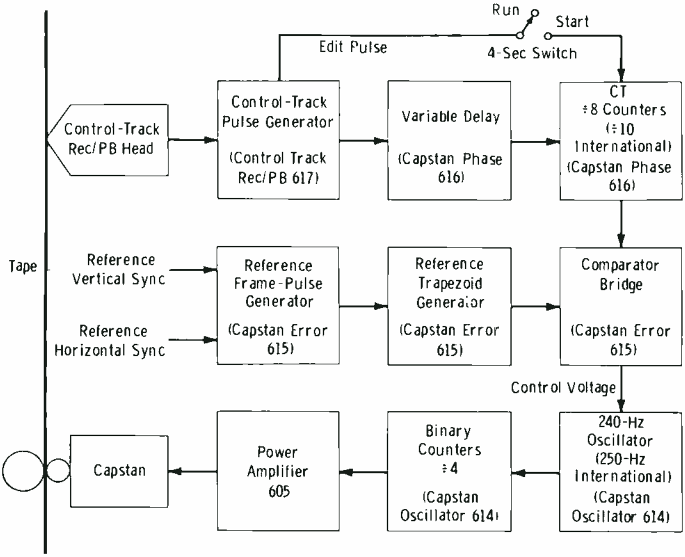


Fig. 7-20. Capstan servo system for playback in tonewheel mode.

The error signal which modifies the local-oscillator frequency to correct the tape speed is generated from the phase comparison of a pulse derived from the playback control-track signal and a trapezoid waveform derived from the reference frame pulse, which in turn is derived from local (reference) sync. The 240-Hz control-track signal is played back from the tape by the control-track record/playback head and is amplified, limited, and formed into a series of 240-Hz pulses. The 240-Hz pulse frequency is then divided by eight (by ten in international machines) by a binary counter chain to obtain a series of 30-Hz pulses (25-Hz, international). These pulses sample the slope of the reference trapezoid waveform to obtain the error signal. Local (reference) horizontal- and vertical-sync signals are combined in a coincidence gate circuit to form pulses at the frame rate, and the reference frame pulses thus formed generate the reference trapezoid waveform. Therefore, as the tape speed increases or decreases, the control-track pulse frequency follows this change, and the error signal generated causes the capstan motor speed to increase or decrease until the divided frequency of the control-track pulses coincides with that of the reference frame pulses (i.e., the capstan motor speed is locked to the reference pulse frequency).

During the first four seconds after the PLAY push button is pressed, control-track frame pulses (edit pulses), if present on the control track, are used to reset the binary counters which divide the frequency of the 240-Hz control-track signal. This permits achieving coarse framing (approximate alignment of tape vertical sync with local vertical sync) before the vacuum-guide air solenoid is activated and video is obtained, since the control-track head is already in contact with the tape. Application of the edit pulses to the binary counters is controlled by the fast lock-up capstan circuit, which consists of a relay controlled by multivibrators. Although this circuit is active during the first four seconds of playback regardless of the mode of servo operation, it is primarily useful in the Switchlock, Pixlock, and Linelock modes. In the tonewheel mode, after the relay disconnects the edit pulses at the end of the four-second interval, the binary counters are no longer reset. Therefore, if framing is lost because of a disturbance, it will not be regained, although the frequency-divided control-track pulses will relock with the reference frame pulses. This is considered normal for the tonewheel mode, since framing is not a requirement.

Provision is made for continuous manual variation of control-track phase over a very wide range. Manual phasing is accomplished by varying the CT PHASE control on the play control panel, which in turn varies a delay inserted into the control-track pulse path. (The CT PHASE control has two ranges: a wide range for coarse phasing and a much narrower range for fine phasing.) The basic purpose of the manual delay is to provide a means of precisely centering the video heads over the recorded video tracks. In the tonewheel mode of servo operation, the CT PHASE control may also be utilized in "slipping tracks" so that video head 1 will play back information from the video track containing vertical sync (which is normal operating procedure in the RCA system) or from any of the three remaining tracks. Provision is also made for manual control of the capstan motor speed, and thereby of the tape speed, during playback by interrupting the error signal fed to the 240-Hz local oscillator and inserting a constant dc current. The constant dc current is inserted by pressing the red (to speed up the tape) or black (to slow down the tape) CAP-

STAN SPEED button on the play control panel. This feature is useful for synchronizing two machines which are playing back the same information.

In the Switchlock and Pixlock modes of servo operation, the capstan servo operates as in the tonewheel mode except that when the edit pulses are disconnected from the binary counters at the end of the initial four-second interval, the edit pulses are replaced by tape frame pulses (Fig. 7-21). (If no edit pulses are on the tape, or if they are of poor quality, tape frame pulses are fed to the counters as soon as they are available.) Use of the tape frame pulses for resetting the counters ensures that the headwheel will be on the track containing vertical sync at the end of a recorded frame when the corresponding vertical interval of local sync occurs. This degree of control, designated coarse framing, or Switchlock, brings tape and local (reference) vertical sync close enough together to permit roll-free switching between the tape-machine output and another video source, or to permit electronic splicing. (In the Pixlock mode of servo operation, a finer degree of framing, which corrects for errors in

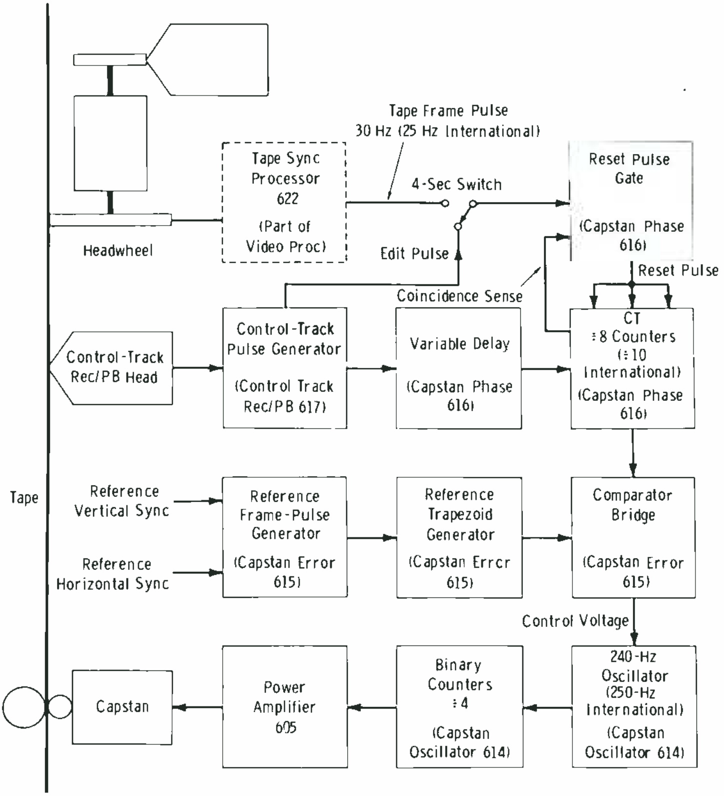


Fig. 7-21. Capstan servo system for playback in Switchlock or Pixlock mode.

placement of vertical sync on the tracks, is achieved by utilizing the tape vertical alignment [tva] circuit in the headwheel servo.)

Eight 240-Hz control-track pulses (or ten 250-Hz pulses on 405/625-line international standards) are fed to the binary counters per frame, but only a particular one of these eight (or ten) pulses occurs when the headwheel is on the track containing vertical sync at the end of a frame. Use of the reset pulse ensures that the single output pulse provided by the binary counters during each frame coincides with this particular control-track pulse. If no reset pulse were applied (as in the tonewheel mode after the initial four seconds), there would be only one chance in eight (or ten) of obtaining this condition, since the counter output pulse could coincide with one of the other control-track pulses occurring during the frame period. Consequently, there would be only once change in eight (or ten) of achieving coarse framing (Switchlock).

The tape frame pulse utilized in resetting the counters is developed from tape vertical and tape horizontal signals in a coincidence gate circuit. If the tape and reference frame pulses are aligned when the machine enters the Switchlock mode of servo operation, the reset pulse will have no effect on the binary counter circuits. However, if the frame pulses are not aligned, the reset pulse will reset the binary counters and thus cause the machine to "shift tracks" until sync alignment is attained.

During tape playback in the Switchlock or Pixlock mode of servo operation, the CT PHASE control may be utilized for precise centering of the video heads over the recorded video tracks as it is during playback in the tonewheel mode. In the Switchlock or Pixlock mode, it is not possible to use the CT PHASE control to "slip tracks" as it is during tonewheel operation; however, the need for "slipping tracks" is eliminated by the fact that it is possible to "shift heads" by utilizing the HEAD SELECT switch on the reference generator module in the headwheel servo system.

Linelock—The initial phases of Linelock operation are identical to those of Pixlock operation, but once the switch to the final, or "lock," phase occurs in the headwheel servo system, the framing requirement is dropped by (1) disconnecting the tape frame pulses from the binary counters in the capstan servo system and (2) switching the reference for the capstan trapezoid from reference frame pulses to pulses derived by dividing the frequency of the tonewheel pulses by eight (or ten on international standards). Refer to Fig. 7-22. This action leaves the capstan free to follow changes in headwheel phasing (which occur after disturbances), thereby maintaining the tracking adjustment made with the CT PHASE control. The changes in headwheel phasing occur after a disturbance that causes loss of Pixlock, because the Linelock circuits in the headwheel servo system lock the tape horizontal sync to a noncorresponding line of local (reference) horizontal sync.

The tonewheel divide-by-eight pulses are obtained from binary counter circuits in the tonewheel servo module. These counters, which are similar

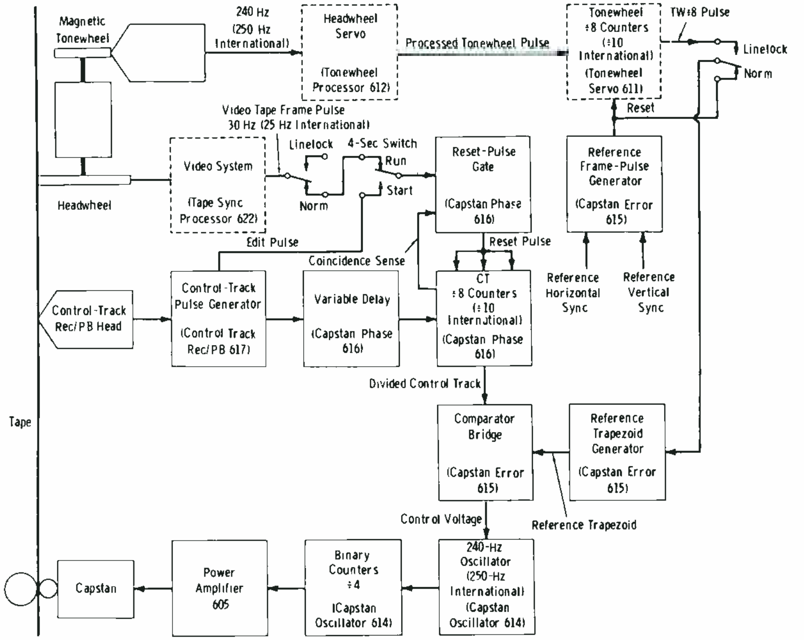


Fig. 7-22. Capstan servo system for playback in Linelock mode.

to the control-track pulse counters in the capstan servo system, are reset by the reference frame pulses so that the divide-by-eight pulse coincides with the tonewheel pulse closest to the reference frame pulse. This eliminates picture disturbances during the transition period after the capstan-servo reference is switched from reference frame pulses to tonewheel divide-by-eight pulses.

When the headwheel phasing changes, the tonewheel-pulse counting speed will vary depending on the direction of change, but the counter output will remain properly phased with respect to the reference frame pulse. If the headwheel speed increases, the counters will count tonewheel pulses faster, and the capstan motor speed will increase until the frequency-divided control-track pulses are again locked to the frequency-divided tonewheel pulses.

Splice Modes—In machines equipped with the accessory electronic splicing feature (Chapter 10), the capstan servo system operates as previously described except when an insert or add-on splice recording is being made. (In an insert splice recording, the video on a section of a previously recorded tape is erased and new material is recorded in its place, leaving portions of the originally recorded video immediately preceding and following the newly recorded section. In an add-on splice recording, however, the new material is added at the end of the original recording.) As far as the capstan servo system is concerned, the essential difference between the insert and add-on mode of splice operation is as follows: In the insert mode, the capstan servo system operates as during normal tape playback, and the previously recorded control track is not erased but is allowed to remain on the tape. In the add-on mode, the capstan servo system operates as during normal tape recording, and the original control track (if any) is erased so that a new control track may be recorded.

In either type of splice recording, the capstan servo must be controlled so that no sudden change in tape speed occurs at the junction of the old and new recordings, and the tape speed during recording will be the same as during playback. These results cannot be obtained by driving the capstan motor with a signal derived from the frequency-divided tonewheel pulses, as in normal recording, since the tonewheel pulses provide no indication of the actual tape speed present when the old recording was made. Therefore, during a splice recording, the capstan is driven, as in playback, with a signal obtained by dividing the frequency of the output from the 240-Hz oscillator. The method of controlling the oscillator frequency depends on whether an insert or add-on splice recording is being made.

For an insert recording, the control-track signal previously recorded (at the same time as the old video signal) is already present along the entire length of tape, and this signal contains precisely the desired information regarding the speed of the old recording. Therefore, instead of erasing the old control track and recording a new one as the new video information is being recorded, the old control track is retained and used, as in Switchlock operation, to derive an error signal which controls the frequency of the oscillator. Operation of the entire capstan servo system during insert splice recording is actually identical to Switchlock playback except that the reset-pulse gating circuits for the control-track binary dividers are disabled so that the binary counters cannot be reset by noise pulses during the record interval of the electronic splicing process.

In an add-on splice recording, the section of tape on which the new video recording is to be made may not already contain a recorded control-track signal, since this section begins at the end of the old recording. Therefore, a new control track must be recorded, as in normal record operation. During the transition from playback to recording, the frequency of the capstan oscillator (and thus the capstan motor speed) is controlled by an adjustable dc voltage from a capstan memory circuit, instead of by an error signal. The dc voltage is related to the original recording speed by adjusting a potentiometer on the splice logic module while playing back the originally recorded section of the tape before starting the add-on recording. For testing the potentiometer adjustment, a momentary-contact toggle switch on the splice logic module controls a relay which permits opening the capstan servo loop and temporarily delegating control of the oscillator to the capstan memory circuit while the machine is in the splice play mode.

> NOTE: Before a splice recording is made, the machine must be playing back tape in the splice play mode, the selector switch on the tape sync processor module must be in the SL position, and Switchlock operation must actually be achieved.

7-5. THE CONTROL-TRACK RECORD AND SIMULPLAY WAVEFORMS

The great difference between the control-track record and playback waveforms was mentioned in the preceding section. This difference will be examined in more detail now.

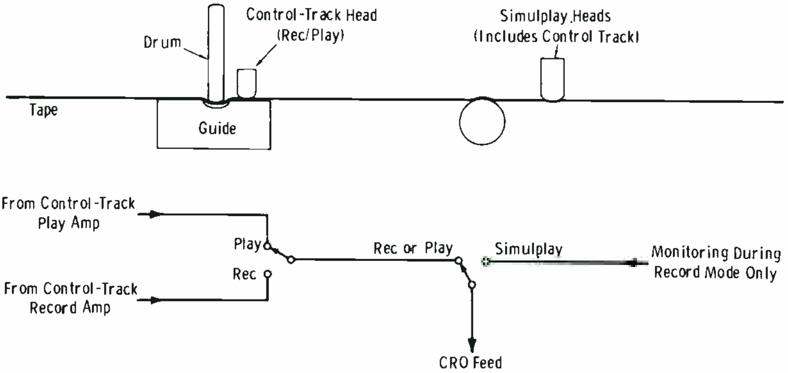
Note from Fig. 7-23A that the control-track head is adjacent to the headwheel (it is actually mounted on the vacuum guide) and that farther down the line is a stack containing simulplay heads. This stack includes a control-track monitoring head to show that a control track is actually being recorded while the machine is in the record mode. In the record mode, either the control-track record waveform (waveform B in Fig. 7-23B) or the control-track playback waveform (C) can be monitored. The question always arises as to why this playback waveform results from a sine-wave recording signal.

Before we continue, let us emphasize a point. In the playback mode, the same control-track head that made the control-track recording is being used. When you monitor control-track playback in the playback mode, you are seeing the signal as it comes from the regular control-track head on the vacuum guide. This signal *also* looks like waveform C. But, the only time you see a signal from the simulplay control-track head is in control-track playback monitoring during the recording mode.

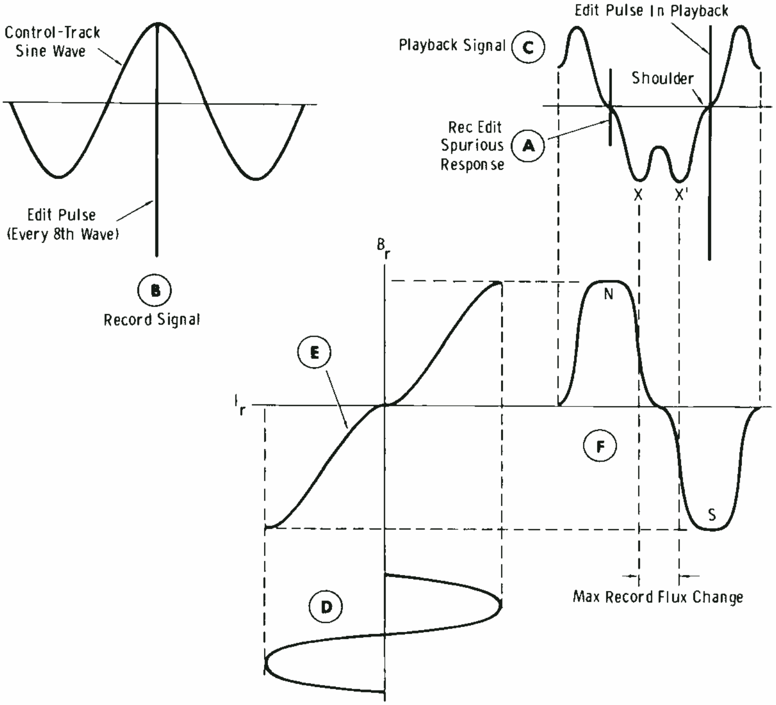
The proper amplitude of control-track signal in the recording head is that which drives the tape to the verge of saturation. Therefore, while the system is recording, the control-track record amplitude should be brought up (while the *simulplay head* signal is being observed) until the "shoulder" appears, indicating the verge of saturation. See waveform C in Fig. 7-23B.

Now let us see what is actually happening. The sinusoidal record current (waveform D) is applied to the control-track head. The transfer characteristic of magnetic tape is nonlinear, as shown by the B_r-I_r curve (E). The flux density recorded is shown at F. Note that the zero axis of the recording current (waveform D), since it corresponds to the most rapidly changing area, results in the maximum recorded flux change of waveform F. The *peaks* of waveform F correspond to maximum flux of the indicated polarity (north or south).

Now refer to the playback *voltage* waveform (C). The region of maximum recorded flux of waveform F, which is on the verge of saturation, results in the zero axis of the playback voltage. The "shoulder" of waveform C shows the verge of saturation on the peaks of waveform F.



(*A*) *Head functions.*



(*B*) *Waveforms.*

Fig. 7-23. Control-track record and playback waveforms.

The points on waveform C corresponding to maximum flux change in waveform F are points X and X′. The "hump" between these points is the result of the nonlinear transfer characteristic (curve E) of the tape. The edit pulse, since it is made to occur at maximum flux, appears at the zero voltage axis of waveform C.

Notice the "spurious pulse" occurring at point A on waveform C. (In some systems, this pulse might be located immediately to the left of the larger-amplitude playback pulse.) This is nothing but cross talk between the actual recording head and the simulplay head. It occurs only during the record mode. Any noticeable drift in this spacing during the record mode is an excellent indication of jitter that occurs during the recording process.

Please bear in mind that the audio and control-track simulplay heads are only indicators that the signals are being recorded on the tape. In normal playback operation, the control-track and audio *recording* heads are used to play back the signals, so that proper timing is maintained. Therefore, these heads are properly termed "record-play" heads.

7-6. THE RCA HEADWHEEL UNLOCK (HW UNLOCK) INDICATOR

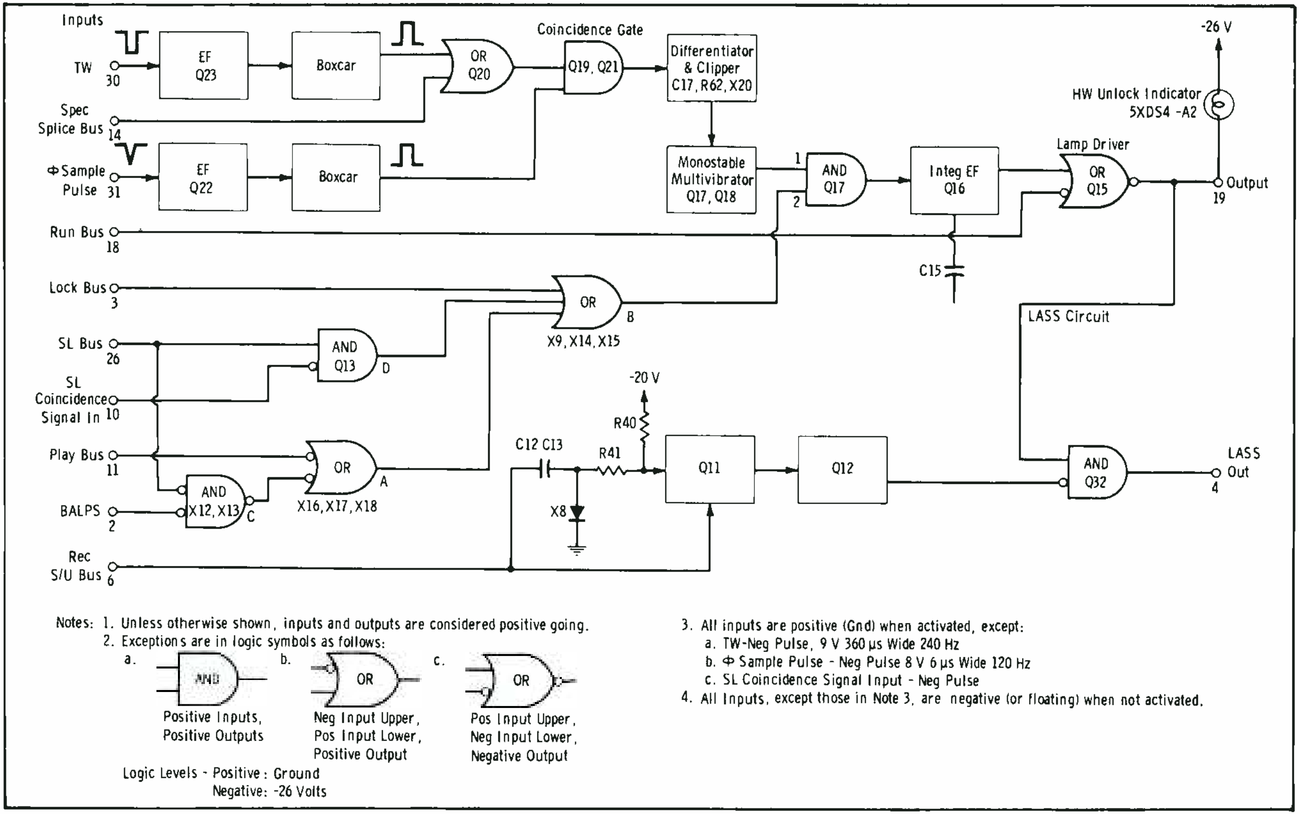
Another function in need of some explanation is the warning indicator on the RCA TR-70 designated as the HW UNLOCK light.

> NOTE: It is absolutely imperative that the reader have a background in logic circuitry at least equivalent to Chapter 3 of *Television Broadcasting: Systems Maintenance,* by Harold E. Ennes (Indianapolis: Howard W. Sams & Co., Inc., 1972).

The HW UNLOCK indicator alerts the operator whenever the headwheel drops out of the lock condition. It is driven by the HW UNLOCK indicator circuit (Fig. 7-24) and warns that not all the conditions required to satisfy a particular servo mode have been met. The lamp circuit is operative only when the run bus (pin 18) is activated (grounded). This occurs in any of the modes in which the headwheel is running, i.e., during record, set-up, wind, standby, and any one of the playback modes.

When the machine is first turned on, the circuit is inoperative. Placing the machine in any of the above run modes causes the HW UNLOCK lamp to light, indicating that the headwheel has not yet come up to the proper speed. Once the headwheel achieves correct speed and is locked in, the indicator lamp will go out. Should the headwheel go out of lock for more than 0.1 second, the HW UNLOCK lamp will light again.

A logic block diagram of the HW UNLOCK indicator circuit is shown in Fig. 7-24. It illustrates the conditions required to extinguish the light. Wherever AND and OR gates are shown, a small circle at the input or output means that a negative (or low) input or output will satisfy the con-



Notes: 1. Unless otherwise shown, inputs and outputs are considered positive going.
2. Exceptions are in logic symbols as follows:
a. Positive Inputs, Positive Outputs
b. Neg Input Upper, Pos Input Lower, Positive Output
c. Pos Input Upper, Neg Input Lower, Negative Output

Logic Levels - Positive: Ground
Negative: -26 Volts

3. All inputs are positive (Gnd) when activated, except:
a. TW-Neg Pulse, 9 V 360 μs Wide 240 Hz
b. Φ Sample Pulse - Neg Pulse 8 V 6 μs Wide 120 Hz
c. SL Coincidence Signal Input - Neg Pulse
4. All Inputs, except those in Note 3, are negative (or floating) when not activated.

Fig. 7-24. Logic block diagram of HW UNLOCK indicator circuit.

ditions of the gate. Lack of a small circle indicates that a positive (high—ground potential, usually) input or output level will satisfy the conditions of the gate.

Operation of the basic circuit is as follows: Tonewheel (TW) pulses from the tonewheel processor module, and tonewheel phase-sample pulses from the reference generator module are fed through emitter followers Q22 and Q23 to transistors Q19 and Q21. These transistors form a coincidence gate and are normally conducting heavily. With the arrival of a negative-going TW pulse and a negative-going phase-sample pulse in coincidence, the gate is opened, and a positive-going output pulse is obtained at the collectors. This pulse, differentiated and clipped, is fed as a trigger to monostable multivibrator Q17-Q18. The positive-going square wave at the collector of Q17 is applied to an integrator emitter follower stage, Q16. The resulting integrated waveform fed to the base of lamp driver Q15 is sufficient to cut off Q15 (which is normally saturated) and prevent the HW UNLOCK indicator lamp from lighting.

A loss of coincidence between the TW pulses and the phase-sample pulses would cause no trigger to be fed to the base of transistor Q18, and no square wave would be fed from the multivibrator. The charge on capacitor C15 would fall (go more negative), transistor Q16 would conduct, providing bias current for Q15, and the light would be switched on. However, transistor Q17 also functions as an AND gate and Q15 as an OR gate. A discussion of the conditions necessary to fulfill the requirements of these gates is given below.

As mentioned above, the logic block diagram illustrates the conditions required to extinguish the light. In the stop mode, it will be extinguished because the run-bus input to the Q15 OR gate will be low. It will be out in any run mode because the other input to the Q15 OR gate will go high when the inputs to the Q17 AND gate have been satisfied by the appropriate lock conditions.

In all run modes (with one exception to be described later), coincidence of the TW pulse and the phase-sample pulse is required to provide a high level to input 1 of the Q17 AND gate. Coincidence of these pulses is indicative of tonewheel lock and is a necessary, but not sufficient, condition to assure that all the requirements of a particular servo mode have been met. Input 2 to the Q17 AND gate supplies the remaining conditions, involving somewhat more complex logic, as shown in the diagram. These conditions are described by modes below.

Record, Set-up, Standby, and Wind Modes

In the record, set-up, standby, and wind modes, input 2 to the Q17 AND gate is high because the play-bus input to OR gate A is low. This produces a high output to OR gate B, which in turn produces a high output. Essentially, a tonewheel lock is the only requirement to extinguish the light in these modes.

Tonewheel Playback Mode

If the tonewheel mode of servo operation has been selected in playback, the Switchlock (SL) bus and the bus asking for Linelock/Pixlock servo (BALPS) inputs to AND gate C will both be low. Therefore, the output from AND gate C to OR gate A will be low, producing a high output to OR gate B, which in turn produces a high output to AND gate Q17. In this mode also, tonewheel lock is the only requirement to extinguish the light.

Switchlock Playback Mode

If Switchlock has been selected as the playback mode, the requirements for lock are dependent on whether the Electronic Splicing Accessory is installed in the machine and whether a splice mode has been selected.

Switchlock With Splice Modules Not in Machine—In this mode, the SL bus input to AND gate D will be high, and the SL coincidence signal input to AND gate D will be an open circuit (equivalent to low). Therefore, the output of AND gate D will be high, and the output of OR gate B to AND gate Q17 will be high. Tonewheel lock is the only requirement to extinguish the light.

Switchlock with Splice, Normal Insert or Add-On Modes With Fixed TW Selected—When the splice modules are in the machine, a coincidence detector in the splice logic module generates a signal which indicates when the reference vertical and tape vertical pulses are coincident. Therefore, although the SL bus is high, the SL coincidence signal input to AND gate D will not go low until coincidence has been achieved. This will normally occur after tonewheel lock has already been achieved. Consequently, tonewheel lock and vertical coincidence are required to extinguish the light.

Switchlock with Splice, Add-On or Insert Mode With Variable TW Selected—When one of the splice modes has been selected, delays are inserted in the reference and signal paths of the tonewheel servo to allow a controllable adjustment of the phase of the servo relative to the reference. This has the effect of moving the phase of the tonewheel-phase sample pulse relative to the undelayed tonewheel pulse so that they are not coincident when a headwheel lock has been achieved. Therefore, for this mode only, the necessity for coincidence is removed by energizing the special splice bus, which produces a high input to OR gate Q20. This will produce a high input to AND gate Q17 as long as the tonewheel-phase sample pulses are present, regardless of any coincidence. The other input to AND gate Q17 still requires vertical coincidence, as described above, to extinguish the light.

Pixlock Playback Mode

The Pixlock playback mode requires that the lock-bus input to OR gate B go high, which produces a high output to input 2 of AND gate Q17. The logic driving the lock bus is contained within the servo modules and requires that the Pixlock playback mode be selected and vertical coincidence be achieved.

Linelock Playback Mode

In the Linelock playback mode, the requirements for extinguishing the light are the same as for the Pixlock mode; i.e., the lock bus goes high and tonewheel coincidence is achieved. However, the logic within the servo modules which drive the lock bus is changed. During initial start-up of the machine, operation is identical to the Pixlock mode. When vertical coincidence is achieved, the lock bus goes high. However, should vertical coincidence not be achieved for some reason, the lock bus still goes high, after an 8-second delay. After initial lock is obtained, whether by achieving vertical coincidence or by the 8-second delay, the lock bus will remain high until the machine enters the stop mode. Thereafter, headwheel unlock will be indicated only by the loss of tonewheel coincidence.

Lazy Simulated Servo (LASS Control)

The lazy simulated servo (LASS) control circuit, consisting of transistors Q11, Q12, and Q32, is initiated by the HW UNLOCK indicator circuit and is operative only in the record mode. Under normal conditions during the record mode, the HW UNLOCK indicator output will have no effect. However, when a loss of coincidence between tonewheel pulses and tonewheel-phase sample pulses occurs during any of the run modes, transistor Q15 is switched on and its collector rises toward ground. Normally, transistor Q32 is biased on, and this change in potential is coupled out of the indicator module to the tonewheel servo module where it activates a relay, reducing the phase gain of the tonewheel servo during the interval of headwheel unlock, in record only.

When the machine is initially placed in the record mode, ground level appears at pin 6, and consequently at the emitter of Q11 and at capacitors C12 and C13. While the headwheel motor is coming up to normal speed, transistor Q11 is held off (approximately 4 seconds) by the positive level change coupled through capacitors C12 and C13. Transistor Q12 is then biased on, biasing Q32 off and preventing a level change from appearing at pin 4. After approximately 4 seconds, transistor Q11 turns on, biasing Q12 off and Q32 on, thereby allowing a level change to be coupled out of pin 4.

7-7. THE VACUUM-GUIDE SERVO

The function of the vacuum-guide servo system (formerly termed "shoe" servo), shown in simplified block-diagram form in Fig. 7-25, is to control the position of the vacuum guide with respect to the rotating headwheel. The position of the guide is one of the factors determining the compatibility of playback between tapes recorded by video heads that have different degrees of wear from one machine to another. Thus the operation of the guide servo in maintaining the proper guide position during tape recording and playback is of great importance.

Essentially, the guide servo system consists of the guide servo module (No. 506), the guide actuating mechanism (located behind the headwheel panel), and the manually operated guide positioning control utilized optionally during tape playback (located on the play panel). The guide servo module contains the electronic circuitry which controls the guide servo system. Operational controls located on the module front panel include the guide positioning control, which may be utilized prior to recording; the record control switch, which allows selection of a fixed or manually preset guide-position reference during recording; and the playback control switch, which allows selection of manual or automatic guide positioning during tape playback. The guide actuating mechanism consists of a two-phase motor coupled through reduction gears to the headwheel panel and the vacuum guide.

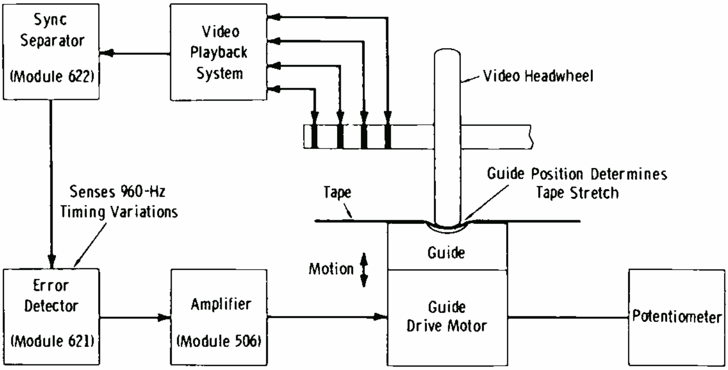
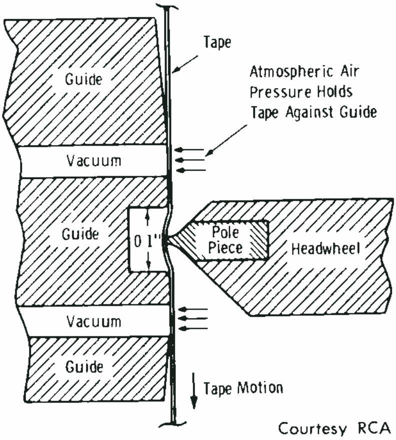


Fig. 7-25. Simplified diagram of guide servo system.

Fig. 7-26 shows a cross-sectional view of the vacuum guide and headwheel, indicating tape stretch due to indentation caused by the video magnetic heads. As the headwheel rotates, the video magnetic heads (protruding beyond the headwheel rim by approximately 1.0 to 3.2 mils, depending on video-head wear) cause the tape to stretch in a localized indentation which travels across the moving tape. This stretching of the tape is essential to correct for minor dimensional variations resulting from video-head wear, differences in machines, and minute expansion or contraction of the tape. In recording, the guide position is normally fixed at a calibrated setting for the particular headwheel panel in use. This ensures the application of a constant pressure between the tape and the video heads, thus resulting in a fixed degree of tape stretch throughout each re-



Courtesy RCA

Fig. 7-26. Cross section of vacuum guide and headwheel.

cording. (The vacuum-guide position may be preset prior to recording, by means of the RECORD GUIDE POSITION control on the front panel of the guide servo module, if other than standard guide pressure is desired.)

> NOTE: The SMPTE test tape (MI-40793 for 525-line standards, MI-40797 for 625-line standards) is used for comparison in playback to determine the proper tape stretch.

To attain optimum machine performance during tape playback, the relative head-to-tape speed must be held constant. The factors which determine the relative head-to-tape speed are the angular velocity of the headwheel and the position of the vacuum guide. The angular velocity of the headwheel is maintained at a constant value by the headwheel servo system; thus, angular timing errors are eliminated. However, unless the vacuum-guide position is tightly controlled, timing errors which cause certain geometric distortions in the picture will occur.

One form of geometric distortion is caused by time-displacement errors which appear in the form of discontinuities at the instant of video-head switching. This form of distortion occurs when the "parallel alignment" of the guide center and headwheel axis is incorrect (i.e., when the pressure of the video heads against the tape is insufficient or excessive). Distortion of this kind is designated "jogs" or "skew," and is shown in Fig. 7-27. Insufficient head-to-tape pressure causes jogs having a positive slope, whereas excessive head-to-tape pressure causes jogs having a negative slope. If a pulse train containing the timing discontinuities is applied to a horizontal oscillator having a "flywheel" time constant slightly greater than the 16-line head-scanning interval, a uniform train of average-frequency pulses is produced in which the timing variations are eliminated (Fig. 7-28). The synchroguide and similar circuits in television receivers, and hence the horizontal-deflection circuits, respond similarly.

However, timing errors in blanking and picture information remain, and these errors cause the jogs mentioned above. The function of the guide servo system during playback, therefore, is jog correction. This correction may be accomplished manually or automatically, depending on the selected conditions for the machine.

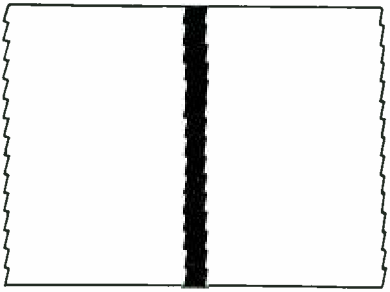


Fig. 7-27. Effect of 1-mil guide error on television raster.

Another form of geometric distortion which may appear in the picture occurs when the "perpendicular alignment" of the guide center and head-wheel axis is incorrect (i.e., when the head-to-tape pressure varies as a video head scans the moving tape). This form of geometric distortion is designated "scalloping," and its correction is entirely mechanical. (A third form of geometric distortion, appearing in the picture as steps, is due to

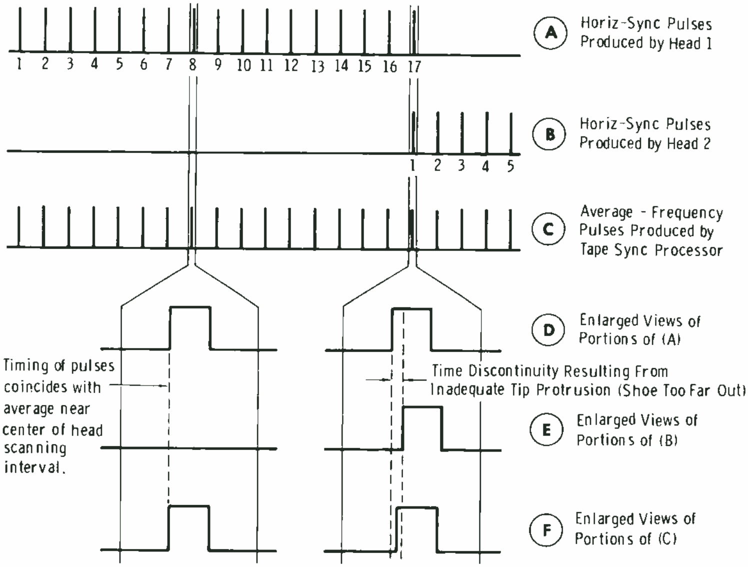


Fig. 7-28. Timing errors resulting from shoe position errors.

slight errors in the physical placement of the video heads around the circumference of the headwheel.)

Movement of the vacuum guide is controlled by a mechanical linkage from a two-phase induction motor. In the play or record mode, the reference winding of the motor is continuously excited by the power-line voltage, and the control winding is driven by an error signal. Therefore, the motor shaft normally remains stationary, and it develops torque in one direction or the other only in response to an error signal. (The direction of the torque, and thus the direction of the motor-shaft rotation, is determined by the phase relationship between the 50- or 60-Hz voltages applied to the reference and control windings.) The error signal may be developed manually (during tape playback or prior to recording) or automatically (during playback only). If the guide position is controlled manually, the error signal is developed when a voltage unbalance exists between the center arms of two potentiometers. One of the potentiometers is geared to the guide-motor shaft. During playback, the second potentiometer is the GUIDE POS control on the play panel; prior to recording, the second potentiometer is the RECORD GUIDE POSITION control on the guide module. If the guide position is controlled automatically (possible during playback only), the error signal is developed in the video and sync processing system whenever the tape horizontal-sync frequency varies from the standard line frequency (15,750 Hz in machines operating on 525-line standards with a 60-Hz field rate).

When guide-motor torque is developed, it causes a lead screw to move in or out (depending on the direction of the torque). The lead screw acts as a stop against which the guide control arm rests when the guide solenoid is activated. The extension of the lead screw therefore determines the position of the vacuum guide and thus the pressure exerted on the tape by the video heads. The guide solenoid is actually a pneumatically operated piston activated by an air valve which is in turn controlled by a relay. The air-valve relay is driven by a signal from the vacuum-guide diode matrix board. The vacuum-guide solenoid logic circuit requires that both a headwheel velocity lock and a play or record command be present before the solenoid driver permits the guide to engage. Therefore, the vacuum guide will engage only when the play or record push button has been pressed and the headwheel motor has come up to speed (as evidenced by the velocity-lock-sense control-bus potential developed in the tonewheel servo module). Thus, it may be seen that if the machine is operated in the set-up, standby, or wind mode, or if the headwheel motor fails to lock in properly during tape playback or recording, the guide solenoid is deactivated, and the vacuum guide is held away from the tape to prevent possible damage to the headwheel and magnetic heads.

An additional precaution is taken to guard against headwheel and magnetic-head damage when tape is being played back with the guide position controlled automatically. This precaution consists of circuitry in the internal reference module which detects an afc lock. The output from this circuit controls a relay which provides a ground potential when the afc lock is attained. The ground potential, fed to the guide servo module, allows the guide to operate normally in the automatic mode. However, if an afc lock has not been attained or is lost during playback, ground is removed, and the guide automatically reverts to a manually preset safe position. This precaution is important, since an erratic error signal may cause excessive tape pressure against the headwheel.

To prevent the guide from "hunting," or oscillating, during normal (nonsplice) recording, the guide motor is disabled following an initial delay of several seconds that allows the guide to reach its proper position. If the machine is equipped for electronic splicing, during the splicing operation the guide motor is disabled immediately when the RECORD button is pressed; thus, there will be no change in guide position when the switch from splice play to splice record is made.

In both the Ampex and RCA vacuum-guide servo systems, the circuits represent an adaptation of a standard servo system designed for a variety of positioning applications. The main output device for the system is a motor that normally remains stationary and moves only slightly in one direction or the other in response to error signals. In general, the motor automatically seeks to position itself so as to keep the error signal at zero.

The error-detector circuit tuned to 960 Hz (Fig. 7-25) is used to sense the presence of timing variations at the head-switching rate. The polarity of the 960-Hz signal developed in this circuit indicates the direction of the timing errors. In the circuitry of the guide-servo chassis, the 960-Hz signal is amplified, clipped, and rectified. To preserve the direction sense in the error signal, the rectifier is a bidirectional type, utilizing 960-Hz clamping pulses derived from the tonewheel attached to the headwheel motor. The clipping is severe enough that if there is any significant error signal at all, the rectifier produces a fixed dc level of a polarity indicating

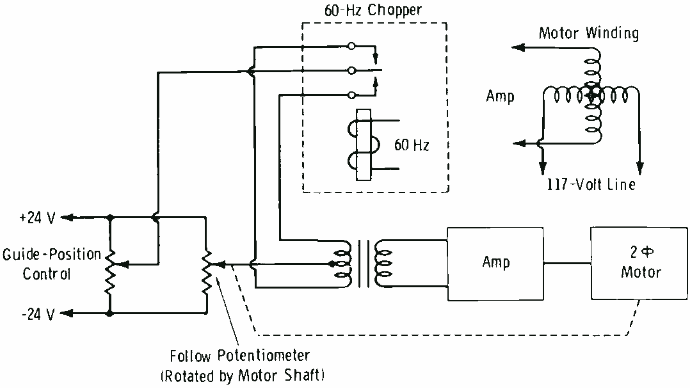


Fig. 7-29. Basic operation of tape-guide servo.

the direction of the error. The rectifier error signal is converted to 60-Hz ac by the action of a chopper-type modulator (Fig. 7-29) and then amplified to the power level necessary to drive the guide-positioning motor. The motor is a two-phase type in which one phase is continuously excited by the power line, while the other is driven by the amplifier. The motor develops torque only when a signal is delivered by the amplifier; the direction of this torque depends on the polarity of the amplifier signal. The motor then drives the guide through an appropriate mechanical coupling. The motor movement is limited to only a few revolutions, and the maximum displacement required for the guide is only about 5 mils. The servo loop is completed through the video heads, slip rings, video-playback system, and a sync separator (Fig. 7-25).

A much smaller servo loop is used for manual positioning of the guide during recording operations and during special cases of playback operation. For manual operation, a potentiometer on the motor shaft is compared with the setting of a second potentiometer, which is mounted on the control panel (Fig. 7-29). The motor turns until the voltage at the arm of the motor potentiometer (follower) is the same as that on the manual guide-position control, resulting in zero signal at the output of the chopper.

EXERCISES

Q7-1. Does the same head which records the control-track signal play back this signal in the playback mode?

Q7-2. How is the proper amplitude of the control-track recording signal determined?

Q7-3. Name the simulplay heads and give their functions.

Q7-4. How do you control which head records the vertical-sync interval?

Q7-5. How do you control which head plays back the vertical-sync interval?

Q7-6. Give the sequence of headwheel (drum) lock-up in going to the fully synchronous playback mode of operation.

Q7-7. (A) Give the sequence of capstan lock-up in going to the fully synchronous playback mode of operation. (B) What requirement for a synchronous operating mode is dropped when phasing is not required for special effects or mixing? (C) Why must the capstan reference be changed when going from A to B?

Q7-8. Define: (A) Edit pulse. (B) Control-track frame pulse, (C) Reference frame pulse. (D) Tape frame pulse.

Q7-9. When it is not required to mix other local signals with the tape signal output, is it necessary to have the servos under control of the local sync generator for color tapes?

Q7-10. In most recent tape systems, why is a trapezoidal waveform generally used instead of a sawtooth waveform?

CHAPTER 8

The Tape-Dropout Compensation System

The Color Dropout Compensator (DOC) eliminates or greatly reduces the effects of dropouts in tape-recorded television signals. A dropout is a brief reduction in the rf level of the reproduced fm carrier due to irregularities in the magnetic tape surface or due to dust or other foreign matter on the tape or magnetic heads. On the monitor, the loss appears as a distracting streak. Multiple dropouts can severely degrade the picture. The Color Dropout Compensator prevents such effects by replacing the missing information with stored luminance and color information from the previous scan line.

The reproduced video signal is continuously stored in the DOC by a delay system having a delay time equal to the duration of one scan line. So long as there are no dropouts, the recorder output is the nondelayed, direct video. If the reproduced rf carrier drops below a preset level, the delay system supplies the video signal, substituting information from the previous scan line for the missing information. Because of the similarity between successive scan lines, the viewer will not be aware of the substituted signal.

The delay system supplies the stored video on demand through a fast-acting switch circuit. A sensing circuit continuously monitors the reproduced rf and actuates the switch circuit whenever a dropout occurs. Since the detector is sensitive to loss of rf rather than video, the circuit is not actuated by "recorded-in" video dropouts. These appear when a duplicate is made from an original tape containing dropouts, unless a DOC was used during the dubbing process to remove them.

The difference between the Color DOC and a monochrome DOC is that the Color DOC correctly replaces the color information as well as the luminance information. If the complete video signal (including the color information) were delayed exactly one scan line and then inserted as substitution material for a dropout, the color signal would produce the wrong color as viewed on the monitor. This is because the color-subcarrier signal frequency (3.579545 MHz) is exactly 227½ times the horizontal line rate. Therefore, the color information is changed in phase 180° on each successive horizontal scan line. This makes it necessary to separate the luminance and color information, because the color signal must be phase inverted to correct for the color error introduced by the one-line delay.

8-1. THE RCA DOC SYSTEM

The color dropout compensation system, as installed in the RCA TR-70, is shown in Fig. 8-1. The system consists of the Dropout Compensator module (620), the dropout processor module (619), and a delay line (1A3). The dropout processor module utilizes a submodule board called the sample-pulse eliminator. This is installed in the ATC error detector module (623).

The dropout fm input to the dropout processor (from the fm equalizer module) is filtered and passed through an automatic gain-control stage. From here, the dropout fm is fed to the Dropout Compensator module, where dropout detection takes place. At the same time, video from the post-emphasis module (529) is fed to the video switch in the Dropout Compensator module. The video signal, after passing through the video switch, is fed simultaneously to a 63-microsecond delay line and back to the post-emphasis module. If no dropout is detected in the fm signal, video continues to pass uninterrupted through the video switch and back to the post-emphasis module. Thus, in the absence of a dropout, the subsequent video output of the post-emphasis circuit is unchanged.

If the fm signal level drops below a predetermined level, the Dropout Compensator module produces a dropout pulse. The fact that a dropout is detected in the fm signal indicates that the counterpart segment is missing from the post-emphasis video. The dropout pulse activates the video switch, causing it to interrupt the incoming video and to send to the post-emphasis module video from the preceding scan line, which is stored in the delay line. Thus the lost segment of video is replaced from the previous line of video.

The dropout pulse is also looped throughout the dropout processor module to the sync-channel video section in the post-emphasis module. This pulse, called the sync-dropout pulse, interrupts the sync-channel video, thus preventing noise caused by the dropout from triggering the sync circuits.

If the dropout takes place during horizontal sync, the sync-dropout pulse, after being applied to the dropout processor module, is stretched by two thirds of a line prior to being fed to the sync-channel video circuit. In this case, a coincidence detector triggers a generator which, in turn, produces a 42-microsecond pulse that is added to the existing dropout pulse. This stretched sync-dropout pulse eliminates horizontal sync plus

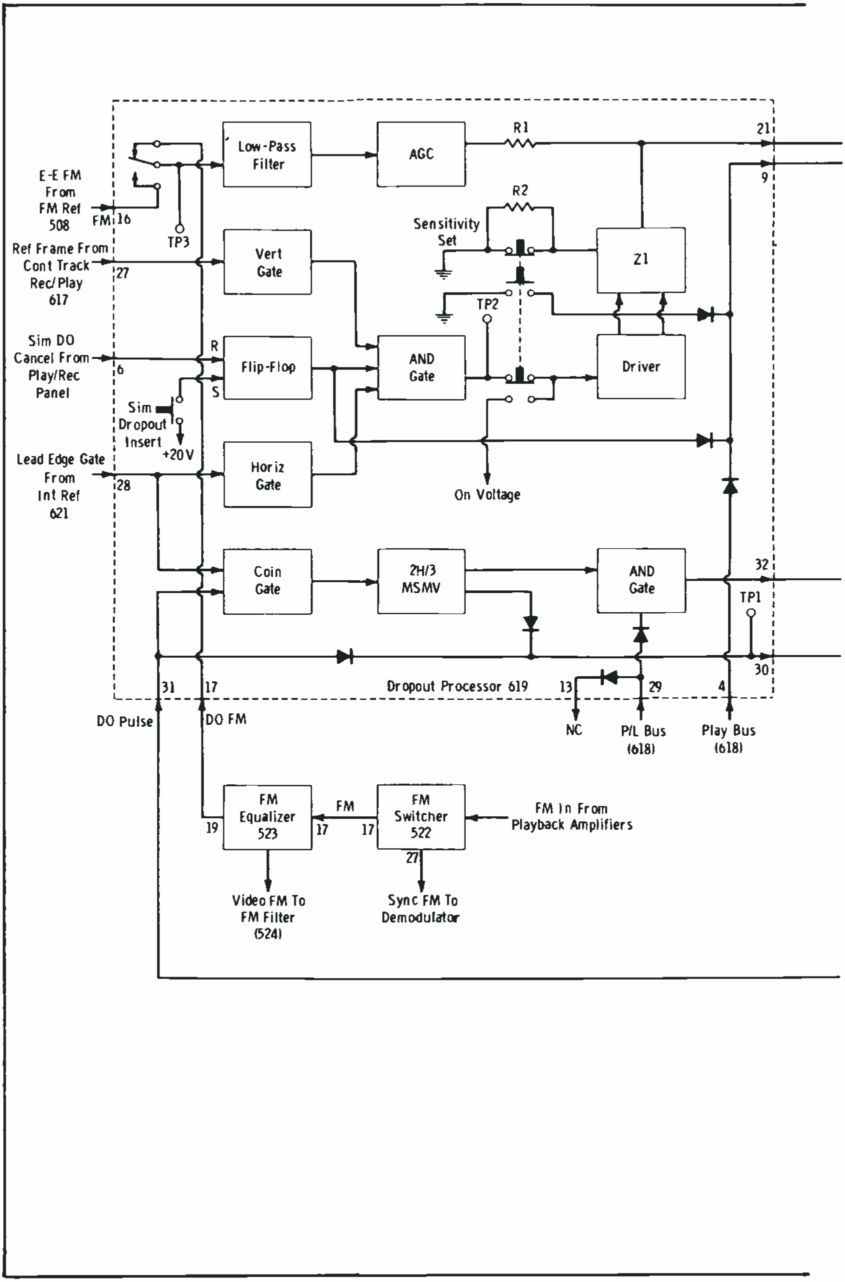
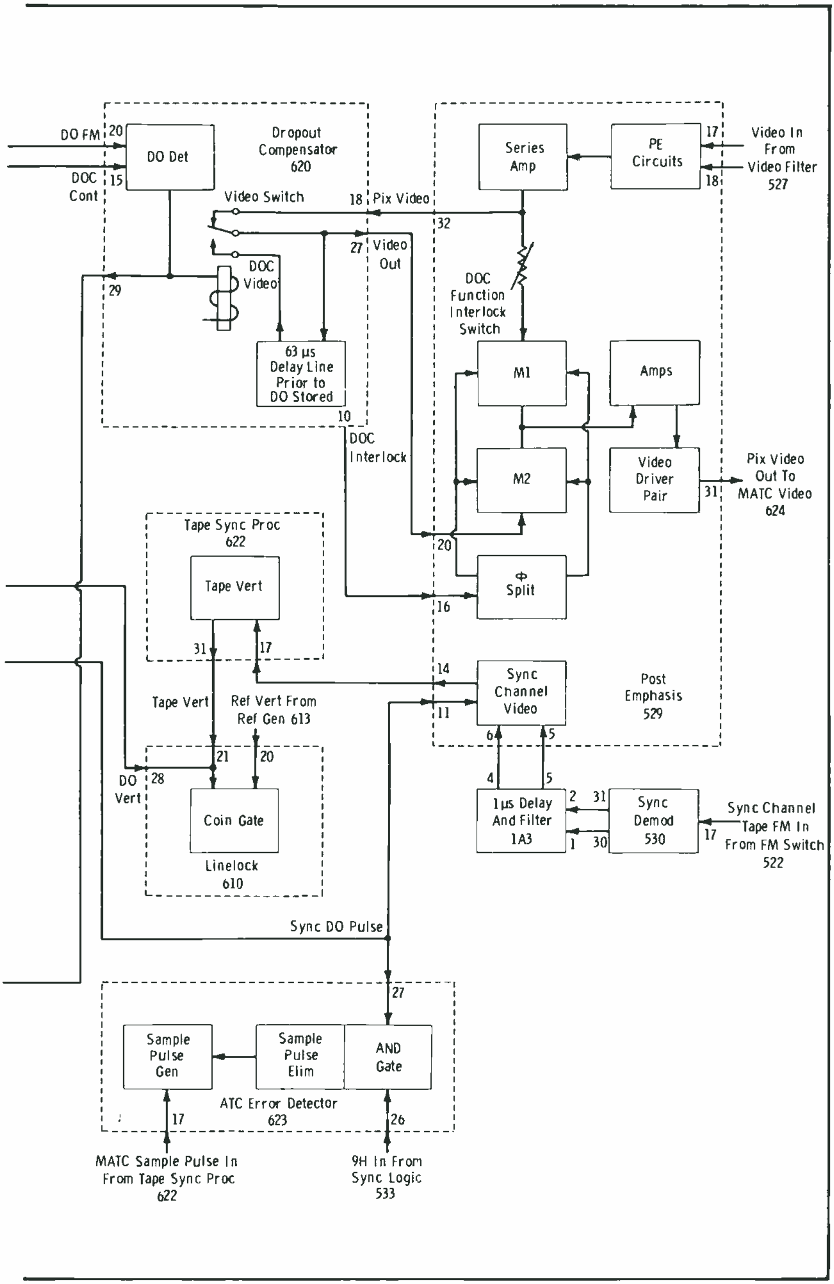


Fig. 8-1. Functional diagram



of dropout compensation system.

a half line of video. If the dropout pulse is derived at horizontal-sync time during the 9H interval, it will remove the succeeding equalizing pulse. The sync-dropout pulse is fed simultaneously to the sample-pulse eliminator in the ATC error detector module, along with the 9H pulse from the sync logic module. When coincidence between both of these pulses exists, ATC operation is suspended.

The same stretched pulse is used to drive a simulated vertical-sync pulse called the *dropout vertical.* The dropout vertical is fed to a coincidence gate (in the Linelock module) that controls the generation of vertical-timing pulses. When Pixlock is achieved, the dropout vertical serves as a substitute pulse in the event that the tape vertical-sync pulse, normally used in timing, is lost due to a dropout.

The delay line, 1A3, delays the sync video to allow time for the Dropout Compensator to sense dropouts. If this delay were not present, the leading edge of the dropout would be able to pass without compensation, and noise would appear in the picture. The passband of the delay line is limited to 2 megahertz, resulting in the elimination of all chroma information in the sync-channel video.

The sensitivity control is used to establish the threshold level of dropout detection. For test purposes, simulated dropouts, which are visible on a monitor, can be inserted into the video in either play or E-E operation.

The Dropout Processor Module

The circuitry of the dropout processor module can be divided into three sections, each broadly classified according to function. (See block diagram, Fig. 8-2).

1. Filtering, automatic gain control, and amplification of the dropout (DO) signal.
2. Simulated dropout generation whereby the functioning of the Dropout Compensator system as a whole can be visually evaluated on a monitor. Included is the sensitivity set circuit. This circuit, in conjunction with the sensitivity circuit in the Dropout Compensator module, determines the fm level at which dropouts will be selected.
3. The dropout pulse circuit, which includes the sample-pulse eliminator in the ATC error detector module. The dropout pulse circuitry provides pulses to supplant primary timing pulses that are lost because of dropouts in the fm signal. The dropout pulses either inhibit circuits used in generating timing pulses for the servo systems or replace missing horizontal- and vertical-sync pulses.

In the play mode, the tape DO fm signal is passed by the input-signal selection relay (K2) to drive a low-pass filter which eliminates high-frequency noise. In the E-E mode, the relay selects the fm reference signal, which prior to filtering is fed through a feedback amplifier. Amplification of the fm reference signal is necessary in order to drive the filter.

The filtered fm signal is applied to the agc circuit across two field-effect transistors, and it is coupled by an emitter follower to the first of two feedback amplifiers.

The feedback amplifiers provide a gain of 36 dB. The field-effect transistors act as electronically variable attenuators in the path of the fm signal. The field-effect transistors are controlled by the dc amplifier, and their impedance is inversely proportional to the magnitude of the rectified feedback signal. If the amplitude of the fm signal tends to increase, the impedance of the field-effect transistors is lessened, and more of the fm signal is attenuated. Conversely, a reduction in the amplitude of the fm signal results in an increase in the impedance of the field-effect transistors, which in turn results in less attenuation. Consequently, the level of the fm signal being fed to the Dropout Compensator module remains constant, despite fm level variations such as those encountered between different fm standards or tape recordings. Amplitude control of the fm signal is such that the output of the agc circuit remains within ±1 dB with an input change of ±10 dB. Since the agc circuit responds only to very slow changes in the amplitude of the fm signal, dropouts do not affect it.

The dropout pulse, derived when a dropout is detected in the fm signal, is at least seven microseconds long; it may be longer, depending on the duration of the fm dropout. On being applied to the dropout processor module, the dropout pulse may follow either of two circuit paths, depending on when it occurs in relation to the sync or video component. If the dropout pulse is derived between sync pulses, the dropout pulse is fed directly through the dropout processor to the post-emphasis module. The dropout pulse is applied to the DO clamp in the sync-channel video circuit, and, as a result, sync video is clamped at gray level during the dropout.

If a dropout takes place during sync, the dropout pulse fed to the dropout processor module is coincident at an AND gate with a 17-microsecond pulse derived from the inverted leading-edge gate pulse. When this happens, the output of the AND gate triggers the 2H/3 multivibrator. The multivibrator in turn produces a pulse lasting two thirds of a line, or 42 microseconds. This pulse added to the dropout pulse becomes the stretched sync dropout pulse, which is fed to the DO clamp circuit in the sync-channel video section of the post-emphasis module. The stretched dropout pulse eliminates horizontal sync or, during the vertical interval, two equalizing pulses.

Besides being fed to the post-emphasis module, the sync dropout pulse, stretched or otherwise, is also fed to the sample-pulse eliminator in the ATC error detector module. The sync dropout pulse is one of the two inputs to an AND gate; the other is the 9H pulse. The sample-pulse eliminator produces a pulse that inhibits the ATC sample-pulse generator if a dropout is present during the 9H interval. Thus, whenever the sync drop-

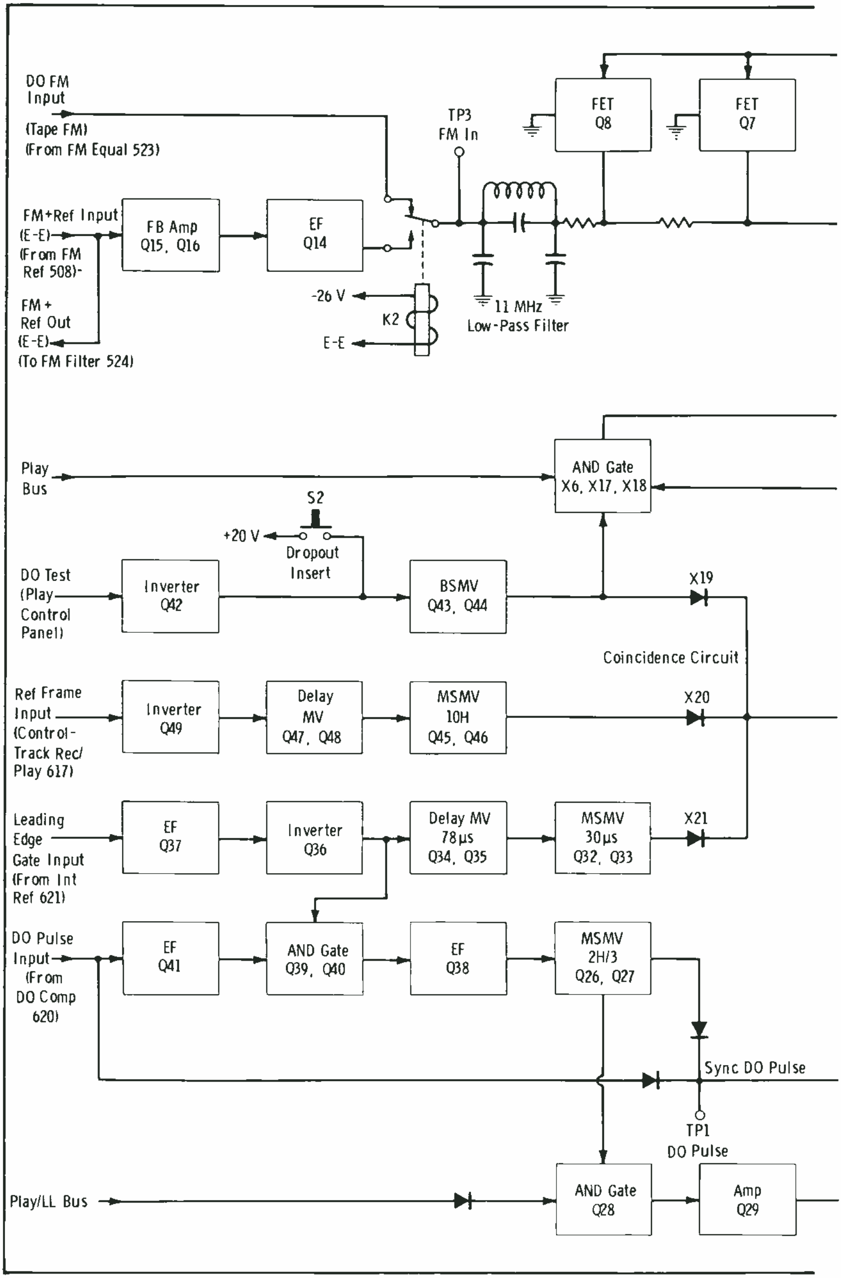
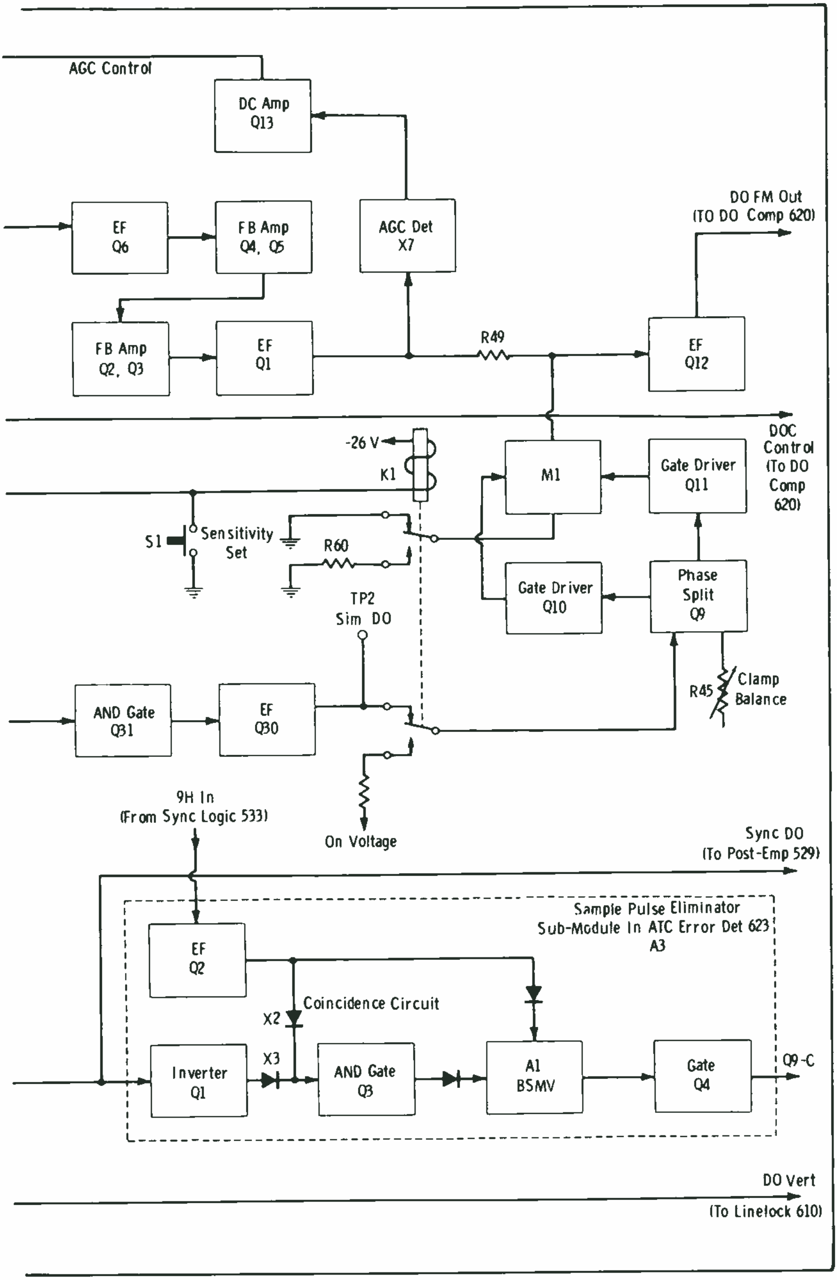


Fig. 8-2. Block diagram



of dropout processor module.

out pulse and the 9H pulse are coincident, the ATC sample pulse is eliminated. This allows the ATC circuits to continue with their previous compensation.

The 2H/3 multivibrator also generates another pulse from which is derived a dropout vertical pulse. This pulse, which is fed to the Linelock module, replaces the vertical-sync pulse normally used in vertical timing in the event it is lost due to a dropout. When Pixlock is achieved, the Pixlock/Linelock bus is at ground potential. This potential and the 2H/3-generator pulse furnish the inputs to an AND gate. During the period that coincidence exists between the AND gate inputs, the AND gate is enabled, and the succeeding amplifier produces the dropout vertical pulse.

The dropout vertical pulse is applied simultaneously with the tape vertical signal to the tape-vertical/reference coincidence detector in the Linelock module. Whenever the vertical-sync pulse that is used in deriving the tape vertical signal is eliminated due to a dropout, the dropout vertical pulse is present as a substitute. Thus, the servo systems are prevented from falling out of lock during a dropout in the tape vertical sync.

The simulated-dropout circuit permits the operation of the dropout-compensation system to be checked by inserting dropouts in the fm signal. The simulated dropouts are inserted just prior to the fm output stage that feeds the line to the Dropout Compensator module. Depending on which signal, fm or video, is selected for observation, the dropouts will appear as gaps in the continuous fm wave or as lines in the video. The simulated-dropout insertion circuitry is activated by pressing the DROPOUT INSERT switch on the front panel of the dropout processor module. To view the dropouts in the signal on the cro or picture monitor, the COMP OFF/MONO ONLY/NORMAL switch on the front panel of the Dropout Compensator module must be in the Mono Only position.

The dropouts are placed in the fm signal by a diode quad (M1) which is gated on during five alternate lines once in every frame. The quad gating signals are derived from the output of a three-input AND gate. One of these input signals is a steady-state control signal. The second is a 10H pulse timed to occur about four milliseconds after the beginning of each frame. The third is a 30-microsecond pulse timed at half the horizontal rate to occur about five microseconds after the start of a line. Consequently, once every frame for a 10H period, all three AND-gate inputs will be coincident. During this period, five 30-microsecond pulses (one every other line) will be passed by the AND gate. These pulses are then split in phase to become the quad gating pulses. The simulated dropout passed each time the quad is turned on causes a reduction in the level of the fm signal being fed to the Dropout Compensator module. This reduction in level is sufficient to activate the dropout-detection circuitry in the latter module. When the demodulated signal is viewed on a picture monitor, five lines about one quarter of the way down the raster will be visible in the display.

The dropouts are eliminated by resetting the flip-flop that produces the steady-state input to the AND gate. This is done by tapping any of the following switches: STOP, WIND, PLAY, STANDBY, RECORD, SETUP, CUE ON/OFF, or AUDIO ON/OFF.

The DOC Module

The Color Dropout Compensator (DOC) normally requires no attention by the operator and functions automatically whenever power is applied. However, there are two operational controls that affect the operation of the Dropout Compensator, and their settings should be considered by the operator. They are the SENSITIVITY control and the mode selector switch (Fig. 8-3). Their functions are explained in the following paragraphs.

The SENSITIVITY control adjusts the sensitivity of the dropout detector circuit. To the detector, a dropout is a reduction in the rf amplitude of the fm carrier. As the SENSITIVITY control is turned clockwise, the sensitivity decreases so that a greater drop in the rf amplitude is required to cause the video to be replaced. As the control is turned counterclockwise, the smaller a drop in the rf amplitude must be to cause the video to be replaced. The useful range of the SENSITIVITY control is the upper (clockwise) two-thirds of its range. This is 10 to 20 dB below the normal rf input level of 0.4 volt. As the SENSITIVITY control approaches the maximum counterclockwise position, the detector sensitivity becomes so great that it causes excessive replacement of the video.

When determining the sensitivity setting, the operator must consider the condition of the tape and the condition of the recorder. Amplitude variations caused by the recorder, such as those resulting from slope detection or tracking variations, could be detected as dropouts if the sensitivity is too great. The ideal sensitivity setting is one which compensates for all dropouts, large and small, up to the point where the replacement video causes an apparent change in the overall picture.

In general, if the rf signal level is consistent, operation at a higher sensitivity is permissible. If the level is not consistent, it is preferable to operate at a lower sensitivity. Under noisy signal conditions, the DOC will, of course, supply more replacement video. If the sensitivity is too great, the difference between the replacement video and the direct video could be perceptible in the overall picture.

The mode selector switch has three positions that correspond to three modes of operation: Normal (normal full compensation of NTSC color signals or black and white), Mono Only (monochrome only), and No Comp (no compensation). These functions are explained in the following paragraphs.

In the Normal position, all functions of the dropout compensator are operating. This is the position that should normally be used for 525-line or 625-line NTSC color or for monochrome operation. The dropout compensator will replace both the luminance and the color subcarrier with the stored video, in the event the reproduced rf level drops below that set by the SENSITIVITY control. If the rf level is normal, the video is routed directly through the video switch to the post amplifier and the video output.

In the Mono Only position, the DOC operates as in the Normal position, except that the color subcarrier is removed from the replacement video. The direct video is not affected. That is, as long as there are no dropouts and the DOC is supplying direct video, the chrominance signal and color burst are unaffected. The color signal is eliminated only in the delayed video inserted in the event of a dropout. The Mono Only position would normally be used with color systems other than the NTSC color system.

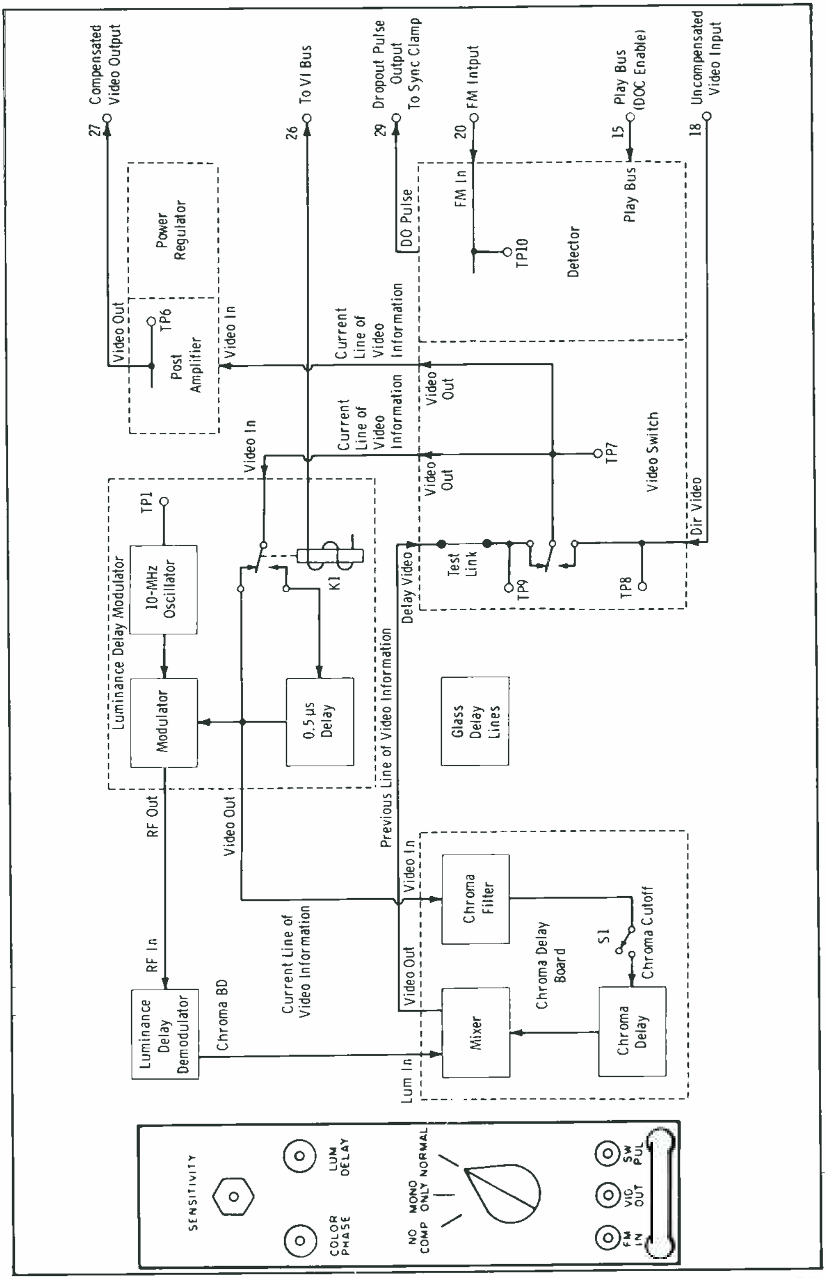
In the No Comp position, direct video is always supplied from the DOC. The detector circuit is locked in the no-dropout state, and the video is routed through the direct-video side of the video switch and amplified to unity gain in the post amplifier.

Operation of the Color Dropout Compensator is based on the concept that lost information may be replaced by information from the preceding scan line with little or no noticeable degradation of the picture. To do this, the dropout compensator always has stored in its delay system the previous scan line of video information. By continuous sampling of the rf level of the reproduced fm signal, it may be determined if the video has a significant loss of information, or if it is acceptable.

If the rf amplitude of the reproduced video signal is acceptable, as set by the SENSITIVITY control, the signal is simply routed through the DOC and back to the recorder output circuitry. At the same time, the acceptable line of video information is sent through the delay system to be ready for use if the following line has a significant dropout. If the rf level drops below the level set by the SENSITIVITY control, the DOC switches from the current video information to the previous line of video information, which is stored in the delay system.

The direct uncompensated video is fed into one side of the video switch circuit, and the delayed video is fed into the other side. The detector controls which video is the output from the DOC. The video output is continuously fed into the delay system and stored for one line.

Fig. 8-3 illustrates the layout of the DOC circuit boards and the signal flow between them. All incoming signals, except the VI bus which controls K1, come into the detector and video switch board. These input signals are the uncompensated video, the fm input, and the DOC-enable signal from the play bus. The detector monitors the fm for dropouts and controls the video switch as previously described. For the detector to operate, a ground enable signal must be provided on pin 15 by the play bus. Also, as previously described, the detector provides a sync clamp pulse on pin 29 when a dropout is detected. The video switch, controlled by the detector, selects which video, the direct video from pin 18 or the delayed video, will be the output.



Courtesy RCA

Fig. 8-3. Block diagram of color dropout compensator.

The output from the video switch goes to two places, the post amplifier board and the luminance delay modulator board. The post amplifier amplifies the video output signal to provide an overall gain of unity through the DOC. The video signal to the luminance delay modulator board goes to relay K1. When the system is operating under the 525-line NTSC system, K1 is de-energized and the video signal is passed straight through. When the system is operating under the 625-line NTSC system, K1 is energized, and the video signal passes through a 0.5-microsecond delay line. From the relay and delay line, the signal goes to two places, the luminance delay modulator and the chroma delay board.

On the luminance modulator board, the video information is modulated onto a 10-MHz carrier. From the luminance delay modulator board, the modulated signal goes to the luminance delay demodulator board, where it is delayed one scan line of time and then demodulated. The delayed luminance then goes to the mixer circuit on the chroma delay board to be mixed with the delayed color information.

On the chroma delay board, the video signal from K1 on the luminance delay modulator board is filtered so that only the chrominance information remains. The resulting signal is phase inverted and then delayed one

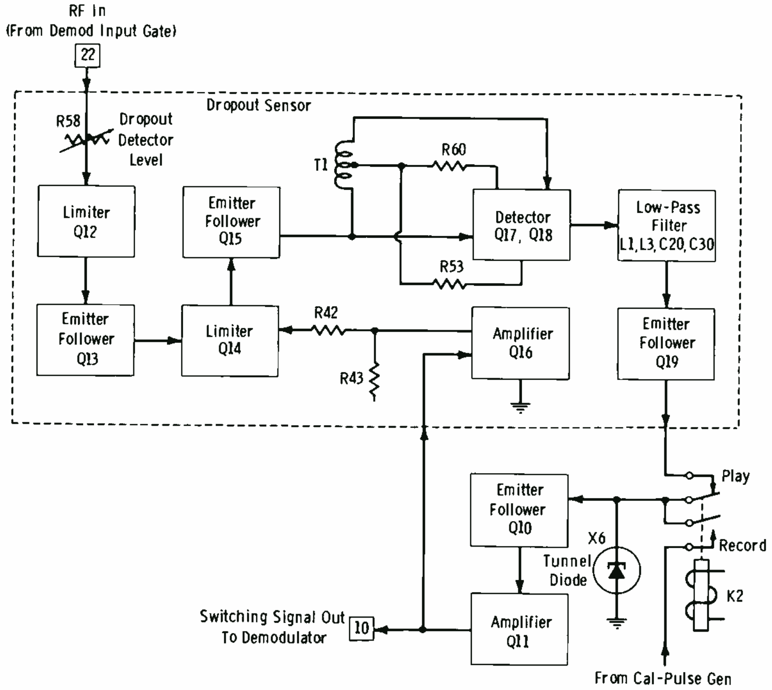


Fig. 8-4. Block diagram of dropout sensor section.

scan line of time. The chrominance information is then mixed with the luminance information, and the complete video signal, delayed one line, is fed from the chroma delay board to the delayed side of the video switch on the detector and video switch board.

The reason the luminance and color are delayed separately is that the color signal of each succeeding scan line is shifted in phase by 180°. Therefore, the delayed video must have its color subcarrier not only delayed one line, but also phase inverted, as previously explained.

8-2. THE AMPEX DROPOUT COMPENSATOR

Module 6 of the Ampex VR-2000 machine includes two principal sections, the outputs of which are relay-selected as a function of the system operating mode (i.e., play or record/E-E). The two sections share a two-stage output amplifier; see Figs. 8-4 and 8-5. (One of the sections is the calibration-pulse generator, which is not discussed here.)

There is a relay-selected rf signal at pin 6 of the demodulator input gate, and this signal is applied to an input of the dropout sensor. This rf signal (approximately ½ volt peak to peak) enters the dropout sensor (module 6) at pin 22 and is routed through dropout-detect level control R58 to the base of limiter Q12. The output of Q12 is coupled by emitter follower Q13 to the base of second-stage limiter Q14. The amount of limiting is a function of the signal level applied to Q12, which in turn is a function of the setting of potentiometer R58.

The output of Q14 is coupled by emitter follower Q15 to full-wave rectifier (or detector) Q17-Q18 through transformer T1, which provides signals of opposite phase at the bases of Q17 and Q18. Because both are pnp transistors, when one turns on, the other turns off, resulting in full-wave rectification at their common collectors. As long as the level of the incoming rf equals or exceeds the limiting level, the output of Q17 and Q18 is a straight line. If the level of the incoming rf falls below the limiting level, both transistors turn off, and their collectors swing toward ground (zero volts).

The limited and full-wave-rectified signal at the output of Q17-Q18 is routed through a low-pass filter to the base of emitter follower Q19. The emitter follower remains cut off as long as the positive voltage of the signal from the collectors of Q17 and Q18 remains at the limiting level. When, however, this voltage falls below the limiting level, Q19 turns on, and its emitter voltage swings negative. The result is a negative pulse the duration of which coincides with the duration of the dropout period (Fig. 8-6).

During the play mode, the output of Q19 is routed through de-energized relay K2 and coupled by emitter follower Q10 to the base of switch Q11. The base circuit of Q10 includes tunnel diode X6, which acts to greatly accelerate the rise times of the negative dropout pulses applied to the base of Q10. Switch Q11 is normally off, but it is turned on by each negative dropout pulse. Its output therefore remains at −12 volts until a dropout pulse occurs, when the output swings to zero volts. The leading and trailing edges, respectively, of each dropout pulse turn Q11 on and off. (Refer to Fig. 8-6.)

The collector output (positive-going pulses) of Q11 is routed to pin 10 and is the switching signal received at pin 21 of the demodulator input gate. The output of Q11 is also applied to the base of hysteresis generator Q16, which functions as a switch. The rf present in the circuit of limiter Q14 includes a small amount of amplitude modulation, which could make the indication of a marginal dropout somewhat ambiguous, rather than positive. As noted earlier, Q11 turns on during a dropout period, and its collector swings (positive) to zero volts. This positive voltage swing is applied to the base of normally on switch Q16 and turns it off.

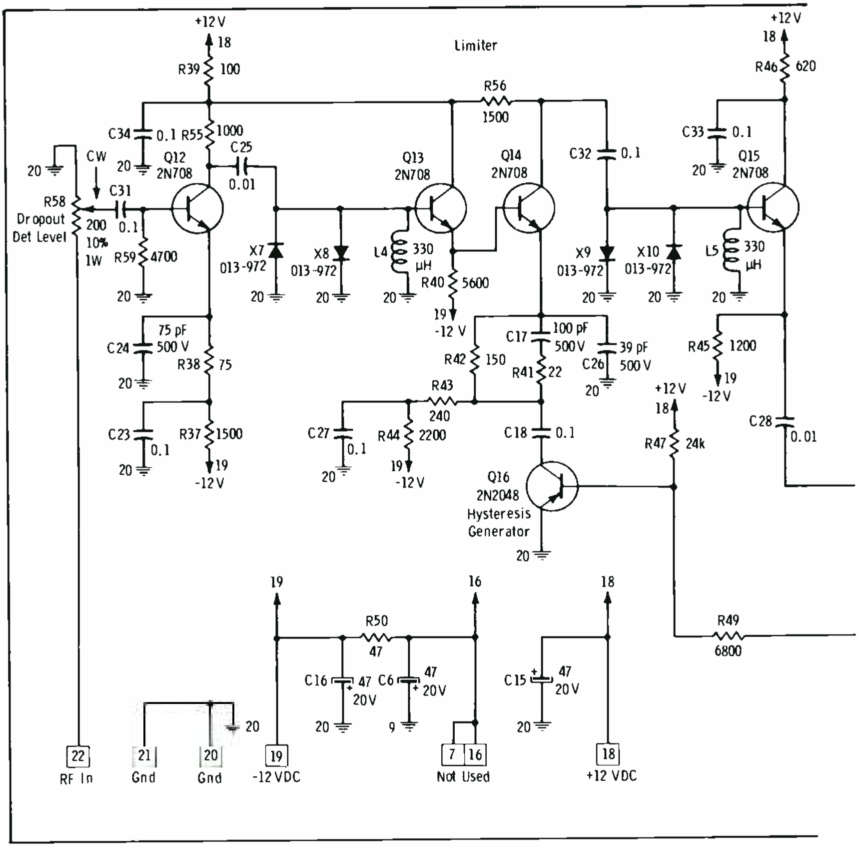
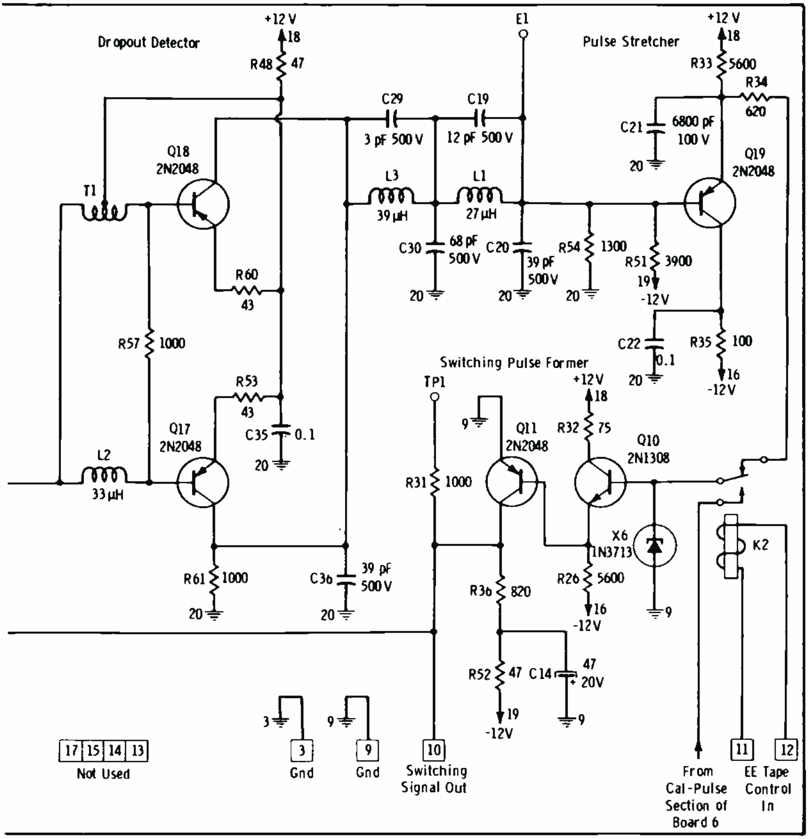


Fig. 8-5. Schematic diagram

When the rf level equals or exceeds the limiting level, Q16 is saturated, and the effective emitter resistor for limiter Q14 is R42 (150 ohms). Thus, under this condition the gain of Q14 is approximately 10 (i.e., R56, 1500 ohms, divided by R42, 150 ohms). When the rf level falls below the limiting level (i.e., the dropout condition), Q11 turns on and biases Q16 off. Under this condition, the effective emitter resistor for Q14 includes R42 plus R43 (240 ohms), and the gain is 1500/390, or approximately 3.8.

When the gain of Q14 falls from 10 to 3.8, the signal level at the base of Q15 falls, removing any possible ambiguity in the indication of a dropout that is marginal. Thus the presence of amplitude modulation cannot cause a marginal dropout to appear to be a cyclic alternation between a normal and a dropout condition. When any dropout occurs (e.g., rf level down 20 dB from normal), Q11 will remain on, Q16 will remain off, and the gain of Q14 will remain at approximately 3.8 until the in-



of dropout sensor.

coming rf level is down only 11 dB from normal. At this point Q11 will turn off, Q16 will turn on, and the gain of Q14 will rise to the normal level of 10.

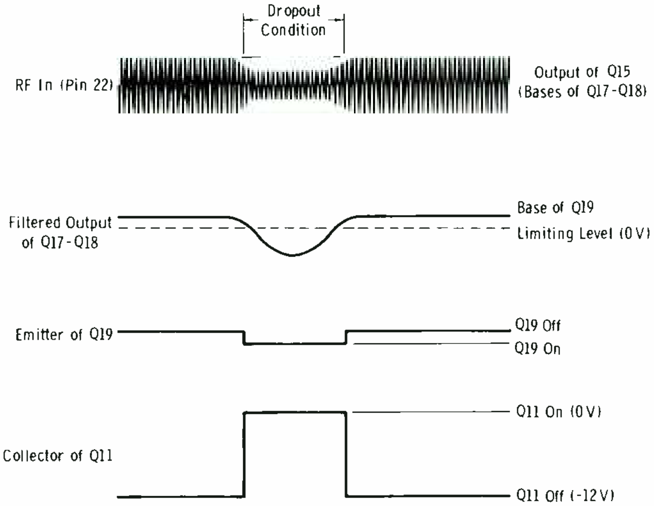


Fig. 8-6. Waveforms in dropout sensor.

EXERCISES

Q8-1. Define the term "dropout."

Q8-2. What is the basic reference for a tape-dropout compensation system?

Q8-3. If an original (first-generation) recording contains dropouts, will a dub of this recording contain the same dropouts?

Q8-4. When a dropout occurs in a given line of picture information, what happens?

Q8-5. What is the basic additional function for color DOC as compared to monochrome DOC?

CHAPTER 9

Advanced Color-Error Correction Systems

Chapter 6 traced the need for special compensation systems for monochrome geometric error, and the additional types of correction necessary for the color information. These corrections act primarily on a head-to-head basis, or on the entire group of 16 to 17 lines occurring within one head pass across the tape.

There are additional color errors which are not "cleaned up" by the previously discussed systems. These are:

1. Hue (phase) shifts within each band of 16 to 17 lines of a head scan.
2. Saturation (amplitude) variations within each band of 16 to 17 lines of a head scan.

The advanced color-error compensation systems required to correct these errors are the *Velocity Compensator,* used in conjunction with the Colortec and Amtec (Ampex), and the *Cavec* (*C*olor *A*mplitude and *V*elocity *E*rror *C*ompensation), used in conjunction with the monochrome and Color ATC systems (RCA).

9-1. THE NEED FOR ADVANCED COLOR-ERROR CORRECTION SYSTEMS

The two major types of errors to be compensated, hue shifts and saturation variations, are produced by mechanical and operational deficiencies that cannot be eliminated by normal machine adjustment. These deficiencies are inherent in this type of equipment and have existed since the introduction of quadruplex tape. It is only during color operation that their effects on tape quality become apparent in the form of color banding. Banding usually occurs during the passage of one head over the tape surface.

Hue banding is commonly referred to as velocity error. It results from differences in head scanning velocity between the recording machine and the playback machine. This can be caused by many small factors, such as different tape tension between record and replay machines, different positions of some of the fixtures on the tape transport, or incorrect guide height adjustment.

As one specific example of saturation banding, review the text associated with Fig. 2-13, Chapter 2. Note that head-to-tape pressure varies between top, center, and bottom of the tape when perfect concentricity does not exist. (Recall that "perfect" concentricity is practically impossible to achieve on a tape-interchange basis.) This change in pressure causes a change in the high-frequency response of the head, due largely to the fact that in spite of the penetration of the pole tip into the tape, a minute air film exists between the head and tape. Pressure changes across the arc of the head path cause a modulation of this air film, which affects the high-frequency response.

For under-penetration (Fig. 2-13B), pressure is lowest at the center of the head pass. At top and bottom, the head is closest to the tape and the air film is smallest. Under these conditions, the carrier frequency itself is reproduced well, but there is a reduction of chrominance (sideband) signal level relative to that at the center of the tape. At the tape center, the lower pressure causes the air gap to increase, lessening the fm high-frequency response and increasing the chrominance signal level relative to the level at the top and bottom of the head-scan arc across the tape.

The net result of this defect is color banding within each band. Not only does the chroma amplitude change across the complete head scan of 16 to 17 lines, but differential gain and differential phase occur also.

Therefore, chroma, or saturation, banding is the result of differences in head-to-head frequency response, tape surface variations, and tape-to-head contact differences. The effect is a change of chroma amplitude between the heads, as well as a saturation change within any one head pass. In simple terms, the chroma amplitude varies from one line to the next. This requires compensation on a line-by-line basis. It is possible to correct manually only for individual head-scan (16-line) intervals; thus the correction is only an averaging for line-to-line errors. Electronic compensation, however, is capable of correcting the actual error, line by line.

Some of the errors present in tv tape recording can be compensated for by manual adjustments in the playback mode. This is true for both chrominance-amplitude errors and velocity errors, but it is difficult to remove both effects simultaneously, and in removing one effect the operator may cause another. An example of this is evident if an interchange recording with objectionable saturation banding is played back. Mechanical adjustments such as guide height may be made, and electrical adjustments on individual heads may be made manually by turning the playback equalizers in the individual channels. The saturation banding might be compensated for perfectly, but in doing so, velocity errors would be introduced. Velocity errors are seen as a continuous change in color phase across the tv line or down the head band. The result is that the picture probably looks worse than it did with the original saturation-banding error. What all this adds up to is that no matter what is done with the original saturation-banding error or how many adjustments are made, the end result of playing back a color interchange recording that had errors in some form is color banding seen by the viewer.

9-2. BASIC FUNCTION

The basic function of the Cavec unit (Fig. 9-1) may be described by dividing it into three basic parts:

1. Integrated-circuit digital memory system from which the line-by-line correction is obtained
2. The velocity or phase error detector (VEC)
3. Chrominance amplitude corrector (CAC)

The line-by-line correction is made possible by the basic assumption that errors found in one revolution of the headwheel will also be present in the next revolution of the headwheel. During the head revolution, each of the four heads scans 16 lines; thus, to store information for one complete revolution, 64 memory units are required. Separate memory units are required for the velocity and chroma-amplitude corrections. Thus, the memory units in any one Cavec total 128. The memory units are really capacitors which are charged in approximately 100 milliseconds, or 24 revolutions of the headwheel. It should be recognized that instantaneous changes in either hue or saturation will not be corrected to some absolute value but will be corrected to the average value of the previous 24 revolutions of the headwheel.

The CAC corrects for frequency-response variations in the video signal, which produce saturation errors in the color picture. The VEC corrects for inaccuracies in head-to-tape velocity, which cause undesired hue changes.

The circuits of the Cavec are similar to those used in computers. Some are of the analog-computer type, and others are of the digital-computer type. As shown in Fig. 9-1, the analog circuits are divided into two groups, one for CAC and the other for VEC. The digital circuits are a single group shared by both VEC and CAC. The output signals which correct the errors are produced by the analog circuits. The digital circuits provide the analog circuits with timing and control pulses required for line-by-line correction.

The input to the CAC (Fig. 9-2) consists of burst separated from the demodulated video. In the analog circuits, the burst amplitude is compared to a reference level, and the resulting error voltage is stored in a

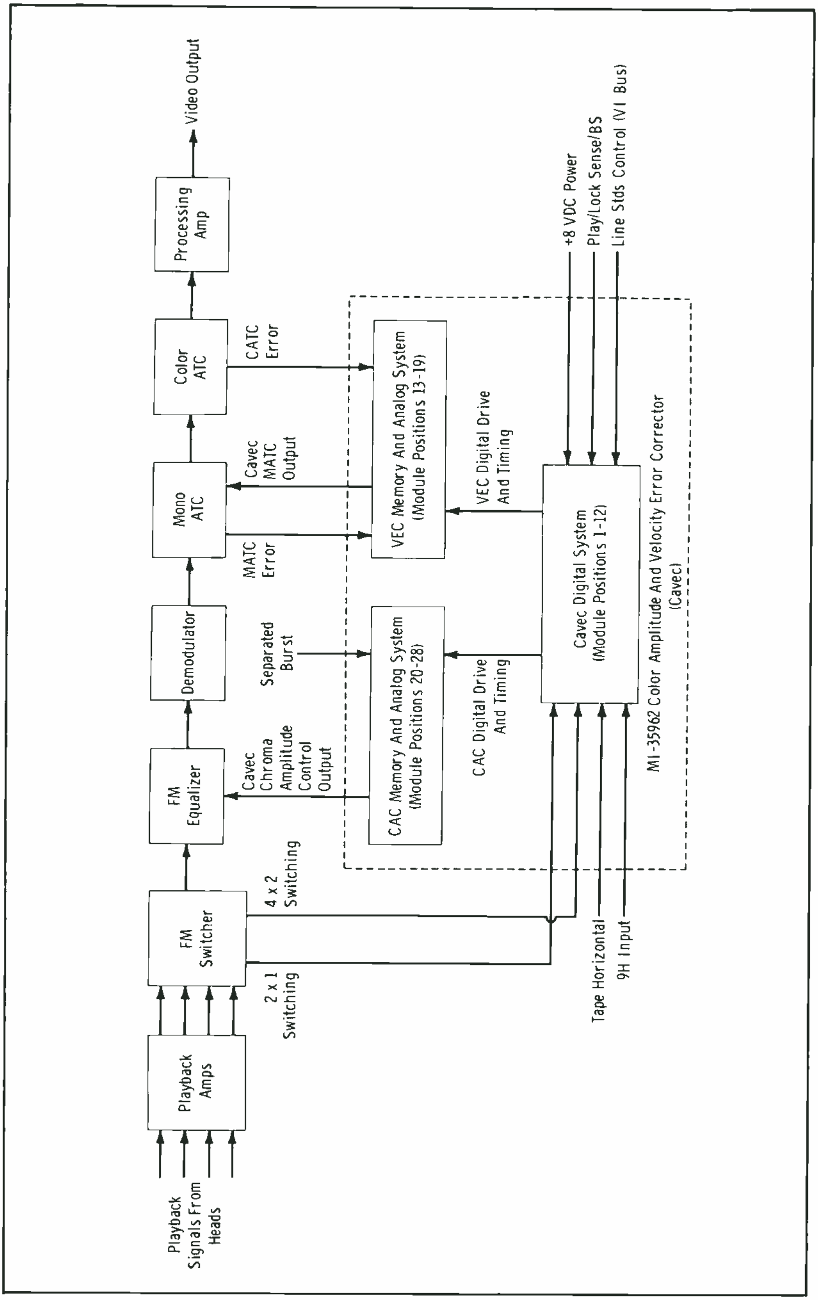


Fig. 9-1. Simplified block diagram of Cavec unit.

capacitance memory. The memory contains 64 capacitors, one for each line in the four head scans; thus, 64 errors are stored. At the beginning of each line, the stored error voltage corresponding to the line is read out and converted into two push-pull voltages which constitute the CAC input signals. These signals are fed out of the Cavec to an electrically controlled attenuator in the fm equalizer module. The attenuator automatically adjusts the fm equalization in a direction that tends to reduce changes in the burst amplitude. Correction occurs before the portion of the fm signal containing the burst arrives at the fm equalizer, thereby providing true closed-loop operation. Thus, the CAC resembles an automatic gain-control system.

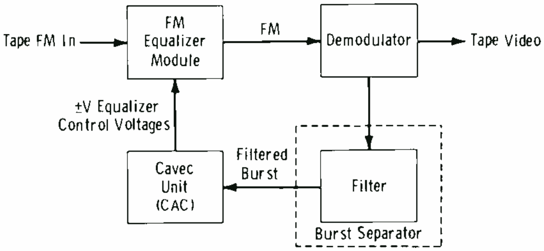


Fig. 9-2. Simplified block diagram of CAC.

The VEC portion improves the monochrome ATC system of the machine by causing the MATC variable delay line to correct timing errors continuously instead of in steps. In machines without Cavec, the MATC error signal is applied to the variable delay line at the beginning of each line and remains constant throughout the line. The error waveform therefore appears as a series of steps, as shown in Fig. 9-3. This type of signal restores video timing to normal at the beginning of the line, but it allows errors to accumulate during the line. As a result, the chroma shifts between correction steps, causing hue banding or, in the case of PAL operation, desaturation.

To correct this deficiency, the VEC adds ramps (Fig. 9-3) to the MATC error signal. The resulting waveform closely approximates the true, continuously variable velocity-error signal. To produce ramps of the correct slope, the VEC analog circuits measure the differences between the successive step voltages and store the difference voltages in a capacitor memory similar to the one used by the CAC. The memory contains 64 capacitors, one for each of the 16 lines in each of the four head scanning periods. (Since some head scan periods contain seventeen lines, the error stored in the sixteenth capacitor is used for both the sixteenth and seventeenth lines.) The time constant of the capacitor charging circuit causes the error voltage to stabilize after 24 headwheel revolutions. Each stored voltage, therefore, is an average for 24 revolutions. At the beginning of each line, the corresponding stored voltage is applied to a circuit which generates a ramp having a final height equal to the error. Each ramp is added to the corresponding MATC step, and the combined signal is fed out of the Cavec to the circuits which control the MATC delay line.

Although the RCA Cavec module, when mounted in the tape machine, looks like the other modules, its internal construction is entirely different. Instead of one large circuit board, the Cavec unit contains a number of small printed circuit boards plugged, at right angles, into connectors on a wiring backplane which extends for the entire length of the assembly. The backplane has connectors, each containing 45 pins, for a maximum of 32 boards.

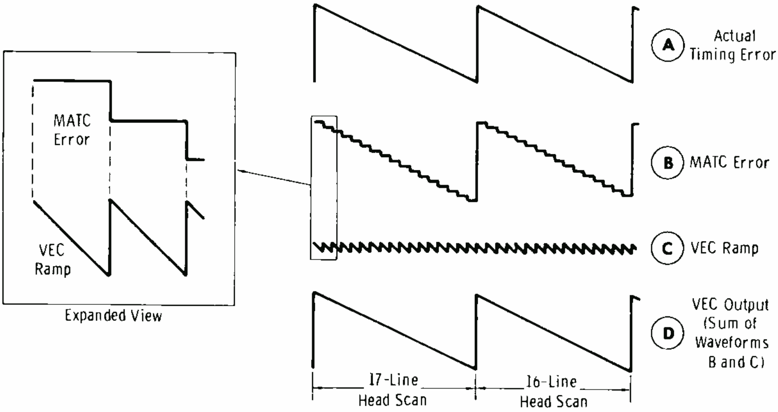


Fig. 9-3. VEC waveforms when guide pressure is misadjusted.

The digital system occupies the first 12 board positions. This system actually contains 11 boards, but only one of the first two positions is used, position 2 in the TR-70 and position 1 in all other machines. Only five different types of digital boards are used. The principal components on these boards are integrated-circuit packages of the dual in-line type. The packages contain logic circuits, such as gates and inverters, or timing circuits, such as one-shots or flip-flops. All logic elements are of the diode-transistor logic (DTL) family.

Positions 15 through 18 are occupied by four identical boards which constitute the VEC memory. These boards contain storage capacitors, transformers, transistors, and semiconductor switches. A total of 64 storage capacitors is provided, 16 on each board. Each capacitor stores information pertaining to a particular line in a particular head scanning interval (for example, line 1 of the head-1 interval).

Positions 13, 14, and 19 contain the VEC analog boards. The components on these boards consist mostly of semiconductor switches and integrated-circuit operational amplifiers. The operational amplifiers are basically high-gain dc amplifiers using large amounts of negative feedback. By connection of various external circuits in the feedback loop, these amplifiers are made to perform a wide variety of functions, such as addition, integration, and inversion of signals.

Positions 23, 24, 29, 30, and 31 contain the CAC analog boards, and positions 25 through 28 contain the CAC memory boards. These boards contain components similar to those on the VEC analog and memory boards.

A regulator providing outputs of +4.5 volts and +12 volts is mounted on the back end plate of the Cavec unit.

The front panel of the Cavec module contains on/off switches for the VEC and CAC systems, a potentiometer for manual control of the CAC burst ratio, and four test points. Internal screwdriver-adjustment potentiometers on the printed-circuit boards can be adjusted without unplugging the modules from the backplane.

To facilitate testing, a connector accessory, a board extender, and a board extractor are provided with the Cavec module. The connector accessory, in conjunction with the standard module extender provided with the machine, permits extending the Cavec module in its normal vertical position so that the backplane is accessible from the left side while most of the potentiometers on the printed-circuit boards are accessible from the right side. The board extractor and extender permit testing components on the individual circuit boards.

9-3. THE VELOCITY-ERROR CORRECTOR (VEC)

> NOTE: It is imperative that the reader have a background in logic circuitry at least equivalent to that contained in Chapter 3 of *Television Broadcasting: Systems Maintenance,* by Harold E. Ennes (Indianapolis: Howard W. Sams & Co., Inc., 1972).

The velocity-error corrector (VEC) contains two main groups of circuits, as shown in Fig. 9-4. The first group, called the analog system (Fig. 9-4A), consists mostly of operational amplifiers and semiconductor switches. The second group (Fig. 9-4B), called the digital system, contains pulse generators, counters, gates, and other forms of digital logic circuits.

The functions of the analog system are to generate a series of ramp signals (straight-line segments), one for each horizontal line in each of the four video-head scanning periods, and to add the ramps to the MATC error signals. The MATC error signal consists of a series of steps which change level at the beginning of each line. The amplitude of each step constitutes a measurement of the velocity error existing at the beginning of the corresponding line. The true velocity error, however, is a smoothly changing signal, rather than a series of steps. Addition of the ramps smooths out the steps to provide a better approximation to this signal.

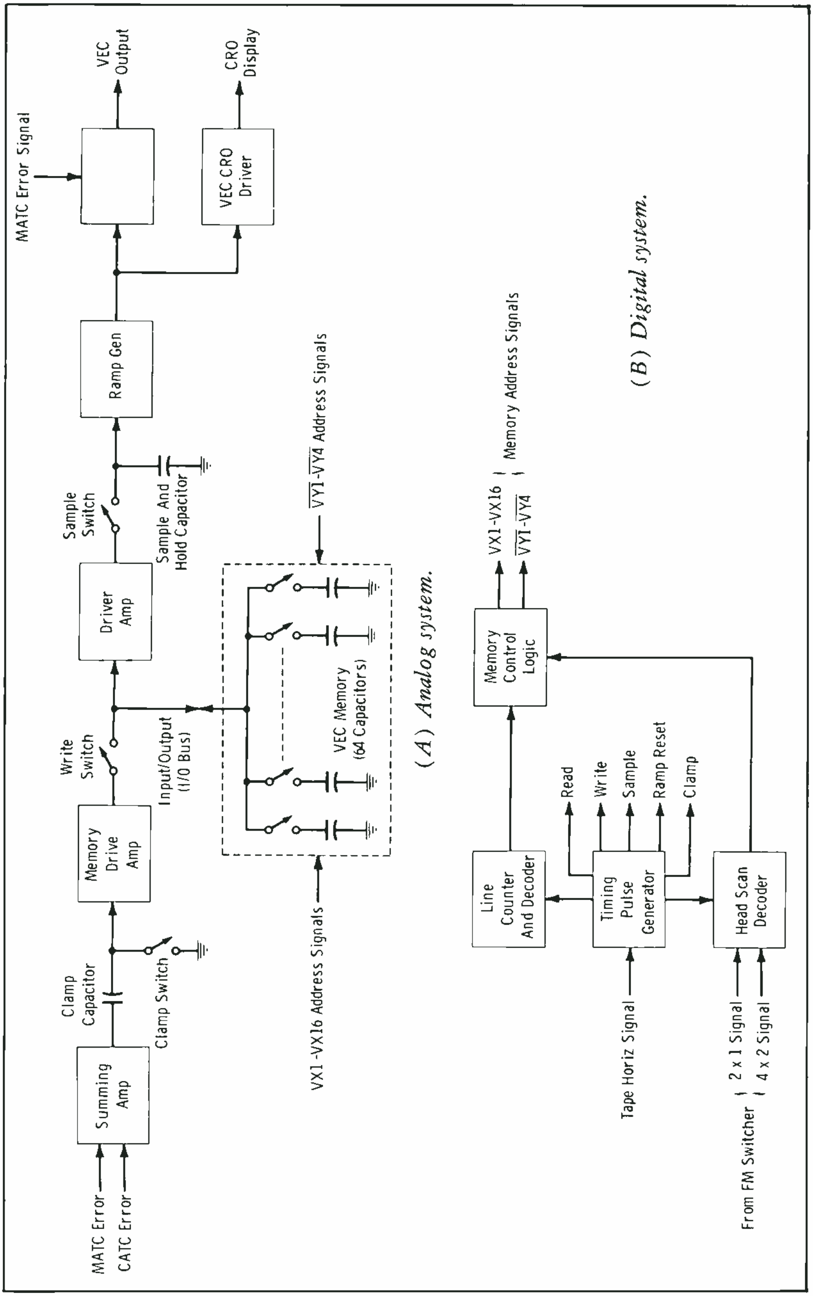


Fig. 9-4. Simplified block diagrams of VEC.

The function of the digital system is to generate a number of timing pulses from the tape horizontal sync, 2 × 1 switcher, and 4 × 2 switcher signals of the tape machine. These pulses control semiconductor switches in the analog system which perform the various functions required for generating the ramps.

VEC Analog System

The peak-to-peak amplitude of the ramp which must be generated to provide a smooth connection between steps depends on the difference between the velocity errors existing at the beginning and end of the line. The total velocity error must include the CATC (Color Automatic Timing Corrector) signal as well as the MATC signal. Consequently, the information required for generating the ramps is obtained by processing both the MATC and CATC error signals as shown in the block diagram Fig. 9-4. The two error signals for each line of a head scan are combined in a summing amplifier. This circuit amplifies each signal by a different amount, to obtain the required balance, and adds the results. For purposes of illustration, the combined MATC and CATC signals for lines 10 through 13 are shown in the top line of the timing diagram, Fig. 9-5. Actually there are either 16 or 17 lines in a head scan on 525-line standards (15 or 16 lines on 625-line standards).

The line-to-line difference voltages required for determining the ramp heights are obtained by clamping the combined MATC and CATC error signal to ground for a short time during each line. As shown in waveform C of Fig. 9-5, the clamping action places the level of each step at ground during the portion of the line remaining after clamping has taken place. The peak-to-peak amplitudes of the clamped waveform constitute the desired error differences.

As a typical example of clamp operation, consider the error differences for lines 10 and 11. The actual amplitude of the combined error signal for line 10 is designated on the timing diagram as V10, and the amplitude for line 11 is designated as V11. Throughout line 10, voltage V10 is applied from the summing amplifier to the input side of the clamp capacitor. When clamping occurs (during the clamp pulse, waveform B in Fig. 9-5), the clamp switch grounds the output side of the capacitor, allowing it to charge to V10. When the clamp switch opens, the output side of the capacitor remains at ground potential for the remainder of line 10, since no discharge path exists. At the beginning of line 11, the voltage on the input side of the clamp capacitor jumps from V10 to V11, and, since the voltage across a capacitor cannot change instantaneously, the voltage on the output side must change by the same amount as the input side. (In effect, the change in voltage passes directly through the capacitor.) The voltage on the output side of the capacitor, therefore, is equal to the difference between voltages V11 and V10. This difference is denoted by E10 on the waveforms in Fig. 9-5.

The clamped error signals are amplified and then fed to a semiconductor switch called the *write switch.* Once per line, for a short interval before the clamping operation, a pulse from the digital system closes the write switch, thereby applying the signals to a bus (input/output, or i/o, bus) which goes to a bank of memory capacitors. As explained later, storage of the error signal differences in the memory bank provides information which allows prediction of the slope of each ramp at the beginning of the corresponding line.

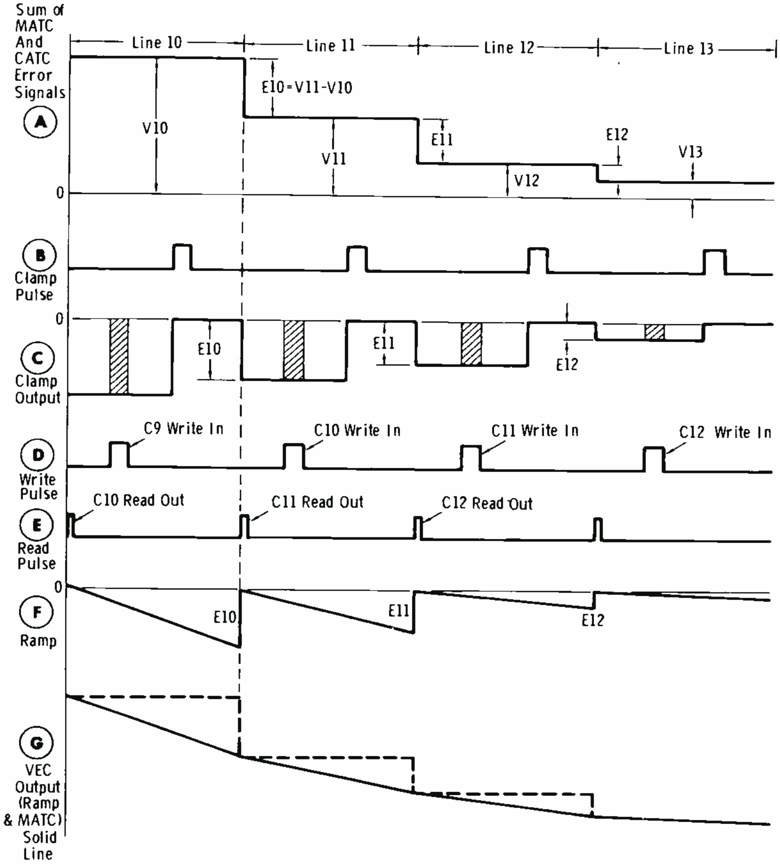


Fig. 9-5. Simplified VEC timing diagram.

The memory bank contains one capacitor for each possible line-to-line difference in a complete rotation of the headwheel. Since a maximum of 17 lines can occur during the scanning period of each of the four video heads, resulting in a maximum of 16 error difference voltages per head scan, 64 memory capacitors are provided in the bank.

While the write switch is closed, additional semiconductor switches in the memory circuits select (or *address*) a particular one of the 64 capacitors and transfer the difference voltage from the i/o bus to that capacitor. In the example previously given, error difference E10 is applied to capacitor C10 during line 11. Similarly, E11 and E12 are applied to C11 and C12 during lines 12 and 13, respectively.

Theoretically, the velocity errors are repetitive from one headwheel revolution to another so that, for example, the error for line 5 of the scanning period of head 4 in one revolution should be the same as in the preceding and following revolutions. Actually, however, small random fluctuations occur. These fluctuations are smoothed out by making the time constant of the memory-capacitor charging circuit about equal to the time for 24 head passes. Thus, after a period of one time constant, the voltage on each capacitor reaches an average value which is more representative of the true error difference than the individual values.

To *extract,* or read out, the required information from the memory bank, gates in the memory-address logic circuits address a particular memory capacitor and connect it to the i/o bus for a period near the beginning of each line. The particular capacitor addressed during readout is not, however, the one which will be written into during that line, but the one which will be written into during the next line. Thus, capacitor C10 is read out during line 10, although it is not written into until line 11. This action is required because generation of a ramp which will connect successive MATC steps requires advance knowledge of the slope necessary for a ramp between those steps.

For example, in order to obtain a smooth connection of the MATC steps for lines 10 and 11, the ramp must start at zero volts and end at −E10 volts (Fig. 9-5). Since the slope of this ramp is proportional to the height, or −E10, the value of E10 must be predicted at the start of the ramp, from the information available at that time. This information consists of the voltage previously stored in capacitor C10, since this capacitor will not be written into again until the next line.

During the read-out period, the voltage from the addressed memory capacitor is applied through the i/o bus to a driver amplifier (Fig. 9-4). The driver output is connected to a semiconductor switch called the *sample switch.* For a portion of the readout time, the sample switch closes and transfers the driver output voltage to a capacitor which serves as a short-term, or temporary, memory. The sample switch and capacitor are referred to as the *sample-and-hold circuit,* because the capacitor retains the sample voltage after the sample switch opens.

The voltage from the sample-and-hold circuit is applied to an integrator circuit, which charges a capacitor at a constant rate proportional to the sample voltage, thus generating the required ramp. The MATC signal is added to the ramp in a summing amplifier to provide the VEC output signal, which is fed to the MATC circuits of the recorder.

VEC Digital System

The pulses provided by the digital system may be divided into two types, timing pulses and memory-control pulses. The timing pulses control the analog-circuit semiconductor switches that perform the basic functions required for generating the ramps, such as clamping, reading, writing, and sampling. The memory-control pulses operate the switches that address the capacitors in the memory bank during the read and write periods.

The timing pulses are derived from the tape-horizontal, 2 × 1 switcher, or 4 × 2 switcher signals of the machine. Table 9-1 lists some of these pulses and their functions.

Table 9-1. Typical Timing Pulses From Digital System

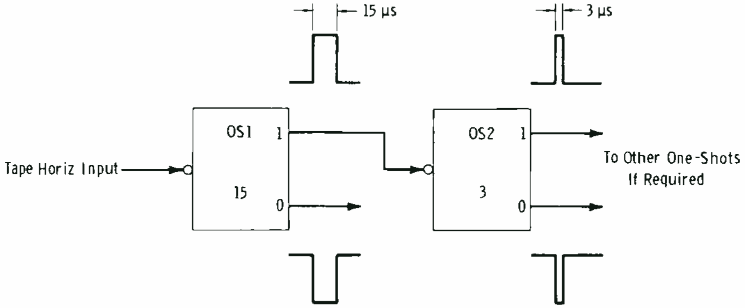
Pulse	Function
Read	Establishes time in horizontal line when memory capacitors are read out.
Write	Establishes time in horizontal line when memory capacitors are written into, or updated.
Sample	Determines time within read interval when memory-capacitor voltage on i/o bus is transferred to sample-and-hold circuit.
Ramp Reset	Resets ramp generator to allow generation of new ramp.
Clamp	Determines time when combined MATC and CATC input signals are clamped to ground, to derive error difference signals.
Clock	Provides horizontal-rate timing reference.

The memory-control pulses consist of two types, called X and Y signals. For the VEC system, there are sixteen X signals (VX1 through VX16) and four Y signals ($\overline{\text{VY1}}$ through $\overline{\text{VY4}}$). One X signal is provided for each horizontal line in a head scanning period, and one Y signal is provided for each of the four head scanning periods. During the read and write periods of a given line, the corresponding X signal causes one side of four capacitors to be connected to the i/o bus, but the Y signal grounds the opposite side of only one of these capacitors, thereby completing its charge path. Thus, selection of each of the 64 capacitors in the memory is uniquely determined by the combination of one X signal with one Y signal.

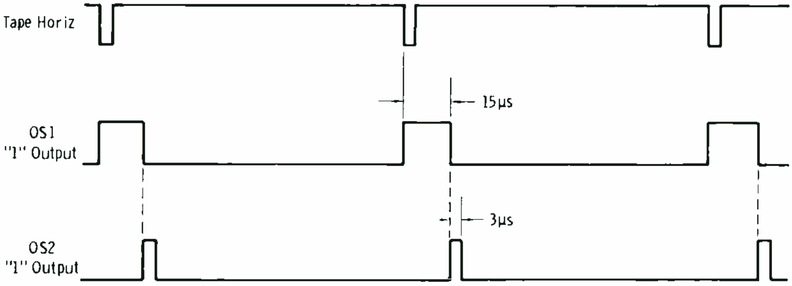
Generation of Timing Signals

Since the various timing pulses are all referenced to the tape-horizontal signal, the basic method of generating these pulses is by connecting two one-shot circuits in cascade. The first determines the delay of the output pulse with respect to tape horizontal, and the second determines the width of the output pulse. For example, assume that it is desired to generate a pulse 3 microseconds wide, delayed by 15 microseconds from the leading edge of tape horizontal. To accomplish this, the tape-horizontal pulse is fed to a one-shot having a period of 15 microseconds, and the output of this circuit is fed to another one-shot having a period of 3 microseconds (Fig. 9-6).

The 1 output of a one-shot is normally at the lower of its two possible levels, jumps to the higher level when the circuit is triggered, and returns to the lower level at the end of the pulse period. Each of the one-shots in Fig. 9-6 can be triggered only by a negative-going transition. Consequently, at the negative-going (leading) edge of each horizontal pulse, the first one-shot is triggered, and its 1 output produces a positive-going pulse. At the end of the 15-microsecond pulse period of this circuit, the 1 output falls to the low level, causing the second one-shot to be triggered. The 1 output of this circuit then produces a positive-going pulse lasting for three microseconds, as desired.



(*A*) *Block diagram.*



(*B*) *Waveforms.*

Fig. 9-6. Use of one-shots in cascade.

The preceding method is extended, in the actual equipment, by connecting more than two one-shots in cascade. For example, the block diagram of Fig. 9-7 and the associated timing diagram of Fig. 9-8 show in simplified form how the clock, clamp, read X, write, and write X pulses are generated.

The tape-horizontal pulse is fed only to the first circuit in the chain, which is called the clock one-shot. When triggered by the negative-going edge of tape horizontal, this circuit produces a positive-going 0.5-microsecond pulse at its 1 output and a negative-going pulse of the same width at its 0 output. The purpose of this circuit is to produce narrower pulses than the tape-horizontal pulses; the narrower pulses serve as more convenient references for the other one-shot circuits.

Both the 1 and 0 outputs of the clock circuit are used as reference. The 1 output produces a delay equal to the pulse width, or 0.5 microsecond, because its trailing edge is negative going. The 0 output, however, produces no delay because its leading edge is negative going.

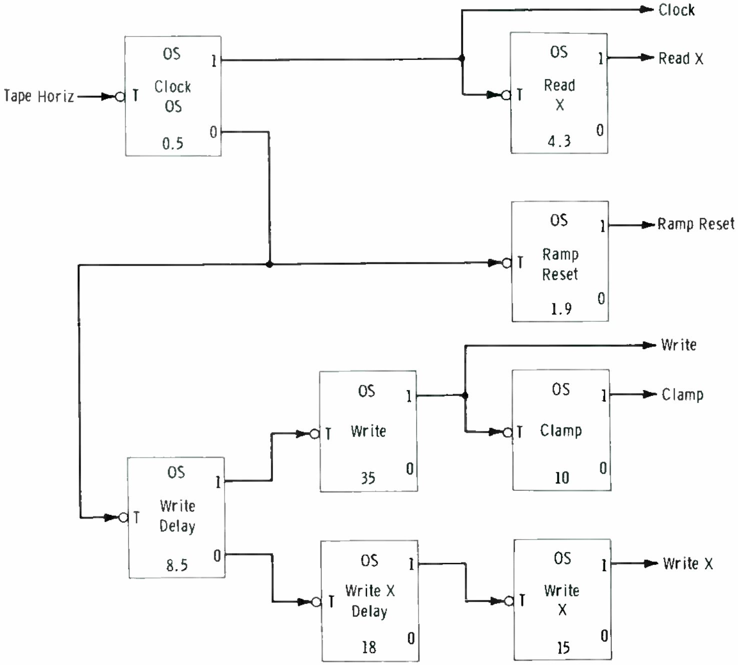


Fig. 9-7. Partial block diagram of VEC timing-generator circuits.

Among other circuits (not shown in Fig. 9-7), the positive-going clock pulse is applied to the read one-shot. This circuit produces a 4.3-microsecond pulse, which is used in the read portion of the memory cycle.

The 0 output of the clock one-shot is fed to the write-delay one-shot, which produces opposing pulses 8.5 microseconds wide at its two outputs. As in the clock circuit, both outputs of the write-delay one-shot are used as timing references. The 1 output produces a delay of 8.5 microseconds, but the 0 output produces no delay.

The 1 output of the write-delay one-shot triggers the write one-shot, which produces a positive pulse 35 microseconds wide at its 1 output. This pulse operates the write switch of the analog system. The trailing edge of the write pulse triggers the clamp one-shot, which has a pulse width of 10 microseconds. The 1 output of the clamp one-shot operates the clamp switch of the analog system. The clamp switch, therefore, closes as soon as the write switch opens, and it remains closed for 10 microseconds.

The 0 output of the write-delay one-shot is used as a timing reference for the write-X delay one-shot, which has a period of 18 microseconds. The 1 output of the write-X delay circuit triggers the write-X one-shot, which produces a 15-microsecond pulse. This pulse is used for control of the memory switching matrix. Note that the write-X pulse falls in the middle of the write pulse (Fig. 9-8).

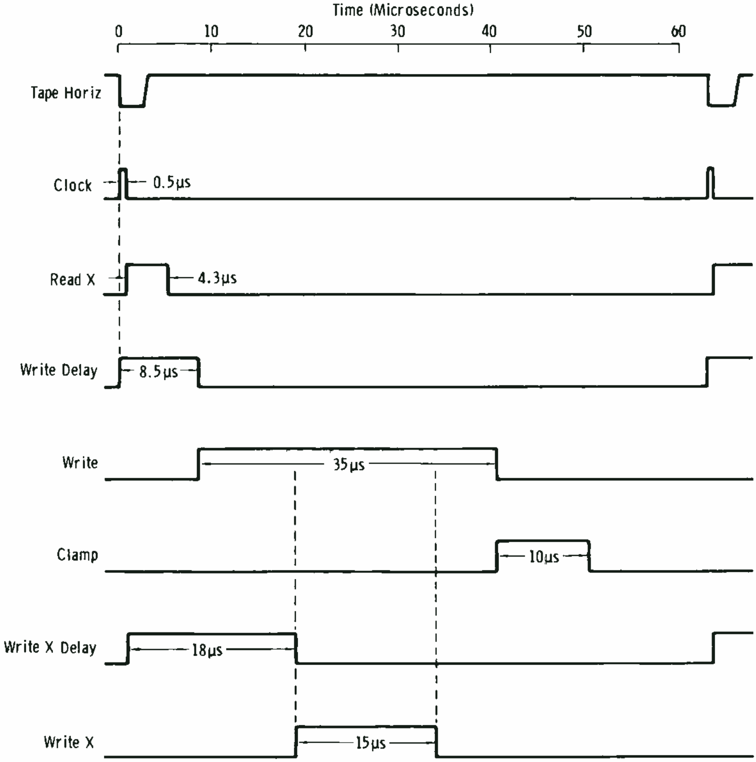


Fig. 9-8. Simplified timing diagram of horizontal-rate timing pulses.

Generation of Memory-Control Pulses

The memory-control circuits of the digital system (see block diagram, Fig. 9-9) are used to produce two basic types of control signals called the X and Y signals. These signals control the semiconductor switches that address the memory capacitors during the read and write periods. There are 16 different X signals and four Y signals, so that 64 pairs are possible,

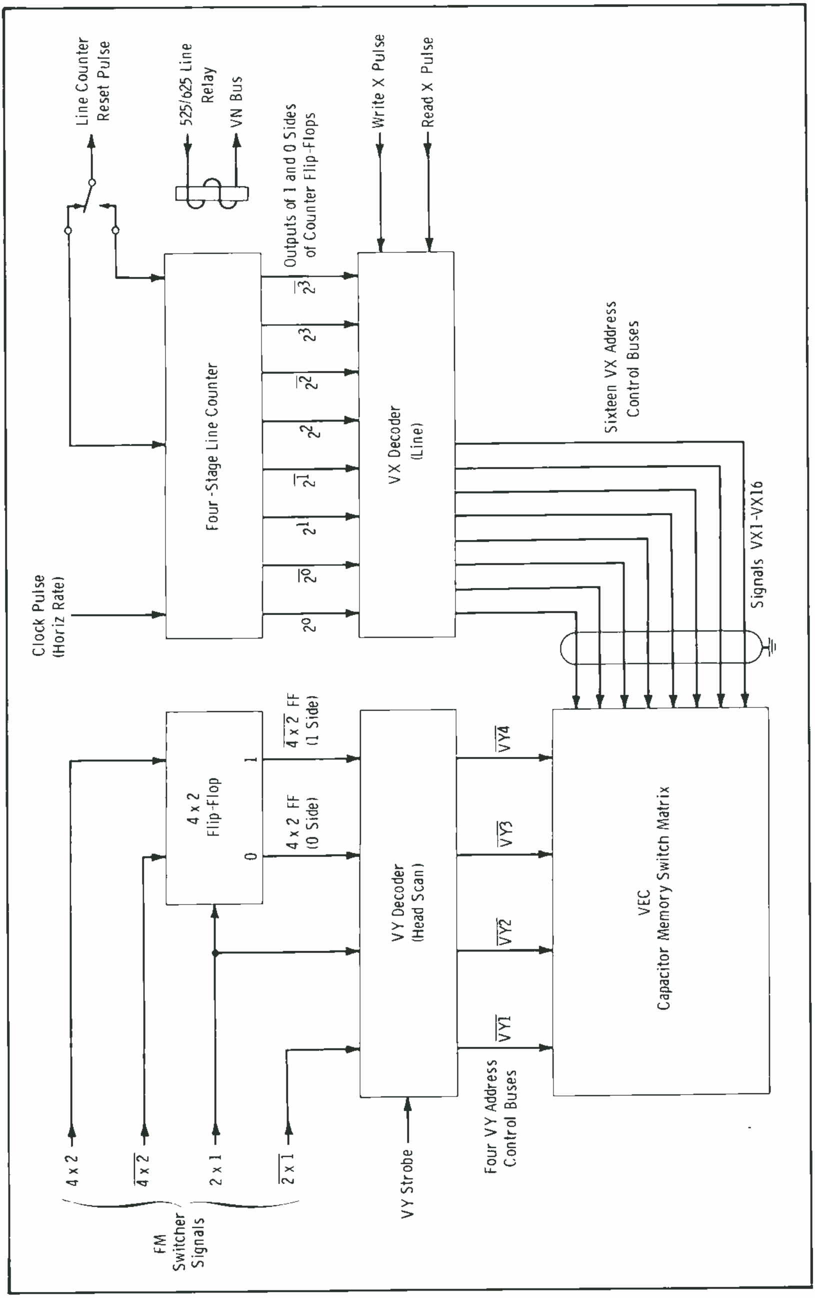


Fig. 9-9. Simplified diagram of VEC memory-control circuits.

each consisting of one X and one Y signal. Each pair corresponds to one of the 64 capacitors in the memory bank. A particular capacitor is addressed when its corresponding X and Y signals occur simultaneously. The X signal closes a switch that connects one side of the capacitor to the i/o bus, and the Y signal closes another switch that connects the other side of the capacitor to ground.

Information for generating the X signals is derived from a line counter and a decoder. The counter provides information as to which line is being scanned in any of the four head scanning intervals. The X decoder combines this line-count information with the read and write pulses to determine which capacitors should be connected to the i/o bus during the read and write intervals. (As previously mentioned, in any one line, different capacitors are addressed during the read and write periods. For example, in line 11, C11 is addressed during the read period, but C10 is addressed during the write period.)

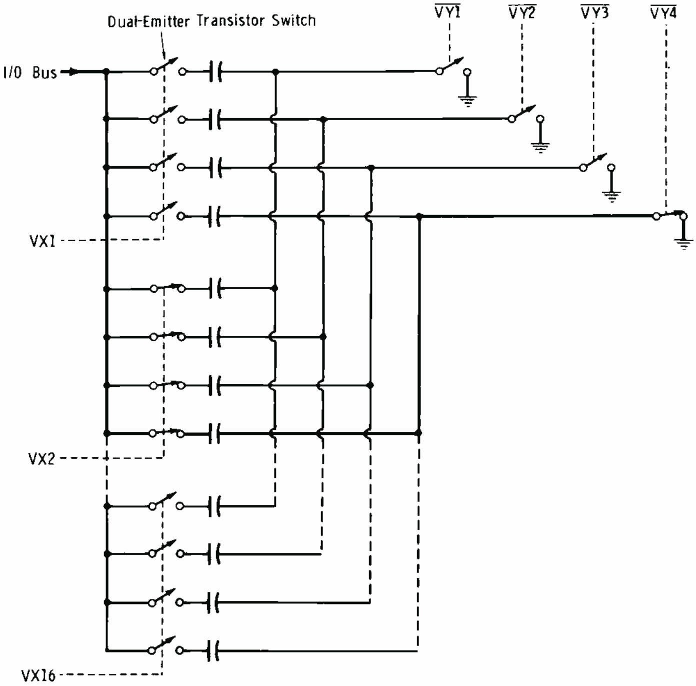
One Y-signal interval is provided for each of the four head scanning intervals. Information for generating the Y signals is obtained by using a decoder to extract from the 4 × 2 and 2 × 1 switcher outputs of the recorder information that indicates which of the four heads is scanning the tape. This information is combined with the read and write pulses to form the four Y-interval signals.

To permit addressing the memory capacitors in the desired sequence, a switching matrix is used as shown (simplified) in Fig. 9-10. There are 16 control buses, VX1 through VX16, from the X decoder, and four control lines, $\overline{\text{VY1}}$ through $\overline{\text{VY4}}$, from the Y decoder. The prefix "V" is used to distinguish the control lines of the VEC memory from the corresponding lines of the CAC memory. The bar over the VY symbols indicates that the switches controlled by these buses are closed when the signal voltages are at the lower of the two possible levels.

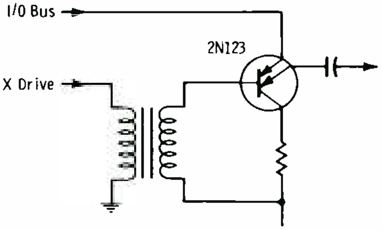
An individual normally open switch is connected between one side of each of the 64 capacitors and the i/o bus. Each VX bus simultaneously controls four of these switches. Each VY bus controls only one switch, but each of these switches is connected between ground and 16 capacitors, one from each of the 16 VX groups.

Normally the VX buses are low and the $\overline{\text{VY}}$ buses are high, so that all switches in the memory are open. When a given capacitor is addressed, however, the corresponding VX bus goes high, thereby closing four switches and connecting four capacitors to the i/o bus. Simultaneously, the corresponding $\overline{\text{VY}}$ bus goes low, thereby closing the Y switch corresponding to the head scanning interval, which grounds 16 capacitors. Only one of the 16 capacitors, however, belongs to the group of four connected to the i/o bus by the VX switches and, therefore, has a complete charge path. All other capacitors are inactive, because one side of the charge path is open. For illustration, the charge path of the capacitor corresponding to VX2 and $\overline{\text{VY4}}$ is shown in heavy lines in Fig. 9-10A.

The signals appearing on the VX and $\overline{\text{VY}}$ control buses are shown in simplified form in Fig. 9-11. With the exception of VX16, as explained later, two positive pulses are applied from the X decoder to each VX control bus during each head scan interval. The first pulse connects the addressed capacitor to the i/o bus during the read time of the particular scanning line, and the second pulse connects the same capacitor to the i/o bus during the write time of the next scanning line. This is done to permit predicting the slope of the ramp required for connecting the two MATC steps.



(*A*) *Simplified schematic diagram.*



(*B*) *Actual transistor switch.*

Fig. 9-10. VEC memory storage matrix.

The pulses on the VX1 through VX15 buses form an overlapping, or interlaced, sequence as shown in Fig. 9-11. For example, the first VX pulse to occur during line 2 of a head scan period is VX2, which occurs during the read time of line 2; the second pulse generated is VX1, which occurs during the write time of line 2. The pulses applied to VX16, however, do not conform to this pattern because, in succeeding headwheel revolutions, a seventeenth line occasionally occurs in each of the four head scan periods, although only 16 capacitors are provided for each head scan. Since the voltage stored in the sixteenth capacitor must serve for both the sixteenth and seventeenth lines, this capacitor can be written into only when a seventeenth line is present. This capacitor is always read out during the sixteenth line of either a sixteen-or seventeen-line pass. In a 17-line pass, however, this capacitor must be read out again during the seventeenth line. The ramps for the sixteenth and seventeenth lines, therefore, will be identical, but little error will be introduced because the differences in slope between adjacent ramps are normally small.

During a 16-line head pass, the only pulse appearing on the VX16 bus will occur during the read period of line 16. During a 17-line pass, however, three pulses will appear on VX16, the first during the read period of line 16, the second during the read period of line 17, and the third during the write period of line 17.

During the scanning period of each of the four video heads, a train of negative-going pulses is applied from the Y decoder to the corresponding $\overline{\text{VY}}$ bus (Fig. 9-11). Each of these negative-going pulses corresponds to a positive-going pulse on one of the sixteen VX buses. The corresponding VX and VY pulses occur at the same time, thereby closing both the X and Y switches of the addressed capacitor for the duration of the pulses.

Because the change in level between the first MATC step in a given head scan and the last step in the preceding head scan does not represent a true velocity-error difference, no capacitor is provided for storing this voltage. Consequently, no write period exists during the first line. The first two pulses in the $\overline{\text{VY}}$ train, therefore, occur during read periods, and the remaining pulses (except during a seventeenth line) occur alternately in write and read periods.

9-4. THE CHROMA AMPLITUDE CORRECTOR (CAC)

Like the VEC, the CAC consists of an analog system and a digital system. The analog system compares the amplitude of the burst in the tape video signal with a threshold level, generates an error voltage proportional to the difference, and stores the error voltage in a capacitor memory. At the beginning of each line, the voltage on the corresponding memory capacitor is read out and used to generate two push-pull control voltages. These voltages are fed to the fm equalizer of the tape machine, where they automatically vary the equalization to keep the burst level constant.

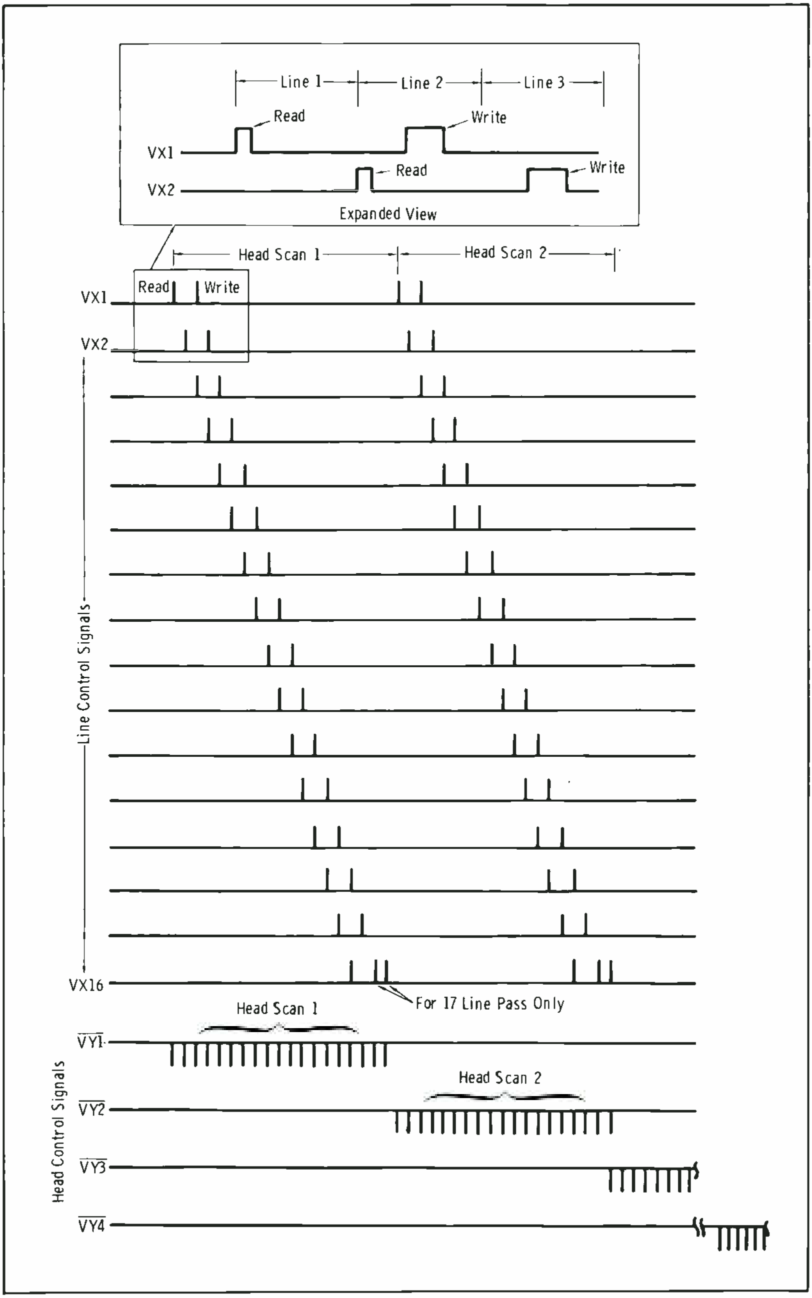


Fig. 9-11. Simplified timing diagram of VEC memory-control pulses.

Although the CAC error voltages are based entirely on the burst amplitude, the burst actually constitutes a sample of the chroma signal. If there is no differential gain in the system, the changes in equalization derived from measuring the burst amplitude alone will be correct for the entire chroma signal.

As in the VEC system, functions such as reading out of or writing into the capacitor memory are controlled by semiconductor switches. These switches are operated at the required times by pulses from the digital system. Many of the digital pulses are identical to those used in the VEC and are produced by the same circuits.

CAC Analog System

A functional block diagram of the CAC analog system is shown in Fig. 9-12. (Basic waveforms are in Fig. 9-13.) The system constitutes a closed loop, since the burst input to the Cavec is obtained from the demodulator of the machine, and the push-pull output signals of the CAC are fed back to the fm equalizer in the machine. To simplify the discussion, however, the operation will be described first as if the loop were opened at the point marked "X" in Fig. 9-12. Under these conditions, the CAC correction voltages are not applied to the fm equalizer, and color errors due to chroma variation therefore appear as differences in burst amplitude from line to line.

Open-Loop Operation

In the machine, the demodulated video is fed to a filter circuit, which removes spurious frequency components. The filter is installed in the burst processor module during the CAC installation. The filtered burst is fed to a half-wave detector and low-pass filter in the Cavec unit. This circuit removes the subcarrier components and leaves only the half-wave rectified envelope of the original burst. The envelope is applied to a peak detector which produces a dc signal proportional to the peak amplitude of the envelope. This signal is fed to a threshold detector which produces an output proportional to the difference between the burst amplitude and a reference level set by a potentiometer. This difference voltage, which constitutes the CAC error signal, is fed to the i/o bus of the CAC memory when the write switch is closed; it is then stored in one of the 64 memory capacitors. The particular capacitor selected, or addressed, is determined by the CAC digital system in a manner similar to that of the VEC digital system. After the writing process has occurred, a clamp signal from the digital system closes another switch which discharges a capacitor in the peak-detector output to ground.

In this manner, there is stored in each of the 64 memory capacitors a voltage which represents the average error between the burst and reference levels for a particular line in a particular head scan interval. At the start of each line, the CAC error signal stored in the corresponding capacitor is

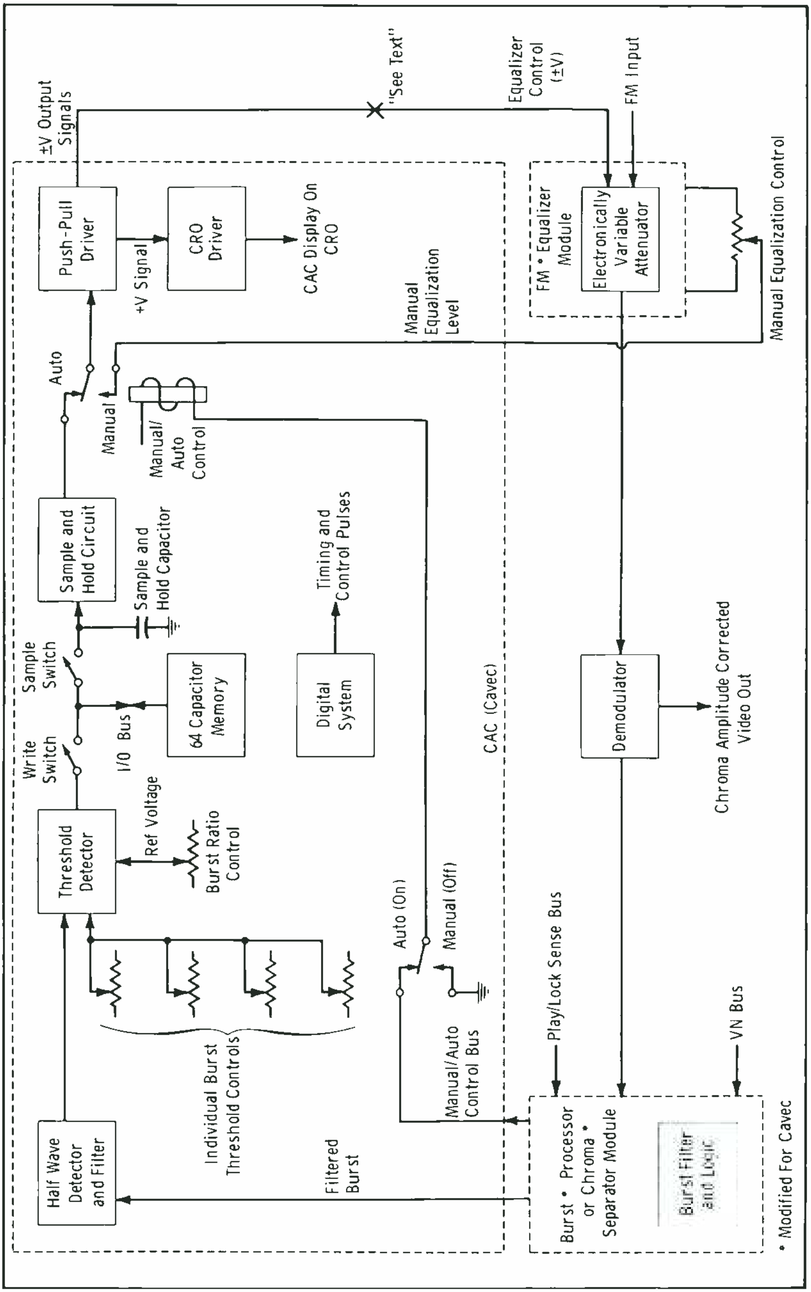


Fig. 9-12. Functional block diagram of CAC.

read out by applying it to the i/o bus. During the read interval, a switch transfers the voltage from the i/o bus to a temporary-memory capacitor in the sample-and-hold amplifier. The output of the sample-and-hold amplifier is fed to two drivers which develop push-pull control voltages (± V) proportional to the sampled error. These two signals constitute the CAC control output of the Cavec unit.

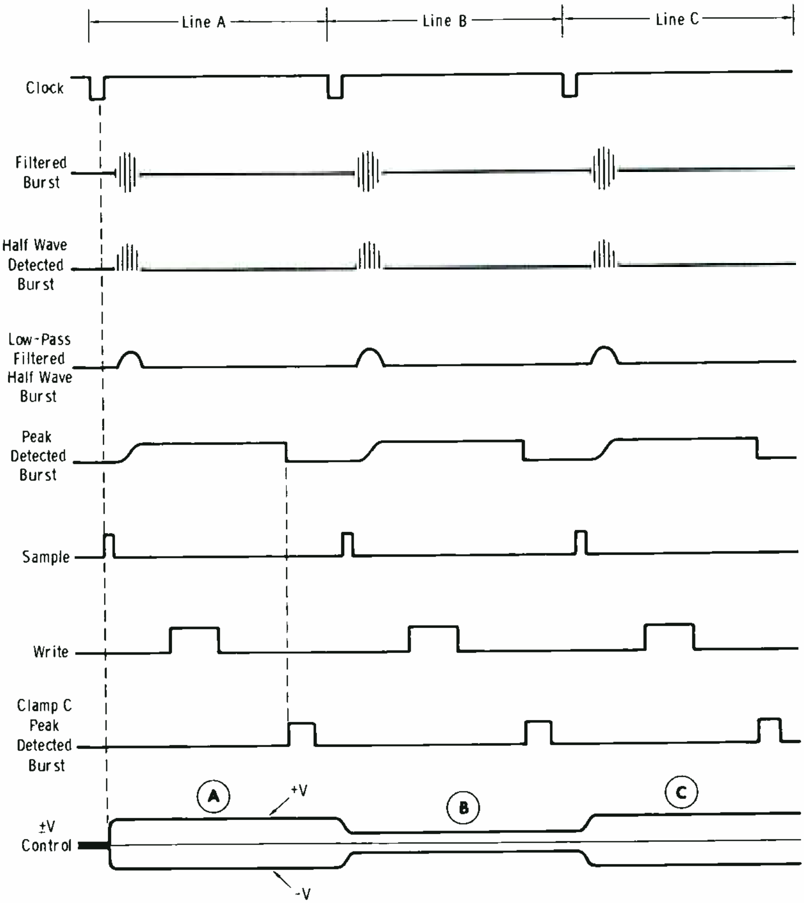


Fig. 9-13. Basic waveforms in CAC.

Closed-Loop Operation

For closed-loop operation, the ± V signals from the Cavec are applied to an electrically controlled variable attenuator installed in the fm equalizer module during the CAC installation procedures (described in more detail later). This circuit performs the same function as that performed by the manual equalization potentiometer before installation of the CAC. Changes in attenuation vary the fm equalization by changing the relationship between the energy in the sidebands and the energy in the carrier. The phasing of the ± V signals is such that they tend to reduce variations in burst amplitude. Thus, the system acts as a feedback loop, with the ± V signals providing the negative feedback. Because of the 64 memory capacitors, the system has the same effect as 64 closed loops, one for each line in each head scan.

To permit effective closed-loop operation, the read-out and write-in of the CAC error for a particular line must occur during that same line, and read-out must occur before the burst appears at the fm input of the fm equalizer. As a result, the read-out and the resulting correction occur shortly after the leading edge of the tape horizontal signal, as shown in Figs. 9-13 and 9-14.

For a 17-line head pass, on 525-line standards, the error voltage on the capacitor written into during the sixteenth line is read out during both the sixteenth and seventeenth lines. (Similarly, on 625-line standards, the capacitor written into during the fifteenth line is read out during both the fifteenth and sixteenth lines.) The inaccuracy thus produced is not visible

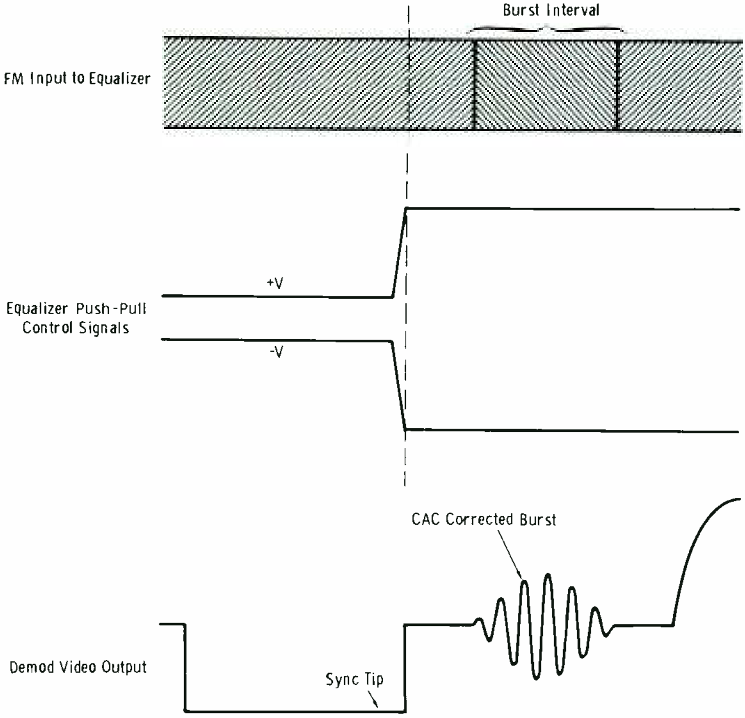


Fig. 9-14. Timing relationship of bursts in fm and video.

in the picture because a seventeenth line does not occur periodically during successive scanning periods of the same video head.

CAC Digital System

As in the VEC, previously described, the basic timing signals for the CAC are derived from the tape-horizontal, 2 × 1 switcher, or 4 × 2 switcher signals. In fact, most of these signals are produced by the same circuits for both the CAC and the VEC.

The CAC uses the same line counter as the VEC (Fig. 9-15). The counter produces 16 unique binary combinations of output signals, one for each line of a 16-line head scan. (When a seventeenth line is present, it is detected by additional logic circuits.) The counter output combinations are decoded to produce sixteen X address signals for the capacitor memory; these are referred to as the CX signals to distinguish them from the VX signals used in the VEC.

A CY strobe signal (similar but not identical to the VY strobe) is generated by combining the read and write pulses for each scanning line. This signal and the 2 × 1 and 4 × 2 switcher signals are combined in a decoder to produce the four Y address signals for the memory, $\overline{\text{CY1}}$ through $\overline{\text{CY4}}$. Each of these signals consists of a train of 16 or 17 pairs of read and write pulses (15 or 16 for 625-line standards) occurring only during a particular one of the four head scanning intervals. The information for determining the head scanning intervals is obtained from the 4 × 2 and 2 × 1 switcher signals.

As in the VEC, each pair consisting of one CX signal and one $\overline{\text{CY}}$ signal addresses a particular capacitor in the CAC memory. Thus, through the use of a switch matrix controlled by the CX and $\overline{\text{CY}}$ signals, the capacitors can be addressed sequentially. When the pair of signals corresponding to a given capacitor occurs simultaneously, one side of the capacitor is connected to the i/o bus, and the other is connected to ground, thereby completing the charge path of this capacitor only. Unlike the case of the VEC, the same capacitor is addressed during the read and write intervals of a given scanning line.

Electronically Controlled FM Equalization

In an fm equalizer module unmodified for Cavec, equalization is accomplished by delaying the fm signal and then subtracting the delayed signal from the undelayed signal in a differential amplifier. Both the crossover frequency of the equalization curve and the degree of equalization (departure from flat response) can be adjusted. The crossover frequency is adjustable in steps by a five-position switch that selects different amounts of delay. The degree of equalization is adjustable by a front-panel potentiometer which controls the amplitude of the delayed signal. (The larger the signal in the delayed path, the less the equalization is, and the smaller the chroma content of the video signal is.)

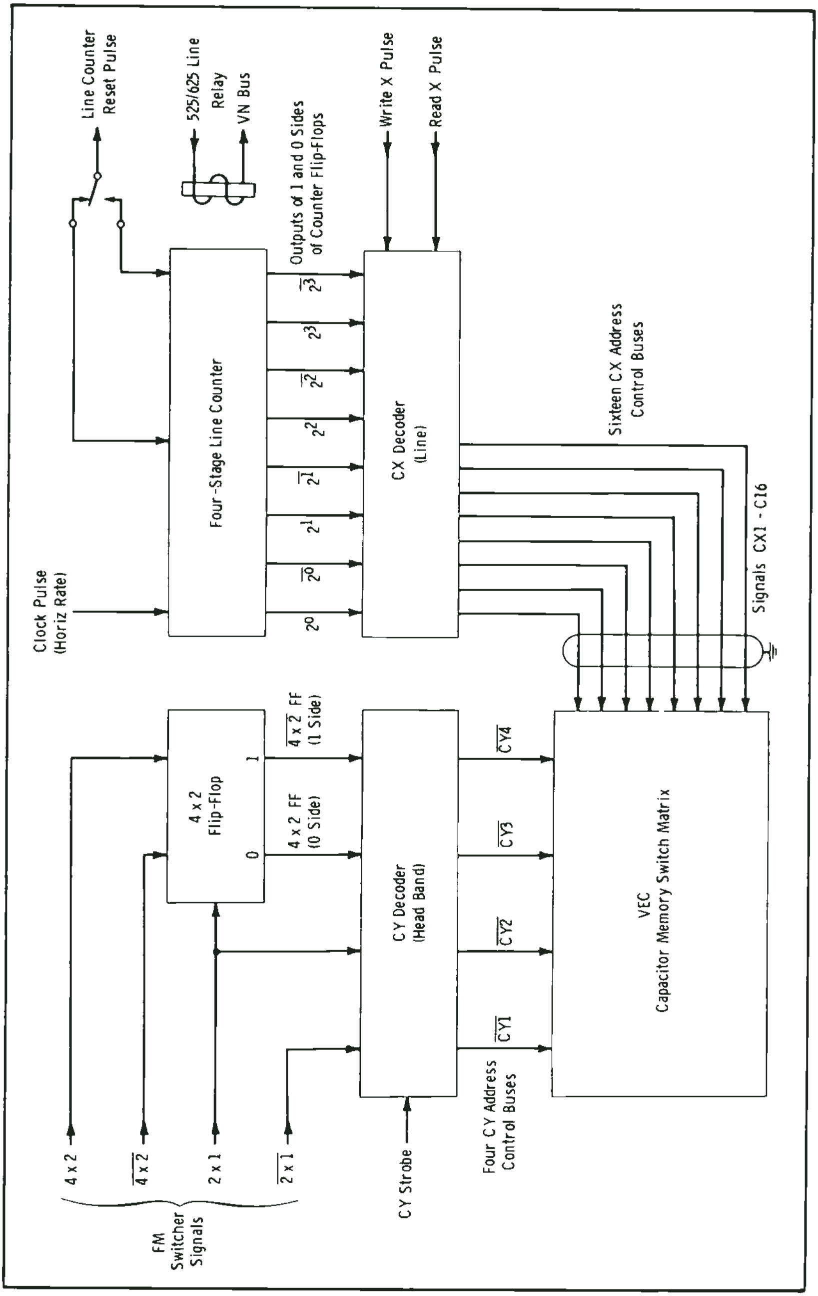
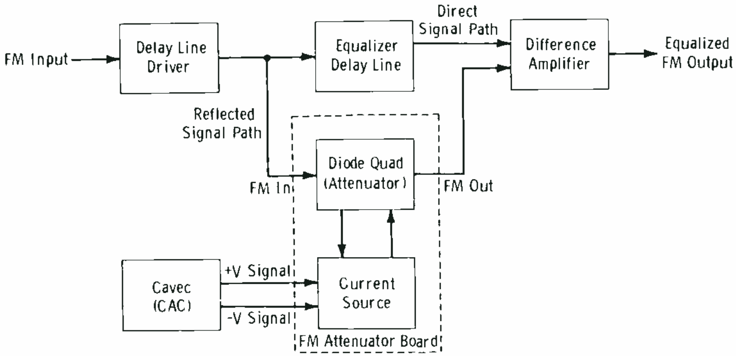


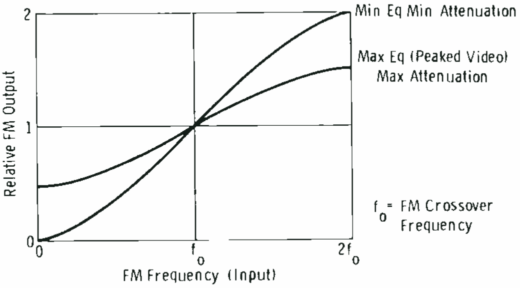
Fig. 9-15. Simplified diagram of CAC memory-control circuits.

When the fm equalizer is modified for CAC, a circuit board containing an electrically controlled attenuator is added to the module (Fig. 9-16). This circuit is inserted in the path of the delayed signal in place of the potentiometer. The ± V signals from the CAC output of the Cavec are then used to control the attenuation. When the manual/auto relay (Fig. 9-17) is in the auto condition (energized), the ± V signals are derived from the error signals stored in the CAC memory. The equalization is thus controlled automatically on a line-by-line basis. Under these conditions, the manual equalization control on the equalizer module is disconnected, and the only way that the degree of equalization can be changed manually is by adjusting the BURST RATIO control on the front panel of the Cavec unit. When, however, the relay is in the manual condition (de-energized), the ± V signals are derived from a dc voltage which depends on the setting of the manual equalization potentiometer on the fm equalizer. The equalization can then be controlled manually by adjusting this potentiometer.

Fig. 9-18 is a schematic diagram of the fm attenuator board. The circuit consists of diode quad M1, transistors Q1 and Q2, and two regulated supplies consisting of R4, X1, and C1 and R7, X2, and C2.



(A) Block diagram.



(B) Equalization curves.

Fig. 9-16. Principle of electrically controlled fm equalization.

An output voltage of −3.9 volts is provided by R7, X2 and C2; R4, X1, and C1 provide +3.9 volts. Transistor Q2 (npn), diode quad M1, and transistor Q1 (pnp) are connected in series between the −3.9- and +3.9-volt supplies. The delayed fm signal is fed into junction A of M1, and the output is taken from junction B. The +V signal from the Cavec module is applied to the base of Q1, and the −V signal is applied to the base of Q2. The networks containing R1, C3, R3, and C4 filter the ±V signals. The +V and −V signals control the current through the path consisting of Q1, junctions C and D of M1, and Q2. The current decreases as the +V signal assumes more positive values (and the −V signal assumes more negative values) because the transistors approach cutoff. For fixed values of +V and −V, the current is constant.

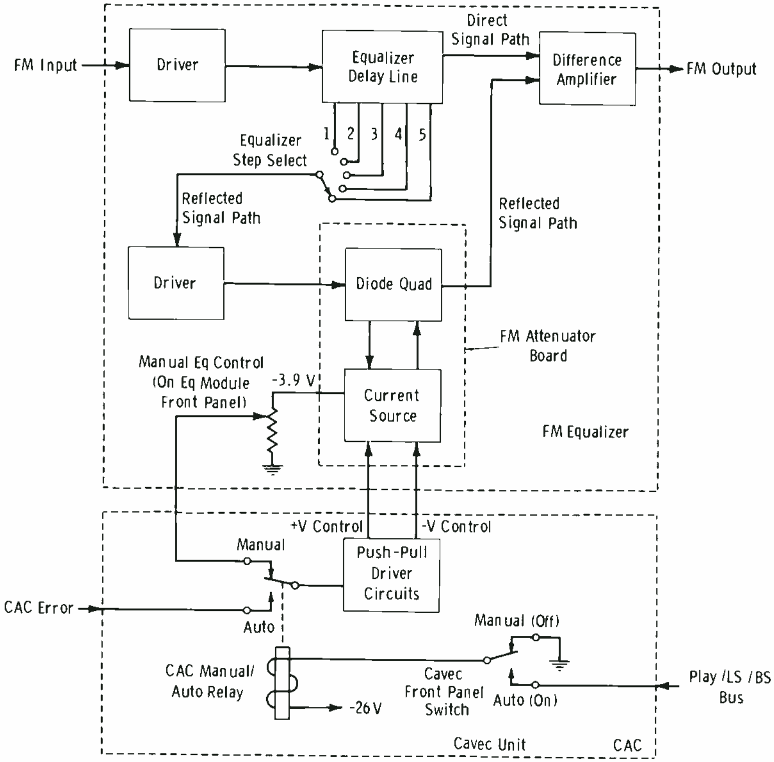


Fig. 9-17. Partial block diagram of fm-equalizer control system.

Since the four diodes are forward biased, the fm signal applied to junction A can flow through the quad to the output at junction B. The impedance between junctions A and B, however, depends on the amount of forward bias current. This, in turn, depends on the current supplied by Q1 and Q2. The quad, therefore, attenuates the fm input by an amount depending on the ±V signals. The larger the +V signal, the greater is the attenuation of the delayed-path fm signal and the greater is the chroma content of the video. Conversely, the smaller the +V signal, the smaller are the attenuation and the chroma content of the video. Use of the two balanced push-pull drive signals reduces transient disturbances and distortion of the fm signal.

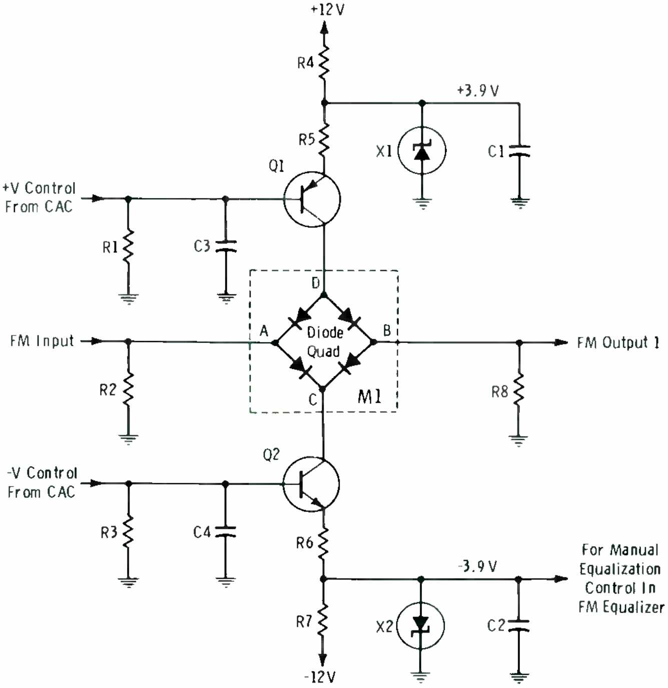


Fig. 9-18. Simplified schematic diagram of fm-equalizer attenuator board.

The −3.9-volt zener regulator circuit (R7, X2, and C2), in addition to providing bias to Q2, provides the input voltage to the manual equalization potentiometer on the fm equalizer module. The arm of this potentiometer is connected through a resistor divider to the manual/auto relay in the Cavec unit. When the relay is de-energized, the attenuated potentiometer voltage is fed to the input of the first push-pull driver stage. Consequently, since the ±V signals depend on the potentiometer voltage, the equalization can then be varied manually by adjusting the potentiometer. When, however, the relay is energized, the potentiometer voltage is disconnected, and the CAC error voltage from the sample-and-hold capacitor is fed to the first push-pull driver. Under these conditions, the potentiometer has no effect, and the equalization is controlled automatically by the CAC signals from the capacitor memory.

EXERCISES

Q9-1. Give the two primary causes of color banding.

Q9-2. What are the primary causes of (A) hue banding and (B) saturation banding?

Q9-3. To what value is any single line of color (hue and saturation) corrected?

Q9-4. What is the basic function of (A) the analog circuits and (B) the digital circuits in Cavec?

Q9-5. Why doesn't the Automatic Time Correction (ATC) circuitry remove color errors occurring in each head pass?

Q9-6. What does VEC basically do to correct velocity errors?

Q9-7. How are the correct slope and amplitude of the ramp described in A9-6 obtained?

Q9-8. Why is the particular VEC memory capacitor that is addressed during readout not written into during that line, but written into during the following line (Fig. 9-11)?

Q9-9. In Fig. 9-10, what are the X and Y signals of the VEC memory-control pulses?

Q9-10. Do the CAC memory capacitors have the same readout and write-in timing as the VEC memory capacitors?

CHAPTER 10

Splicing and Editing for Quadruplex Recording

Motion-picture film can be examined on a frame-by-frame basis at zero speed for the purpose of cutting and splicing for editing. Video tape, however, produces no output unless it is moving, and it must be moving near the recorded speed for a usable picture. Thus video-tape editing is essentially a dynamic function rather than a static one, and it requires special considerations.

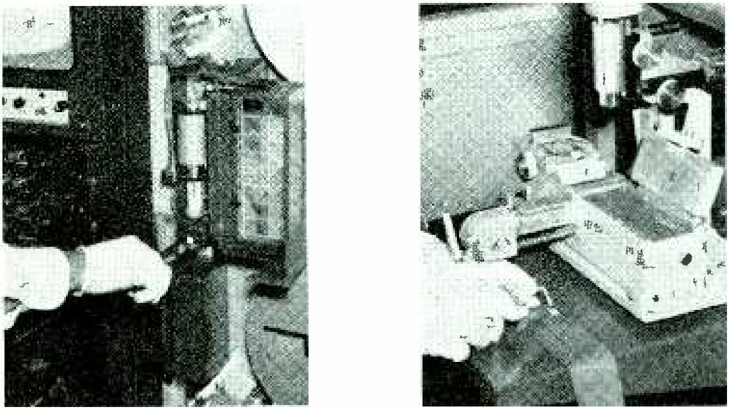
It is natural that the first approach to video-tape editing or splicing was a mechanical operation which involved making the magnetic tracks and editing marks visible (see Fig. 2-10 in Chapter 2 for an example) so that tapes could be cut at the proper place to avoid picture disturbances. Mechanical splicing is still used in limited applications, and we will consider this technique first. We will then examine the more recent systems of electronic editing, and, finally, we will study automatic (computerized) editing programmers.

First, it should be known that early tape systems (monochrome) did not operate synchronously with local station sync, and 60 edit pulses per second (one pulse per field) seemed most appropriate. However, when synchronous operation became a practical reality, a specific field was used for reference so that splicing always occurred on the same field to avoid a momentary half-line "bobble." Therefore, the edit-pulse rate became 30 pulses per second, and these pulses are termed frame edit pulses. Later, with the advent of color, the edit-pulse rate became 15 pulses per second in many systems so that the four-field cycle of the NTSC color signal could be accommodated.

10-1. MECHANICAL SPLICING

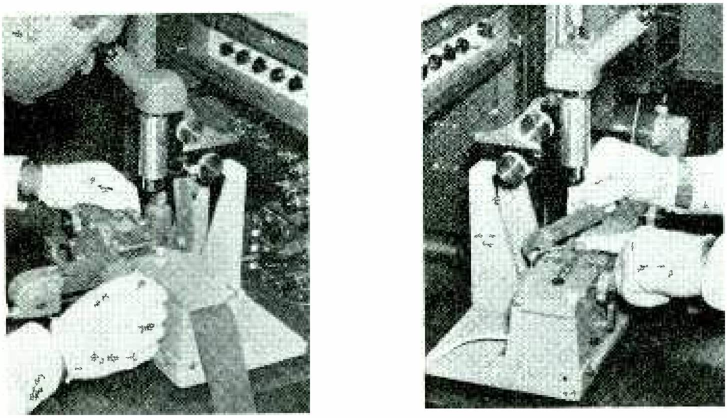
Fig. 10-1 illustrates the steps in splicing video tape using the RCA optical tape splicer. A 40-power microscope is employed for location and precise alignment of frame pulses. To eliminate rollover and/or temporary horizontal instability following a splice, the cut must be properly framed with the edit pulse and formed to a clean, solid, square butt-splice.

A mechanically perfect video-tape splice can be accomplished by observing precautions of cleanliness, application, and handling. Dust, dirt, debris, fingerprints, and solvents must all be carefully removed prior to the application of the splicing tape. The adhesive area of the splicing tape should not



(A) Stop recorder at desired location and cut tape.

(B) Develop tape with solution of iron oxide to locate nearest edit or frame pulse.



(C) Align edge of video track on built-in reticle to cut tape halfway between adjacent video tracks.

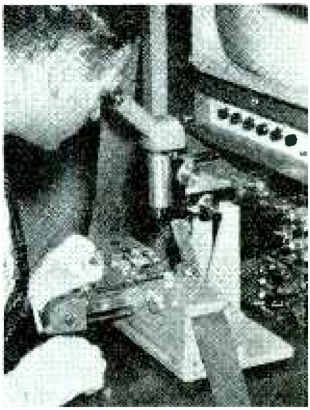
(D) Bring cutter into position and make cut.

Fig. 10-1. Steps in mechanical

be touched or exposed to airborne contamination by excessive exposure to air before application. Adequate pressure must be applied to the splice to remove air bubbles and to assure proper sealing. With the use of a quality splicing tape and proper splicing techniques, a video-tape splice will last indefinitely, therefore contributing additional tape life and economy.

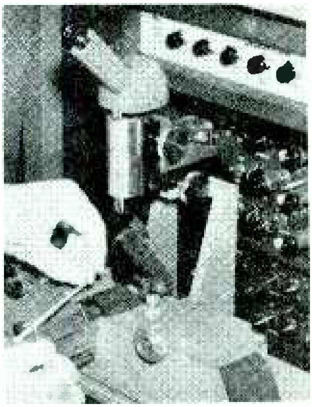
There are three basic reasons why a splice fails: improper application, contamination, and improper handling of the splicing tape. Any one of

(E) Drape tape from supply reel over tape support post and position under left hold-down door.



(F) Align tape track prior to making cut.

(G) Shear tape to be joined to tape already in splicer.

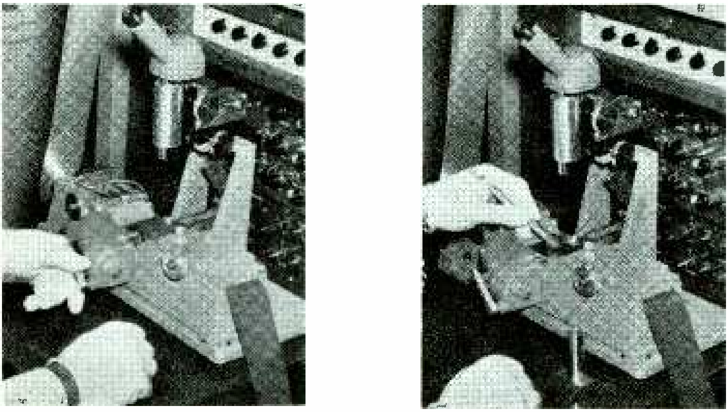


(H) Dispense splicing tape and prepare to put it in place.

splicing of video tape. (Cont'd on next page.)

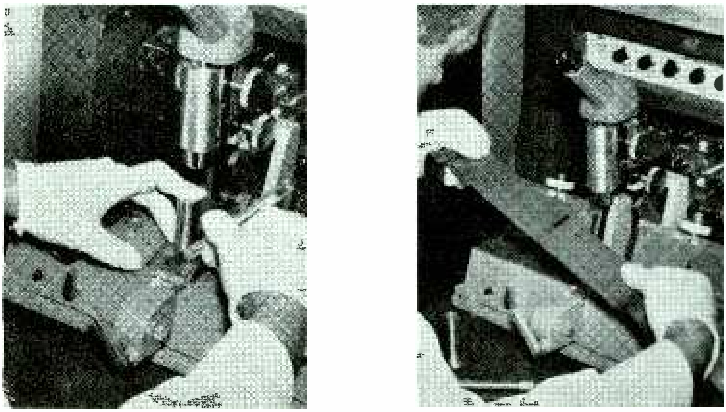
these elements or a combination of them can cause splice failure and excessive tape and head wear.

The adhesive used in a splicing tape is pressure sensitive. This special adhesive, to assure a perfect bond, requires adequate pressure during application. Occasionally, an operator does not apply sufficient pressure to the entire surface of the splicing tape, causing an improper bond between the video tape and the splicing tape. After the splicing tape is applied to the



(*I*) *Insert splicing tape beneath the lifted ends of the two tapes to be joined.*

(*J*) *Press both ends of the tape firmly to provide a perfect butt joint.*



(*K*) *Trim away excess splicing tape with trimming tools.*

(*L*) *Examine the completed splice.*

Courtesy RCA

Fig. 10-1. Steps in mechanical splicing of video tape.—cont'd.

video tape, pressure may be applied across the entire surface of the splicing tape with a clean blunt instrument or clean rubber roller.

Proper alignment and centering of the splicing tape directly over and in line with the splice cut must be assured for maximum strength. If the splicing tape is not centered over the spliced sections, a lopsided splice will result, with the narrow side being weak and susceptible to failure. If any of the splicing-tape edges are not tightly sealed to the video-tape backing, contamination will tend to collect at the areas of exposed adhesive. Contamination deposits may cause tape damage and head wear in a manner similar to the action of air bubbles.

Contamination of video-tape splices is caused by a variety of sources such as solvents used for cleaning the tape, fingerprints, debris from transports and splicing fixtures, and airborne dust.

Weakening and subsequent failure of splices can occur if the solvent used to clean the video tape (such as that used to remove splicing powder) is permitted to seep onto the adhesive of the splicing tape. The finite separation which exists between the sections of video tape being spliced can allow the solvent to deteriorate the adhesive. Most commonly used solvents (alcohol, Freon TF[1]) are low-viscosity solutions which can easily penetrate the small splice separation. To avoid solvent damage to the adhesive, be certain that the tape is completely dry before applying the splicing tape.

Fingerprints, debris, and wear products can weaken the bond between the splicing tape and the video-tape backing. A fingerprint is a deposit of body oil which greatly reduces the bonding strength of the pressure-sensitive adhesive. Fingerprints on either the video tape or the adhesive surface of the splicing tape can be eliminated by proper handling or by wearing lint-free gloves.

Ideally, the video-tape backing should be cleaned with a cotton swab moistened with Freon TF to remove fingerprints and contamination. After cleaning, the splice area should not be touched with exposed fingers. When the solvent has evaporated and the tape is completely dry, the video-tape sections can be aligned and the splicing tape applied and secured.

Cleanliness of the splicing fixture and the immediate work area must be conscientiously observed during splicing operations. The knife portion of the splicer and the splicing-tape application plate must be kept meticulously clean to avoid trapping contamination within the splice. In addition, the loose end of the splicing tape which protrudes from the dispenser is subject to airborne contaminants and loose debris that can make it unsuitable for use.

In handling the splicing tape, avoid touching the adhesive surface which will contact the video-tape backing, protect the splicing tape from contamination, and do not distort or stretch the splicing tape during application.

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[1] DuPont Trademark

10-2. ELECTRONIC SPLICING (AMPEX)

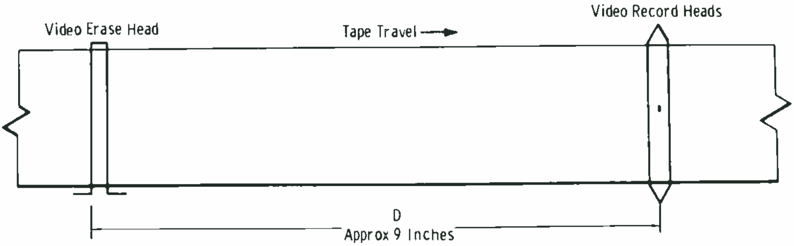
With electronic splicing, the recorder may be started and stopped at random between scenes for costume or scenery changes, for animation effects, or for any other special purpose. In addition, the recorder may be used to insert new scenes or commercials at any chosen point in the middle of a previously recorded program. This feature permits the correction of production "fluffs" that may have occurred anywhere in an otherwise perfect recording.

The heart of the Ampex system is the *Electronic Editor,* a solid-state unit that modifies the switching logic of a standard Ampex television recorder. Consider the situation that would exist in an unmodified recorder if a recorded tape were threaded onto the machine, and, at some point during the replay of this tape, the record button were operated to record a new scene into the middle of the existing program. Record current would be fed to the video record heads to record the new scene, and erase current would be fed to the erase head to erase the old scene. However, a number of problems would arise which would make the attempted transition from the original recording to the new recording impossible to achieve. These problems involve servomechanism disturbances, incorrect phasing of the reproduced tape signal and incoming video signal, and an overlap of recording caused by the distance between the video record and erase heads.

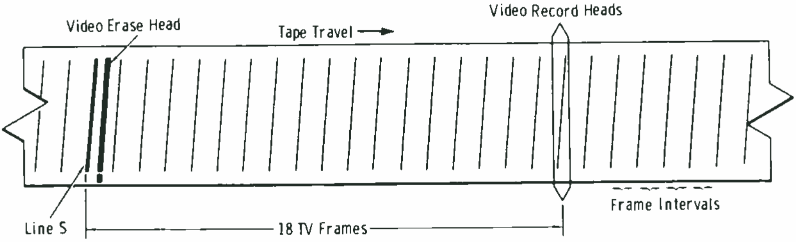
Fortunately there are straightforward solutions to each of these problems. It is possible to arrange the servo system so that it uses the same sources of drum and capstan drive signals on entering the record mode that it uses during the play mode. Specifically, the drum drive signal remains phase locked to the system vertical sync, and the capstan drive source remains a 60-Hz Wien-bridge oscillator. During the record mode, this oscillator is free-running, but no difficulty from long-term drift occurs, because any minor variation in frequency will be tracked out during replay.

The correct phasing of the reproduced tape signal to the incoming video is obtained by using the Intersync television signal synchronizer. This unit is a precision servo-control mechanism that guarantees that synchronizing pulses recovered from the tape have a very close time relationship to synchronizing pulses from the studio sync generator.

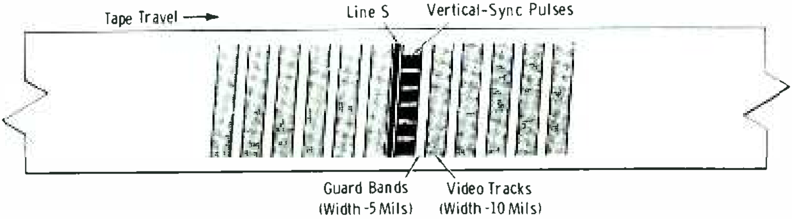
The problem of the distance between the video record and erase heads remains. This distance (Fig. 10-2A) would cause a double recording to exist for 9 inches of the tape. The double recording, in turn, would cause both the sync-processing and servomechanism circuits to malfunction. To deal with this problem, the distance must first be translated into units precisely and readily measurable by electronic means. It has been found convenient to do this by considering the distance as a time interval corresponding, at the linear tape speed of 15 in/s, to slightly less than 18 television frames. On the section of tape in Fig. 10-2B, line S is exactly 18 frames ahead of the video record head and is slightly ahead of the intended splice.



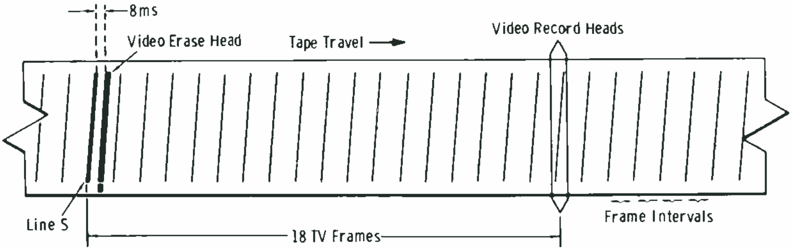
(*A*) *Separation of erase and record heads.*



(*B*) *Measuring head separation.*



(*C*) *Detail of splicing point.*



(*D*) *Initial position of splicing point.*

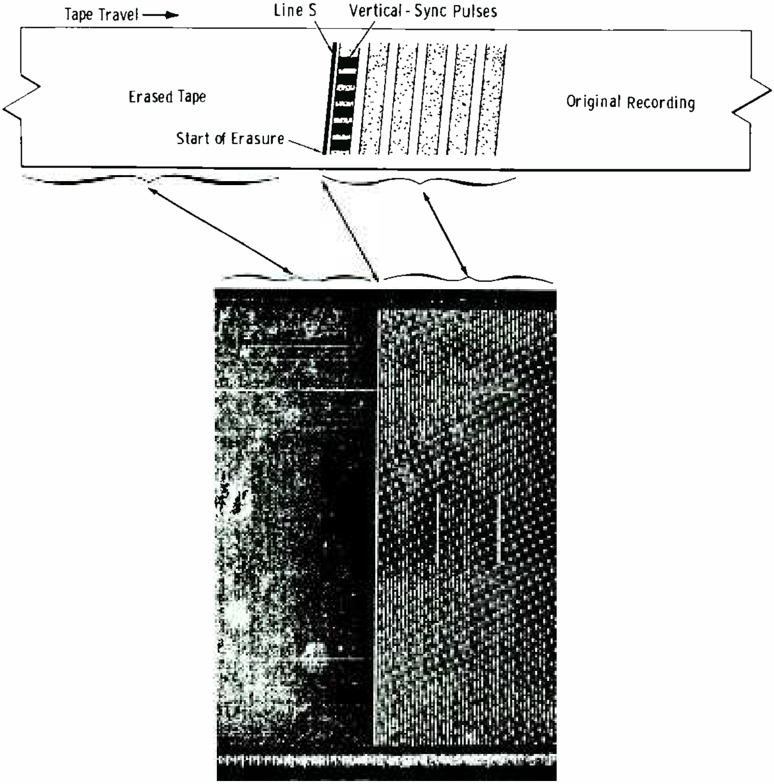
Courtesy Ampex Corp.

Fig. 10-2. Head separation and location of splicing point.

This line is further defined as existing in the guard band following a video track that bears vertical-synchronizing pulses, as shown in Fig. 10-2C.

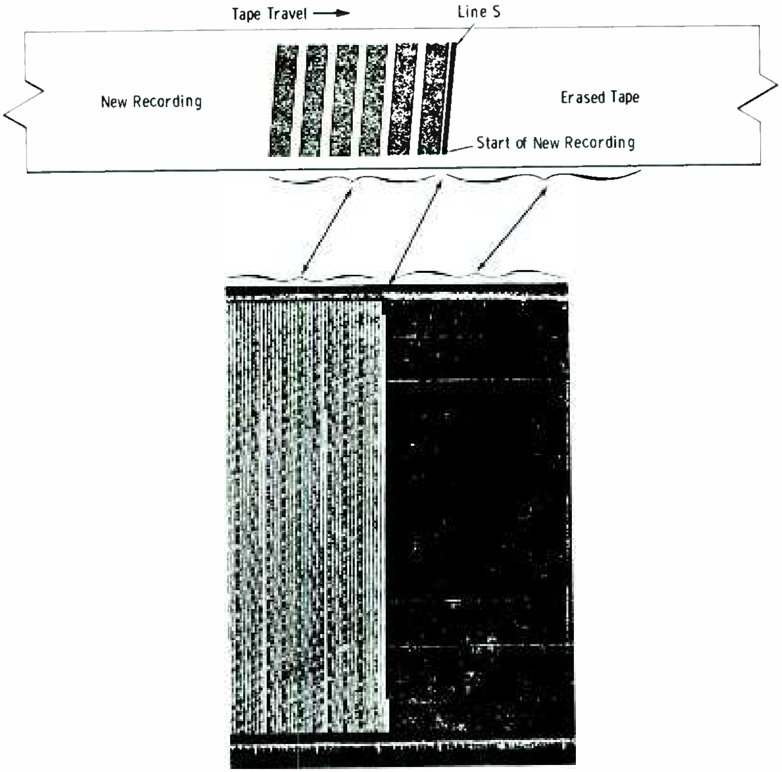
In the operation of the Electronic Editor, the location of line S is determined after a random cue by means of a vertical-gating circuit, which detects the first frame synchronizing pulse following the cue. At this instant in time, the tape lies under the heads as shown in Fig. 10-2D. The times taken for line S to travel to the video erase head and the video record heads may be defined as 8 milliseconds and 18 frames, respectively.

The 8-millisecond delay is obtained from a delay multivibrator; at the end of this period, the erase head is energized by an electronic gating circuit. Turn-on time is approximately 30 microseconds, and erasure starts exactly on line S (Fig. 10-3). The 18-frame delay is computed by a binary counter system. At the end of this period, the record current is gated on electronically. Turn-on time in this case is 2 microseconds, and the new recording starts immediately following line S, as shown in Fig. 10-4.



Courtesy Ampex Corp.

Fig. 10-3. Start of video erasure.



Courtesy Ampex Corp.

Fig. 10-4. Start of video recording.

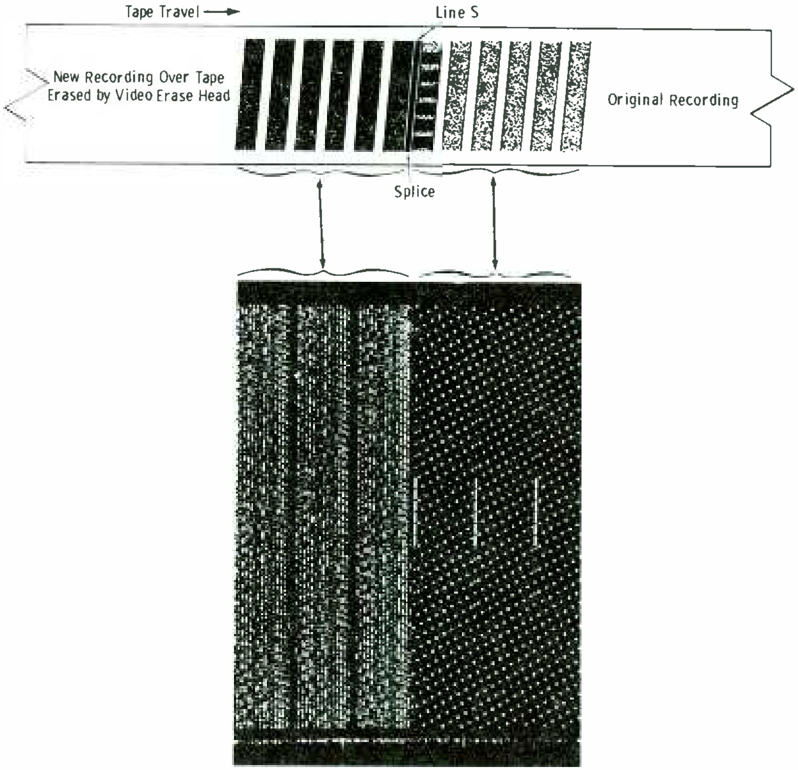
The accuracy obtained from the foregoing system is approximately 0.05 percent, which enables the operator to make perfect butt splices by merely pressing the record button. The preservation of all video information at the splice and the accuracy of tracking is evident from an examination of Fig. 10-5.

The Electronic Editor has two modes of operation, referred to as insert and assembly. In the assembly mode, the unit may be used to add further program material to the end of an existing program, and, in this way, assemble a complete program from individual short scenes. In fact, a completely edited tape may be prepared with only one camera and one recorder.

The insert mode is used to insert fresh material into the middle of an existing tape. In this mode, commercials, for example, may be added to a recorded program at any time following its original preparation. Also, because any information behind the inserted material is erased and there is no loss of sync, it is possible to correct errors in the original production.

If the action is repeated and the RECORD button is pressed, the scene containing the production error is replaced with a new scene.

Obviously, in the insert mode it is necessary to make two splices per operation and still maintain synchronism. The first (or ingoing) splice was described previously. The second (or outgoing) splice is made in a similar manner, except that at the end of the measured time intervals, the erase and record currents are turned off instead of on. This is performed with the same precision as that of the first splice.



Courtesy Ampex Corp.

Fig. 10-5. Electronic-splice configuration.

During the recording of the insert, the capstan-oscillator frequency is not controlled; therefore, it may drift slightly if the inserted material is of considerable length. This drift, in turn, will cause a variation in the wavelength of the recorded control-track signal and result in an abrupt phase shift in the reproduced control-track signal at the outgoing splice.

One solution to this problem would be to employ a phase-correction system in the capstan-oscillator output circuit during recording. This, however, would be extremely complex. The adopted solution utilizes the fact that in the insert mode a control-track signal already exists on the tape. This information would normally be erased by the full-width video erase head; however, a new head which has a separate section for the control-track erasure has been developed (Fig. 10-6). The control-track section is disconnected when the insert mode is selected, and, although the machine is placed in the record mode, reproduction of the control track continues. Thus, it is possible to retain normal control of the capstan oscillator, and any possibility of control-track phase shift is avoided.

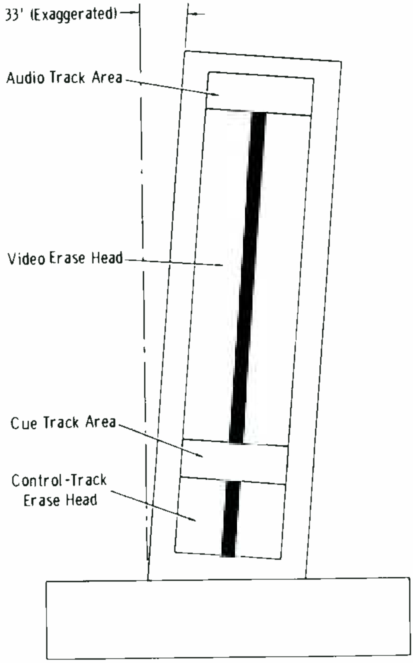


Fig. 10-6. Detail of erase-head assembly.

Courtesy Ampex Corp.

The video erase head is a new design which gives an improved erase efficiency. It uses only a half turn in contact with the tape, and the electrical gap width is 5 mils, the same as that of a guard band. The gap is optically straight and inclined to the perpendicular at an angle of 33 minutes of arc. Thus, the erasure pattern is exactly parallel with the video record pattern. The audio and cue tracks are not affected by the new head, and control-track erasure is optional.

It will be seen that the functions of the Electronic Editor are of the logic type and serve to provide precisely timed and electronically gated video erase and record currents. A block diagram is given in Fig. 10-7. The various delay multivibrators, flip-flops, gates, and binary counters are all classic circuit configurations that will not be discussed at this time. The overall functions, however, may be traced as follows.

Following the initiation of the record mode, a delay multivibrator provides a 60-millisecond delay during which all normal record relays have time to operate. Flip-flop 1 then operates and places AND gates 1 and 3 in a ready state. Pulses, derived from the Intersync unit, that mark the third vertical-sync pulse in every frame interval are reshaped in a pulse former and routed to AND gates 1 and 2. Gate 1, which is in a ready state, therefore operates at the first frame pulse and triggers variable delay one-shots (multivibrators) 1 and 2. One-shot 1 serves to provide the necessary 8 milliseconds of delay before the video erase current is turned on. Erasure turn-on is acomplished by flip-flop 3 and an electronic switch.

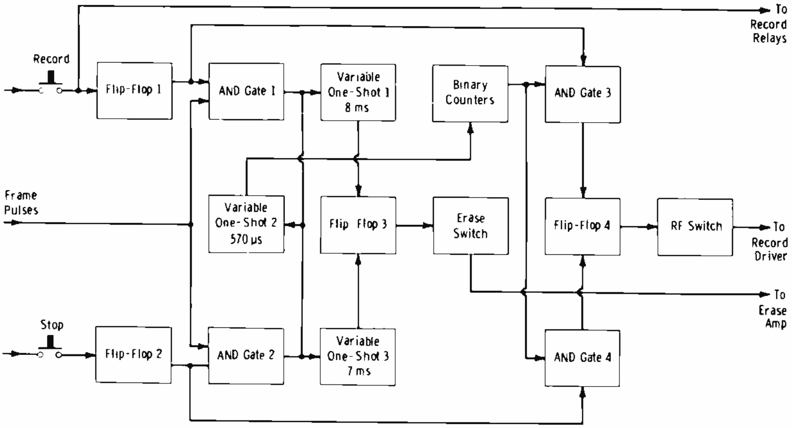


Fig. 10-7. Block diagram of Ampex Electronic Editor.

Because timing is referenced to the third pulse in the vertical-sync train, and at this time the rotating video-head drum is positioned to place the active head tip at the center of a video track, a 570-microsecond delay is provided by one-shot 2. This delay allows the head to travel to the end of the track, at which time the succeeding head on the drum periphery is positioned at the beginning of the next track. From this timing reference, 18 television frames are counted off by the binary counter system, and at the end of this period gate 3 operates. Video record current is then turned on by the action of flip-flop 4 and a second electronic switch.

Timing for the outgoing splice is provided by the operation of gate 2, gate 4, and variable delay one-shot 3. The operation of these stages, together with the reuse of the counter train, resets flip-flops 3 and 4 and places the two electronic switches in the off condition.

An additional flip-flop (not shown in the block diagram) is operated by the binary counters exactly 18 frames after the video record current is turned off. This permits the audio track to be cleared of all extraneous video information by the action of the audio erase head. (New audio information has, of course, accompanied the new video information.) A time-delay circuit allows all audio functions to revert to normal before the machine is stopped. In this way, any possibility of transients on the audio track is avoided.

The quality of the finished splice can be observed in Fig. 10-8, which shows the video, blanking, and synchronizing information in the video waveform at the moment the electronic splice passes the video heads. The splice appears the same as a change of picture caused by camera switching.

The rapidity with which the editing function is performed becomes apparent when it is realized that the entire splicing operation is performed while the recording medium is in motion at normal speed.

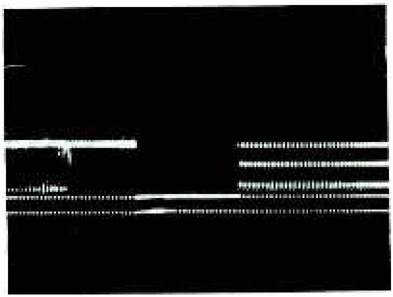


Fig. 10-8. Vertical waveform at moment of splice.

Courtesy Ampex Corp.

10-3. ELECTRONIC SPLICING (RCA)

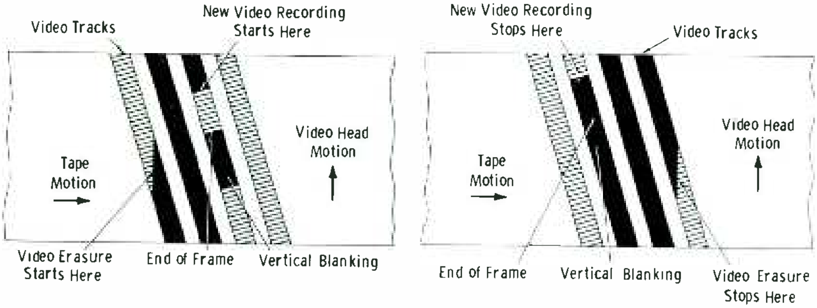
The RCA Electronic Splicing Accessory permits recording a new video signal on a tape containing a previously recorded signal so that a smooth transition, similar to a video switch transfer, will occur during playback. The equipment is designed to operate on 50- or 60-field standards and at normal or half tape speed.

Types of Splices

In an electronic splicing operation, the junction of the two video signals at the beginning of the new recording is called an ingoing electronic splice. If a portion of the old recording is retained after the new section, the junction at the end of the new recording is called an outgoing electronic splice.

Typical ingoing and outgoing splices are shown in Fig. 10-9. Note that the new video starts or ends near the top of a track containing vertical sync. Also observe that a small unerased section, on which the new recording is superimposed over the old, exists in both splices. The overlaps are deliberately created to allow for differences between the machines on which the two recordings are made and will produce no subjective disturbance except in animated recordings. However, since the series of splices in an animated recording are made on the same machine, no tolerances are involved, and the overlap can be eliminated by an adjustment.

The overlap for an ingoing splice is normally adjusted for 1½ tracks with the supply reel fully loaded and the tape running at normal speed. The splice timing circuits then automatically change the overlap to 2½ tracks for an outgoing splice. When the tape is running at half speed, the overlap is automatically doubled. Thus, with the preceding adjustment, the overlaps become three and five tracks.



(*A*) *Ingoing.* (*B*) *Outgoing.*

Fig. 10-9. Typical electronic splices.

Formation of Splices

An ingoing splice is formed by applying the video erase and record currents to the respective heads at different times, instead of at the same time as in normal recording. This is necessary because the master erase head (in the RCA system) is approximately 7.5 inches from the headwheel, and, if the two currents were applied simultaneously, the two signals would overlap, without erasure, on the entire length of tape between the heads. Similarly, formation of an outgoing splice requires that the video erase and record currents be shut off at different times since, if they were shut off at the same time, the section between the heads would be erased but not rerecorded.

The timing of the erase and record functions during formation of a splice is automatically determined by an electronic counter which, in effect, counts the recorded frames on the tape as they pass the headwheel (Fig. 10-10). The counter controls separate delay circuits for recording and erasing. In turn, the delay circuits control transistor switches that either allow or prevent application of the currents to the heads.

Add-On and Insert Operation

Two types of electronic splicing, called add-on and insert recording, are possible. Each type requires a different set of operating conditions.

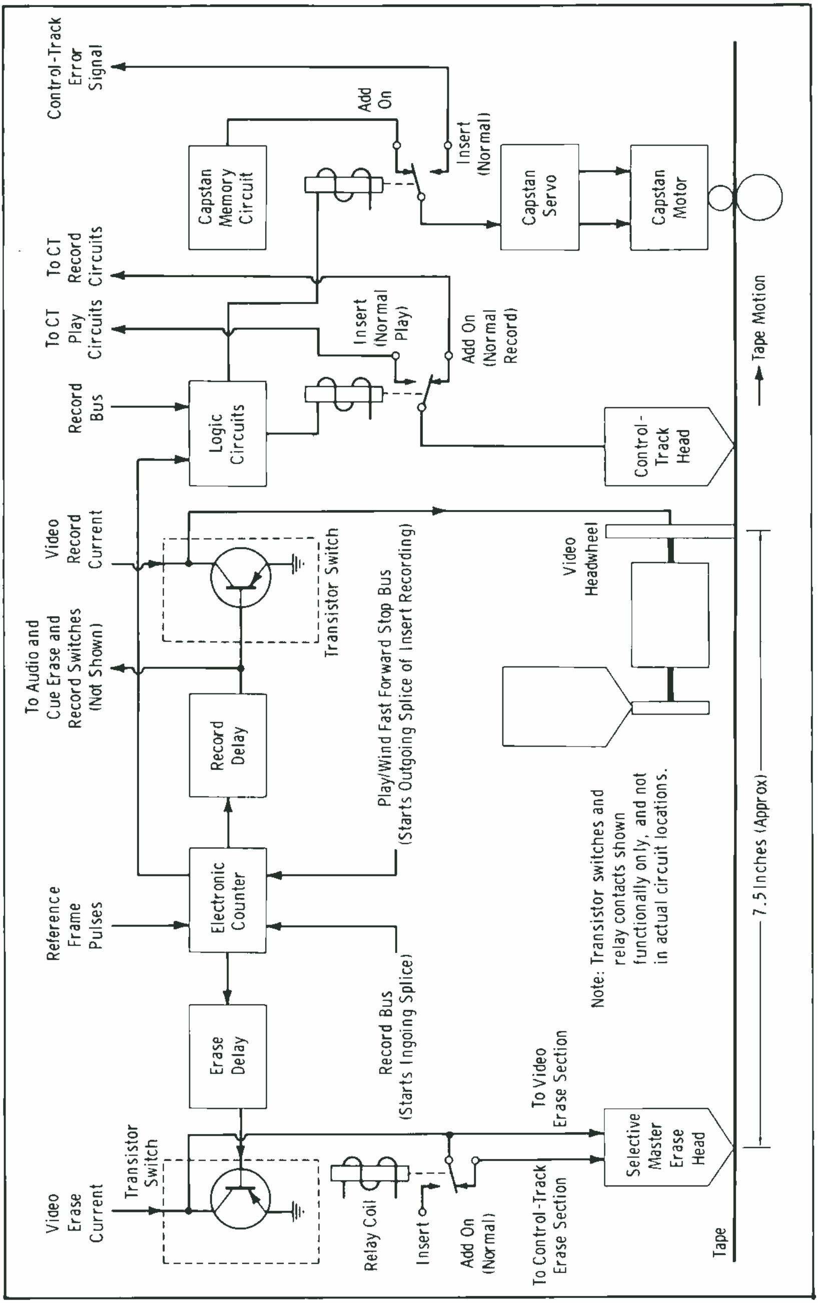


Fig. 10-10. Simplified diagram showing principles of electronic splicing.

In an add-on operation (also called *assemble*), the new recording is merely added at the end of the old recording, and therefore no outgoing splice is required. A control track is recorded as in normal operation, but the capstan servo is modified by use of a capstan memory circuit which matches the speed of the new recording to the original tape speed. The capstan memory circuit provides a steady dc voltage which serves as a reference for the capstan oscillator during recording. The dc voltage is related to the original tape speed by adjusting a potentiometer while playing back the tape before recording.

In an insert operation, the new recording starts at any desired place but ends before the old recording ends. Therefore, since part of the old recording is retained, an outgoing splice is made in addition to an ingoing splice. Also, the original control track, which already exists on the entire length of the tape, is retained and played back to control tape speed during the recording. Retention of the control track is made possible by replacing the original master erase head with a selective erase head containing separate sections for the control and video tracks. A relay removes the erase current from the control-track section during an insert recording.

Mode Selection

A selector switch on the splice logic module permits placing the machine in the add-on, insert, or normal mode. As a special feature of the equipment, the selector switch may be left in either the Add-On or Insert position, and the machine will still make a normal recording if the RECORD button is pressed before the PLAY button. This feature is obtained by use of a splice-mode circuit on the splice control module; the circuit is similar to the mode memory circuits of the control system.

When the switch is on Add-On or Insert and the PLAY button is pressed, the splice-mode circuit becomes energized, and the machine enters the splice play mode. In this mode, the splice circuits are placed in a state of readiness for insert or add-on operation, as selected, and the machine will not go from play to record unless the servo selector switch on the tape sync processor module is on Switchlock and the machine is actually in Switchlock. In addition, the following operation and setup controls are actuated:

1. Aud Record Off position of toggle switch on record control panel.
2. CAP ADJ/FIXED TW/VAR TW switch and CAPST ADD ON ADJUST control on splice logic module.
3. SPLICE RECORD HOR PHASE control on splice timing module. (If machine is not in Pixlock and switch on splice logic module is on Var TW.)
4. ERASE TEST buttons on splice timing module.

If the switch is on Add-On or Insert and the audio or cue record buttons are pressed, the video circuits will enter the play condition. Therefore, the splice-mode circuit will be energized, and, except for the audio or cue record circuits, the machine will enter the splice play mode. When the switch is in the Norm position, the machine cannot enter a splice mode and therefore functions normally. Similarly, if any of the splice modules are removed, a splice interlock circuit is broken, and the machine reverts to normal operation.

Electronic splicing is facilitated by installation of a new ADD ON/INSERT indicator and modification of the original SL (Switchlock) indicator. If the splice selector switch is placed on Add On or Insert but the splice-mode circuit is off, the corresponding section of the ADD ON/INSERT indicator glows red. However, when the splice-mode circuit goes on, the lamp color changes to white. Similarly, when the servo selector switch on the tape sync processor is on SL, the PLAY button is pressed, but the machine is not yet in Switchlock, the SL indicator glows red; when the machine actually enters Switchlock, the indicator color changes to white.

Provisions for Retaining Original Audio and Cue Tracks

To permit retaining the original audio or cue track, if desired, while recording new video tracks, a number of modifications are made to the record control panel during installation of the splice equipment. These modifications consist of replacing the original audio and cue release push buttons with three-position toggle switches, rewiring the audio and cue mode indicators to provide either on or off indications, and installing a transistor switch, SA14A, on the mounting bracket of the splice control module, behind the panel.

On each toggle switch, two of the positions, marked Off and Norm, are fixed, and the third, marked Release, is momentary. When both switches are in the Norm position, the corresponding sections of SA14A connect the master record bus to the audio and cue record buses, as in the original machine. Therefore, when the MASTER RECORD button is pressed, recording will occur on the audio, cue, and video tracks, and the on sections of the audio and cue record indicators will light.

When the cue toggle switch is in the off position, it turns off the corresponding section of SA14A, applies −26 volts to the unlatch input of the cue mode module, and lights the off section of the cue record indicator. Therefore, recording will not take place on the cue track if the MASTER RECORD or CUE RECORD buttons are pressed.

If the audio toggle switch is placed in the off position, the results depend on whether the splice-mode bus is energized. If the splice bus is energized, the corresponding section of SA14A is turned off, −26 volts is applied to the unlatch input of the audio mode module, and the off section of the audio record indicator is lighted. Consequently, the audio recording circuits cannot be energized. If the splice bus is not energized, the same actions occur, except that SA14A is not turned off. Under these conditions, the audio recording circuits will be energized if the MASTER RECORD button is pressed, but not if the AUDIO RECORD button is pressed.

The momentary release positions of the toggle switches serve the same functions as the original momentary push buttons. If the machine is in audio or cue record, or both, and either switch is moved to the release position, the corresponding record function will be turned off.

Horizontal-Phasing Provisions

To prevent a horizontal lurch in the picture, the phasing of the tonewheel with respect to the headwheel during a splice recording must match that of the original recording machine. Therefore, to permit adjusting the steady-state headwheel phasing, a ten-turn potentiometer marked SPLICE RECORD HOR PHASE is provided on the front panel of the splice logic module. The control operates in conjunction with the last two positions of the CAP ADJ/FIXED TW/VAR TW toggle switch on the splice timing module. When this switch is in the Fixed TW position, the phasing potentiometer is disabled. If the toggle switch is on Var TW, the phasing potentiometer will be actuated when the machine enters the splice play mode. The control may then be adjusted as directed in Chapter 11 to make the new recorded sync occur in the same places on the tape tracks as the original recorded sync.

Control of Tape Speed During Add-On Recording

As previously mentioned, during an add-on recording the capstan oscillator is referenced to a dc voltage obtained from a capstan memory circuit. A control, marked CAPST ADD ON ADJ, on the splice logic module permits adjusting this voltage for the correct tape speed when the machine is in the splice play mode and the CAP ADJ/FIXED TW/VAR TW toggle switch is held in the momentary Cap Adj position.

Erase Test Feature

An erase test circuit is provided to permit adjusting the video erase timing without the need for making the recorded tracks visible with a developing solution. The operating controls for this circuit consist of two red buttons marked ERASE TEST and a potentiometer marked ERASE DELAY on the front panel of the splice timing module. The two buttons are momentary and are connected in series. This arrangement prevents undesired erasure of the tape in case the operator presses one of the buttons accidentally.

When the machine is in the splice play mode and the two buttons are held down, the erase test circuit causes the tape to be erased in pulses of 200 microseconds duration. The timing of these pulses with respect to the recorded sync is the same as if a series of ingoing splices were being made. The effect of this pulsed erasure is visible on an oscilloscope connected to the fm switcher output as a "butterfly" interruption of the signal. Since the butterfly position depends on the setting of the ERASE DELAY control, the operator can easily adjust the control to start erasure at the desired time.

This test should be made only while playing back a tape containing unneeded material, since the tape will be erased. Once the adjustment is made, it will require no further attention until the headwheel is changed.

A short functional description of the electronic splicing system is given in the following paragraphs. Fig. 10-11 is a functional block diagram of the system, and Table 10-1 lists the major circuit designations and functions.

Add-On Operation

For add-on operation, the mode selector switch on the splice logic module is placed in Add On, and the tape is played back until the place where the splice is to be made is found. The tape is then rewound and the PLAY button is pressed. This action turns on the splice mode circuit on the splice control module, which energizes the splice bus. The splice bus then turns off the normalizer circuit on the splice timing module, which allows the machine to enter the splice play mode. In this mode, the Switchlock detector on the splice logic module applies an inhibit voltage to the master-record mode module (unless the machine is in Switchlock); the reference generator, capstan oscillator, and guide servo are locked in the play condition; and the splice switches on the erase oscillator module and auxiliary circuit boards are turned on.

The operator then observes the Switchlock indicator to see whether the machine has entered Switchlock and, if it has, presses the MASTER RECORD button approximately ½ second before the predetermined splice point if the tape is running at normal speed, or one second before if the tape is running at half speed. This action turns on the master-record mode module, and the output bus of this module starts the electronic counter in the splice timing module.

At this time, the various record and erase functions are inhibited by the splice switches and logic circuits, although the master record bus is energized. However, as the recorded section then present between the master erase head and the headwheel moves past the headwheel, an automatic cycle timed by the counter occurs, during which the inhibitions are removed at the proper times for an ingoing splice.

During the cycle, the counter is timed by reference frame pulses derived from external sync. Since the machine was previously in Switchlock, each of these pulses occurs at the same time that the headwheel is scanning a track containing vertical sync at the end of a frame. Therefore, in effect, the recorded frames on the tape are being counted.

The timing of the splice cycle depends on the number of recorded frames between the master erase head and the video headwheel. This number, in turn, depends on the distance between the heads, the tv frame rate, and the tape speed. On a tape recorded at 30 frames (60 fields) per second and at normal tape speed (15 in/s), each frame occupies ½ inch of tape length, and, since the distance between the center of the erase-head bracket and the headwheel is 7.5 inches, approximately 15 frames are

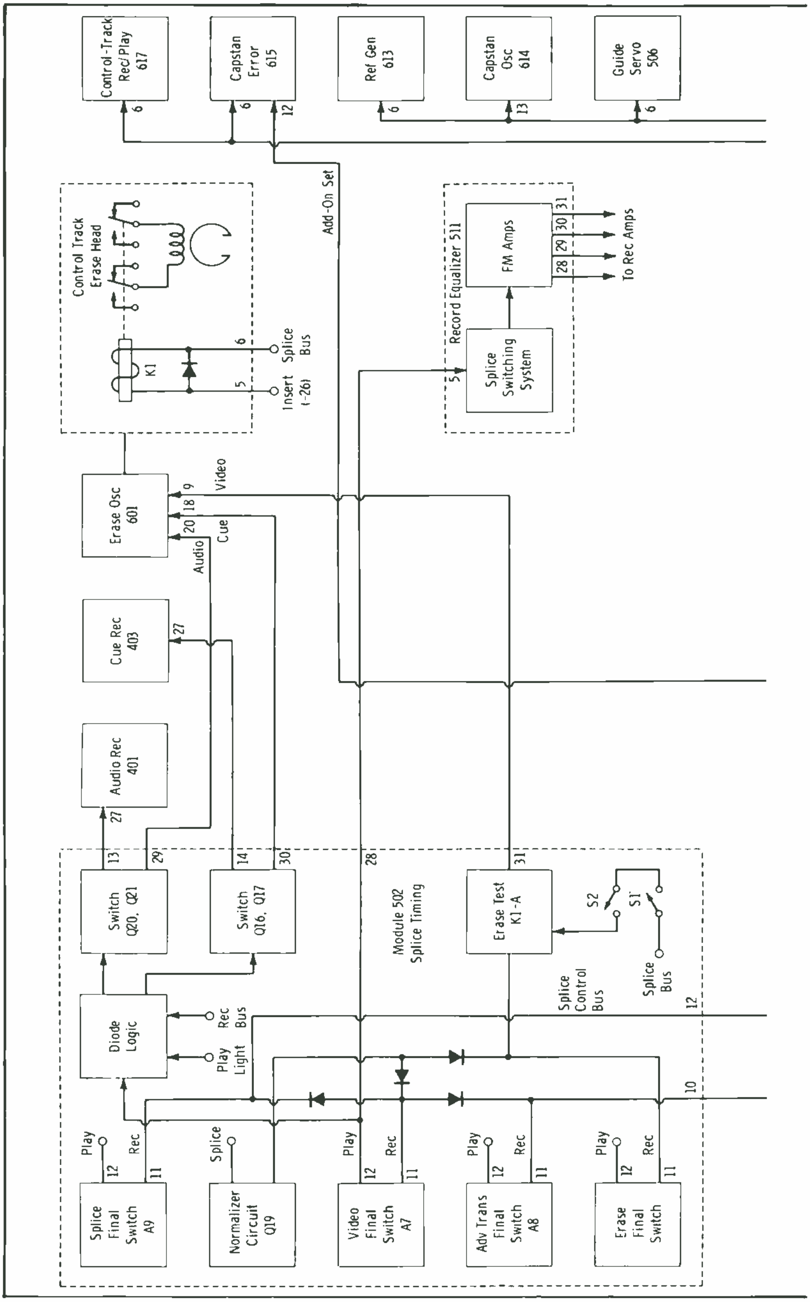
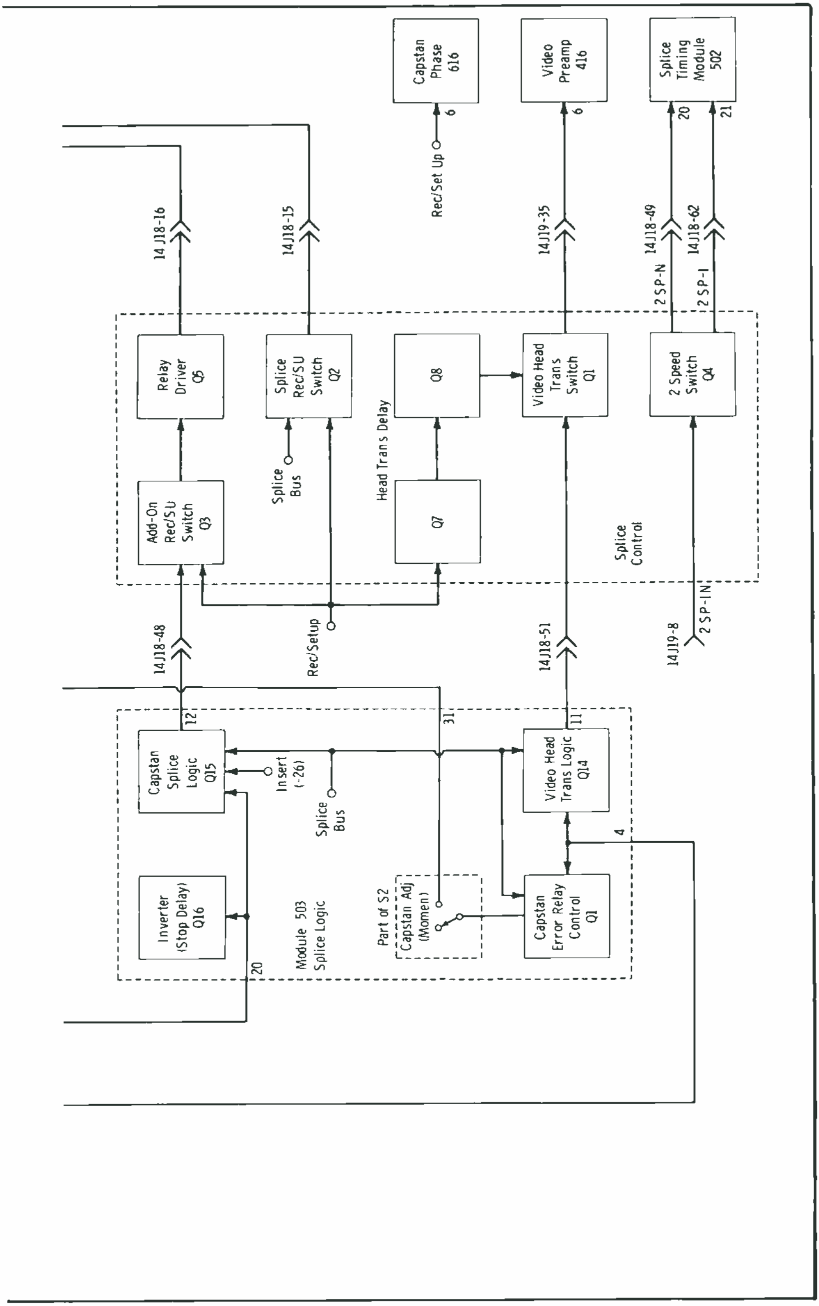


Fig. 10-11. Functional block diagram



of RCA electronic splicing system.

Table 10-1. Major Components of Electronic Splicing System

Component	Mounting Location	Major Circuits	
		Designations	Functions
Splice Timing Module	Module Bank	Electronic Counter, Erase and Record Delay Circuits	Automatically control starting and stopping times of record and erase functions during formation of ingoing or outgoing splices.
		Final Binary Switches	Energize or de-energize output buses to other splice modules or auxiliary splice circuits at times determined by counter and delay circuits. Have two stable states, record and play.
		Normalizer Circuit	Keeps final binary switches in record state when splice mode bus is off. This disables splice circuits and places recorder in normal condition.
Splice Logic Module	Module Bank	Switchlock Detector	Detects whether machine is in Switchlock during playback before splicing (splice play mode). Prevents entry into splice record mode if machine is not in Switchlock. If machine is in Switchlock, informs operator by lighting white SL indicator lamp.
		Stop Memory Circuit and Associated Gates	Delays entry into stop mode until end of outgoing splice cycle, if STOP button is pressed during an insert splice recording.
		Logic Circuits	Prevent unlatching of record, play, wind, or fast forward mode modules during outgoing splice cycle. Determine operation of video-head transfer and servo-control circuits during splice operations.
Splice Control Module	On Frame Behind Record Control Panel	Splice Mode Circuit	Allows machine to record normally even if splice mode switch is in a splice position, provided that RECORD button is pressed before PLAY button. If PLAY button is pressed first, circuit energizes splice mode bus, which enables operation of splice circuits. Configuration of this circuit is similar to mode modules in control system.
		Play, Wind, Fast Forward Matrix	Combines play, wind, fast forward buses of control system into a single control bus called the PWFFS bus. This bus starts outgoing splice cycle when PLAY, WIND, FAST FORWARD, or STOP buttons are pressed during an insert recording.
		Two-Speed Switch	Modifies splice timing circuits for normal or half tape speed.
		Reference Generator and Capstan Oscillator Transistor Switch	Keeps reference generator, capstan oscillator, and guide servo in play mode when splice mode bus is on.
		Video Head Transistor Switch, C.T. and Cap Error Switch, Unlatch Inhibit Switch	Perform additional logical operations on output buses of splice logic module.

Table 10-1. Major Components of Electronic Splicing System (Cont)

Component	Mounting Location	Major Circuits	
		Designations	Functions
Selective Master Erase Head and Erase Bracket	Replace Original Master Erase Head and Bracket on Tape Transport		Selective erase head has separate sections for erasure of video tracks and control track. Relay on bracket permits disconnecting control-track section from source of erase current. This permits retention of original control track for insert recording.
Auxiliary Circuit Board SA101	Audio Record Module	Splice Audio Record Switch	The splice audio, cue, and video record switches permit inhibiting the record functions when required during formation of a splice even though master record, audio record and cue record buses from control system are energized. The switches are controlled by output buses from the final binary switches on the splice timing module. When the corresponding binary switch is in the record state, the inhibition is removed and the function is performed normally. However, when the binary switch is in the play state, the inhibition is applied. When splice bus is off, normalizer circuit on splice timing module places all binary switches in record state. This removes all inhibitions and allows recorder to function normally.
Auxiliary Circuit Board SA105	Cue Record Module	Splice Cue Record Switch	
Auxiliary Circuit Board SA207	FM Modulator Module	Splice Video Record Switch	
Auxiliary Circuit Board SA14A	On Mounting Frame of Splice Control Module, Behind Record Control Panel	Cue Retain Transistor Switch Audio Retain Transistor Switch	Permit retaining original audio or cue tracks while recording new video tracks. Audio and cue sections controlled by separate toggle switches which replace original RELEASE push buttons on record control Panel. When audio or cue section is off, master record bus is disconnected from audio or cue record bus, and erasure and recording on corresponding tracks is prevented while machine is in master record.
Auxiliary Circuit Board SA319	Control Track Record/Play Module	Filter and Multivibrator Clamp Circuits	Prevent abrupt change in control-track level when machine is switched from play to record.
Auxiliary Circuit Board SA321	Capstan Error Module	Capstan Memory Circuit	During add-on splice recording, matches tape speed to that of original recording. Not used during insert splice recording because tape speed is referenced to original control track.
AUDIO and CUE RECORD Toggle Switches and Indicators	Toggle Switches Replace Original AUDIO and CUE RELEASE Buttons on Record Control Panel		Toggle switches, in conjunction with auxiliary board SA14A, permit choice of retaining original audio or cue tracks while recording new video tracks. Modified AUDIO and CUE RECORD indicators provide both off and on indications.
Erase Oscillator Module	Replaces Original Module in Module Bank		Has circuit modifications which improve erase and bias waveform, reduce clicks due to mode switching, and permit audio spot erasure. Provides dc noise balance control for cue channel, and auxiliary splice audio, cue, and video erase transistor switches. Erase switches inhibit erase functions when corresponding final switches on splice timing module are in the play state. Inhibitions are removed when final switches are in the record state.

(Table continued on page 306.)

Table 10-1. Major Components of Electronic Splicing System (Cont)

Component	Mounting Location	Major Circuits	
		Designations	Functions
Indicators	Mode Indicator Bank Above Tape Transport	SL Indicator	Original SL indicator modified to include both red and white lamps. Red lamp lights when machine is in splice play mode and servo selector switch is on Switchlock. White lamp lights when machine actually enters Switchlock.
		ADD ON/INSERT	Two sections each containing both red and white lamps. Red ADD ON lamp lights when splice mode switch is on Add On. White ADD ON lamp then lights when machine actually enters splice mode (splice bus energized). Insert section operates in similar manner when switch is on Insert.
		SPOT ERASE	Lights when audio spot erase circuit is energized.

present. Actually, the master erase head is offset by about ⅛ inch, so slightly less than 15 frames are present between the heads. The offset is provided because of mounting tolerances and circuit requirements.

Because of the preceding considerations, when the machine is set for 60-field standards and normal tape speed, the counter is automatically set to permit counting a maximum of 16 frame pulses just after the MASTER RECORD button is pressed. Then, when the first frame pulse occurs, the track on which video recording will start is exactly 15 frames in advance of the headwheel.

At this time, the erase delay circuit is actuated. This circuit allows enough unerased tape to go by after the end of the fifteenth frame has passed the master erase head to create the desired overlap between the old and new recordings (normally adjusted for 1½ tracks). It then causes the video erase switch in the erase oscillator module to allow application of current to the erase head. Since the splice mode selector switch is in the add-on position, the control-track erase relay remains de-energized. Therefore, the erase current is applied to both the video and control-track sections.

During the remainder of the cycle, the capstan servo remains in the play condition, and the tape speed is controlled by the unerased portion of the original control track. No further action occurs until the fifteenth frame pulse. At that time, the counter actuates an advance transfer circuit which energizes the video-head changeover relay. The advance transfer allows time for the changeover to take place before the video record current is turned on. In addition, the advance transfer circuit cuts out the guide servo to prevent a change in head-to-tape pressure during the recording.

At the sixteenth frame pulse (end of fifteenth frame), the counter actuates the record delay circuit and the splice-control final switch. The record delay circuit delays video recording until the headwheel nears the end of the track. The splice-control switch shuts off the counter and switches the control-track record/play module to the record condition.

At the end of the record delay (approximately 560 microseconds), the splice video record switch on the fm modulator module allows the record current to enter the video heads. At the same time, the audio and cue splice switches go off and allow erasure and recording on the corresponding tracks (unless the audio or cue toggle switches on the record control panel are in the off position).

Recording then proceeds normally except that the guide servo is cut out, the capstan oscillator remains in the play condition, and the oscillator is referenced to the output of the capstan memory circuit. (Also, if the CAP ADJ/FIXED TW/VAR TW switch is on Var TW, the headwheel phase is shifted by the amount determined by the SPLICE RECORD HOR PHASE control.) This condition of the machine is called the add-on splice record mode.

At the end of the add-on recording, the operator may immediately switch the machine to a desired mode by pressing the PLAY, WIND, FAST FORWARD, or STOP button. If play is selected, the splice mode circuit remains on, and the machine returns to the splice play mode; otherwise, the splice mode circuit goes off, and normal operation is restored.

Insert Operation

The operating procedure for insert operation is the same as for add on, except that the mode selector switch is placed on Insert. Circuit action during the initial phases is also the same, except for the following:

1. When the PLAY button is pressed, the control-track erase relay becomes energized and disconnects the control-track section of the selective erase head. As a result, the control track will not be erased during the recording.
2. At the end of the ingoing splice cycle, the recorder enters a condition called the insert splice record mode. In this mode, the entire capstan servo remains in the play condition, and the tape speed is governed by the original control track. Also, unlatching of the master-record mode module is prevented by an inhibit voltage, and the unlatch bus is disconnected from the play, wind, and fast-forward mode modules.

An insert splice recording may be terminated by pressing the PLAY, WIND, FAST FORWARD, or STOP button. This action starts an outgoing splice cycle during which the master-record mode module remains latched but the various recording and erase functions are shut off in the proper sequence. In addition, the mode module corresponding to the button pressed becomes energized, but the functions normally performed by this module are delayed. (This delay is caused by a number of changes in the control-circuit connections made during installation. One change consists of reconnecting the wind relays so that they cannot be energized until the capstan-roller solenoid is de-energized. Another consists of shorting the sections of the STOP buttons in the stop ground interlock system to prevent the mode modules from being turned off as soon as the STOP buttons are pressed.)

No mode module for the stop mode is included in the original recorder, but a stop memory circuit on the splice logic module serves the same purpose. This circuit "remembers" that the STOP button has been pressed but does not allow the machine to enter the stop mode until the end of the outgoing splice cycle.

The actions occurring during an outgoing splice cycle, in 60-field standards and at normal tape speed, may be summarized as follows:

1. On the first frame-pulse count, the erase delay circuit is actuated. At this time, the track at which video recording will stop is 15 frames from the headwheel, and the point at which video erasure will stop is 2½ tracks closer to the headwheel (assuming that the ERASE DELAY control was adjusted to produce an overlap of 1½ tracks for an ingoing splice.)
2. At the end of the erase delay period, the correct point reaches the master erase head, and the video erase switch shuts off the erase current. (The outgoing erase delay is automatically reduced by 4 milliseconds from the ingoing erase delay to produce an asymmetrical overlap.)
3. At the sixteenth frame pulse (end of the fifteenth frame), the counter actuates the record delay circuit. After a delay of 560 microseconds, this circuit actuates the video record switch and the cue and audio erase and record switches, thereby shutting off the currents to the corresponding heads.
4. The counter then starts another complete cycle of sixteen counts. During this cycle, the master-record mode circuit remains on, but the machine neither plays nor records.
5. At the fifteenth count of the second cycle, the advance transfer circuit de-energizes the video-head changeover relay and places the guide servo in operation.
6. At the sixteenth count, the splice-control final switch stops the counter, unlatches the master-record flip-flop, and allows the machine to enter the selected mode. If play was selected, the machine returns to the splice play mode. However, if wind, fast forward, or stop was selected, the capstan-roller bus unlatches the splice mode circuit. The normalizer circuit then restores the machine to normal operation.

NOTE: It should have been observed by the careful reader that the Ampex and RCA systems have a different number of frames between the selective erase head and the video head. This has nothing to do with *interchange-*

ability of tapes made on the two systems. It simply involves different splicing logic for the individual electronic splicing systems.

10-4. PRINCIPLES OF PROGRAMMED ELECTRONIC EDITING

We have covered the progress of splicing techniques from the razor blade to the electronic method. Programmed electronic editing permits a computerized, automatic programming type of operation.

Early (manually controlled) electronic editing removed the necessity for cutting the tape and eliminated the audio/video offset problem. Using devices to count edit pulses provided a means for identifying individual frames. The pulses also provided proper timing for performing push-button electronic edits. This process still left much to be desired, however, and was primarily limited to "assemble" editing functions. The final breakthrough to modern electronic editing came in approximately 1966 with the addition of a serial time code. This code, recorded on the audio cue track, provided a convenient means of frame identification at any point on a given tape.

Modern electronic (code controlled) editing has added several new dimensions to the business of producing material for television. Easy edit-point selection is facilitated through high-speed search of the recorded material. Cueing to a selected edit point is a simple automated function. Tape locations are easily logged, and, with frame-by-frame control, highly sophisticated editing procedures may be employed. Complete preview before edit is easily implemented. Most important, these new systems increase efficiency and reduce costs.

The remainder of Section 10-4 consists of excerpts from "Creative VTR Editing," by O. F. Wick and J. H. Frishette (*RCA Broadcast News,* Vol. 146, June 1971). These excerpts will serve to outline briefly how programmed electronic editing is used at NBC in Burbank, California. They appear here through the courtesy of RCA.

In the spring of 1958, a new recording facility was installed at the NBC Burbank studios. A total of 12 colorized video tape recorders were included. With this expanded capability, we were in a position to undertake prerecordings that had not previously been possible. Within a sort time, the need to edit and rearrange this material became very clear, and the possibilities for doing so were investigated. The only implements available for the cutting and splicing of video tape were rather crude: a milled channel, a straightedge, and a razor blade. The splices produced invariably resulted in severe picture disturbance—an intolerable situation if we were to compete with motion pictures.

To improve our ability to assemble prerecorded tapes with acceptably smooth transitions and to cope with other problems that had become apparent, such as the handling of picture and sound offset, a study and development project was initiated. This effort was quite productive, and a procedure for the double-system editing of video tape[2] (independent editing of pictures and sound) was evolved that has been in use to the present time. Many of NBC's top shows have been assembled using the tools and techniques that were developed in the course of this original project. The Bob Hope shows and the Rowan and Martin "Laugh-In" series are specific examples.

With the advent of the direct color recovery systems, high-band recording, and numerous other improvements, the duplication of video tapes became practical. This, in turn, made electronic editing feasible, but the original equipment designed for this activity had a rather limited range of usefulness—especially evident when complex sound-track manipulation was required. Despite the limitations, however, a considerable number of major productions have been assembled using this "first-generation" equipment, both by us and by others.

Edit Control System

In 1967, a system of edit control was introduced that utilized a recorded time code. The system not only provided a means for predetermining edit points, but also included high-speed search and intermachine synchronizing capability.

At about this time, we in Burbank were confronted with the need to expand our editing facilities, so a careful study of the new system was made. After considering as many of the factors as possible, we concluded that the time-code system of control had many immediate advantages and that there were potentially a number of other areas into which its usefulness might be extended. We decided to purchase two sets of this equipment and to construct a special edit room to contain the two vtr's so equipped. This installation was completed during the summer of 1968 and was used on several shows during the fall season of that year.

After several months of experience—and a number of unexpected problems—the system was once again carefully examined, and once again we concluded that it was the correct approach to the task at hand. Two additional sets were ordered and another special editing room constructed. However, our experience had shown that with improved editing equipment, more complete video and audio switching facilities immediately available to the editors were also needed. So, the new room was designed to include these. Also, the slow-motion disc had become an indispensable accessory, and this, too, was provided in the room.

RCA Time-Code Editor

As the use of time-code editing systems increased, more effort on the part of several manufacturers was devoted to the study of video-tape editing

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[2] See Oscar F. Wick, "Double-System Recording and Editing With Video Tape," *Journal of the SMPTE,* March 1960, p. 164.

problems. The advantages and disadvantages of the systems in use in our plant were discussed in detail with engineers from RCA Camden. Their investigations resulted in the design of a new system incorporating many improvements in "human engineering" and providing automation for several of the routine operations that must be performed repetitively. Examples are: the entry of edit-point time-code data directly into memory by depressing a single button, the performance of arithmetic calculations within the editing circuitry, and precise recueing by depressing a single button.

In view of the heavy schedule projected for the fall of 1970, still another editing facility for NBC Burbank came under consideration early in the year. It was decided that a third room complete with six-channel audio and video switching equipment, video effects unit, slow-motion disc, and extensive video and audio monitoring facilities would be constructed. It would utilize the newly designed RCA time-code editing system (Fig. 10-12). In September, this editing complex was placed in operation and assigned to handle the post-production requirements on the Dean Martin and Red Skelton shows. The Dean Martin Show provides some interesting examples of the capability of this equipment.

To begin, we should mention that it is standard procedure in our plant to feed the time code to all machines at all times. Whenever a recording is made, the cue track contains a time code representing the accurate time of day. Normally, on a show such as the Dean Martin Show, the editor also operates some of the recording equipment. This allows him to become familiar with all of the details and to log all "takes" as they occur using clock time. Later, during the editing session, these logged times are used to locate any desired segment quickly, utilizing the high-speed search capability of the system.

This high-speed search capability is also used in nonediting functions. If we wish, for example, to play several segments of a football game in close sequence into a live sports program, the unit programmer is set to cue the game tape precisely before each segment. All the video-tape operator needs

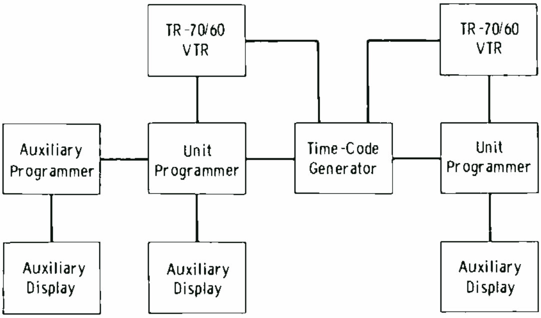


Fig. 10-12. Typical two-machine time-code editing system.

to do is to enter the desired time into the unit programmer stop register (by using the 10-key keyboard) and press the SEARCH button. Generally, a log of noteworthy activity is kept during the progress of these games, and the use of the time code permits desired action to be cued reliably without prior rehearsal.

Using the Time-Code Editor

On the Dean Martin Show, it is customary to record two separate feeds from the originating studio. One feed carries the entire studio output, while the second represents the unswitched output of the single camera normally used for close-ups. Here again, the common time code supplied to both sets of recorders permits the two pictures to be "intercut" during editing while precise sound synchronization is maintained.

The principal elements of the Martin show are recorded on Saturday evenings, and editing is scheduled for Monday and Tuesday. A total of about 24 hours is required to complete the editing of the average show. Usually, the editor and an assistant are employed in the editing process. The editor operates the vtr on which the show is being assembled, as well as the switching and effects equipment. The assistant handles the playback vtr, its programmer, and the slow-motion disc equipment. When dissolves between reels are used, a second assistant and a third vtr are assigned. A 64-minute reel containing previously recorded control-track, black-burst, and time-code (from 0 to 60 minutes) signals is used as the assembly medium. This becomes our electronically edited master, and all edits are in real show time.

When "freeze" is employed, picture and sound from the segment to be frozen are assembled in the normal manner on the master reel. While this is being done, the picture is simultaneously recorded on the disc. The picture on the master reel is then replaced by a replay from the disc, with action stopped at the appropriate point. It is, of course, essential that precise synchronism be maintained between the vtr and disc, since the disc picture must exactly match the previously recorded sound up to the "freeze" point. To achieve this necessary condition, use is made of a contact closure that is externally available from the unit programmer. This closure is used to start the disc from the master-reel time code when the material is recorded, and, consequently, an exact time relationship between vtr and disc is insured for playback.

Time-code-actuated contact closures are used to control a variety of external equipment in addition to the slow-motion disc. Sound playback machines, auxiliary vtr's, and automatic effects units are frequently started and switched by this means.

A and B Rolls

On the Martin show, opening and closing titles are produced during the editing operation. Separate A and B rolls are prepared by careful assembly from selected portions of the original recordings, and these are played back in synchronism utilizing the synchronizing feature of the unit programmer.

The standard closing for the Martin show is 60 seconds long and consists of roll titles matted over a series of stills followed by a segment in normal motion. Finally, the scene fades to black. Sound during the closing is the show theme. In a first step, as indicated previously, the editors prepare A and B rolls of the entire series. These are rolls of tape that contain successive show segments so arranged that, in playback, dissolves may be made from roll A to roll B, and vice versa, and thus produce the sequence desired. The stills required are obtained by freezing selected frames from the original recordings. In making the assembly, a third vtr, also started by contact closure in the unit programmer, is used to play back previously recorded roll titles. All picture signals are routed through the switching equipment in the room so that the roll titles may be matted and the dissolves executed. Theme music is also "laid down" at this time. The time-code editing system has substantially reduced the time and effort required to produce a sequence of this type.

Sweetening the Sound

When shows are edited, it is generally necessary to reprocess the sound track because small but objectionable changes in background level and quality often occur at the edit points. This is especially noticeable when the splice is made during applause or laughter. Then, too, it is sometimes necessary to add sound effects, musical bridges, and audience reaction (if an audience was not present during the recording). The Dean Martin Show is performed before a live audience and the response is quite adequate. However, "sweetening," as it is called, is necessary to obtain a complete, smooth, and uniform finished track.

The average Martin Show contains 15 to 20 sketches, songs, etc., and each of these frequently requires some internal editing, making for an average of about 90 splices in the completed master tape. During sweetening, the jumps in the edited track are bridged by sound similar to that already existing. For example, if the edit occurs in applause, similar applause would be mixed in to cover the discontinuity.

After editing of the show has been completed, the sound track and time code are transferred to two tracks of a four-track audio recorder. This recorder is of the type employing a capstan servo and sync track, so synchronism with the vtr is absolute. During the sweetening session, the four-track audio machine is used in the playback mode to provide program sound and is also used as the source of the time code to which the vtr is synchronized by the unit-programmer synchronizing feature. This results in a situation wherein the picture is supplied from the edited master tape, and the program sound is supplied from the four-track recorder, both in precise interlock. These signals are routed to a postproduction studio containing extensive audio mixing and equalizing facilities as well as excellent audio and video monitoring. Any necessary modifications to the original track are made in this studio, and the composite sound output is fed back to and recorded on the vtr as the final sound track.

10-5. THE EECO EDITING SYSTEM

Although the specific Electronic Engineering Company equipment described in this section includes refinements over some simpler systems, a brief description of it will serve to illustrate fundamentals of all modern pogrammed editing systems. This equipment is designed specifically for use with RCA TR-60/70 and Ampex VR-1200/2000 series television recording systems. The basic equipment consists of an electronic editor programmer and a time-code generator. Accessory equipment includes an auxiliary programmer, an auxiliary time display, and a remote transport control panel.

The Edit Code

An edit code is the key to efficient indexing and electronic editing of video tapes. Essentially it is a binary time code that is recorded on the cue channel or the second audio channel. The SMPTE edit code uses 80 bits per frame to carry the following data:

1. Hour, minute, second, and frame count
2. Eight optional four-digit words for additional information or control
3. A sync word to indicate the end of each frame and the direction of the tape

Edit-code time is based on the frequency of line power or the video/sync input. The SMPTE edit code (Fig. 10-13) offers control capability for the fully automated editing of the future.

Color (NTSC) video requires a "drop-frame" technique not required with monochrome recordings. The actual NTSC frame rate is 29.97002618 per second, hardly as practical a time base as 25 or 30 frames per second. In working with NTSC video, the edit-code time reference is set at 29.97 Hz (or frames per second). To prevent a resulting time-error accumulation of 86 seconds per day, two frames are dropped every minute except on the tenth minutes. The drop-frame reference signal is shown in Fig. 10-13.

The edit code contains the generated time of day in binary-coded decimal (bcd) form, the frame count in bcd form, a sixteen-bit sync word, and spaces for eight optional four-bit binary words. The time of day in hours, minutes, and seconds is represented in six code segments of four bits each. The frame count is represented in two code segments of four bits each. A logic 1 in the eleventh bit of the code indicates a code that drops frames for correction. The sync word is a unique bit pattern that cannot be duplicated by other information in the time code. It is used to indicate the end of each code frame and to show the direction of tape motion. The eight

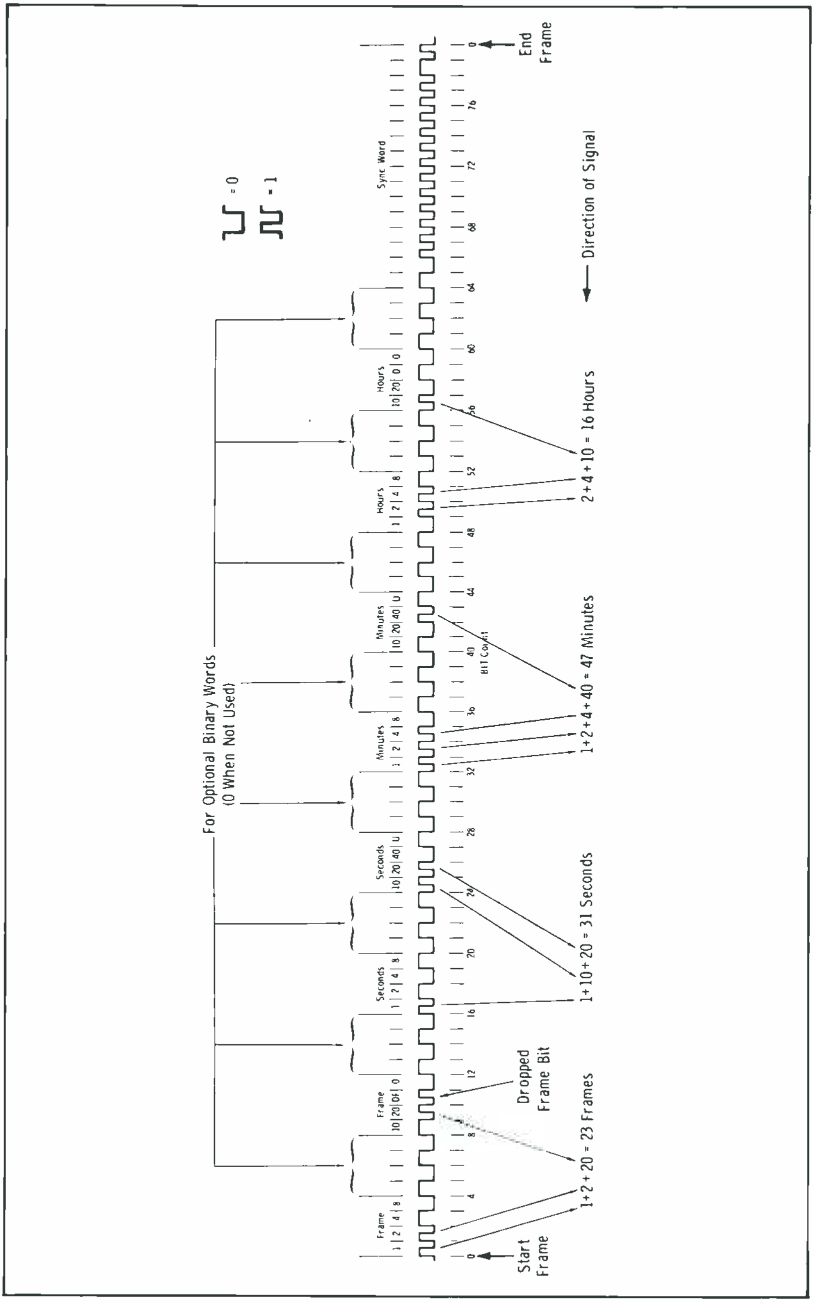


Fig. 10-13. Example of SMPTE edit code for one frame.

optional binary words may be used to convey additional information when the binary word option is included.

Each 80-bit code frame has a duration established by the video frame rate. The code frame is updated and repeated once for each video frame.

A transition from low to high or high to low occurs at the beginning of each bit. The code is therefore self-clocking. A binary 0, or false, may be either high or low. A binary 1, or true, is represented by a *transition* occurring at the midpoint of the bit. This change of state from high to low or low to high results in a pulse of ½-bit duration. (See upper right-hand section of Fig. 10-13.)

Tape Indexing-Editing "Mini-Modules"

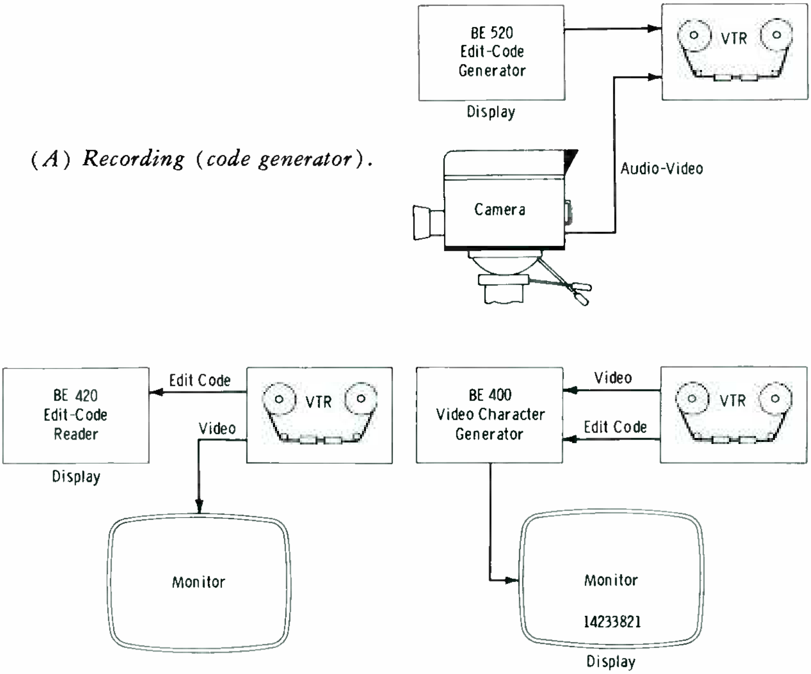
The EECO "Mini-Module" units are normally used in pairs. Fig. 10-14 shows two of these units. The BE 520 (not illustrated) generates an electronic signal (edit code) that is recorded on video tape. Either the BE 420 or BE 400 (right and left, respectively, in Fig. 10-14) can read this signal as taped video scenes are monitored, and either unit provides a visual display of the edit-code signal expressed in terms of real or elapsed hours, minutes, seconds, and frames. All three units are small (approximately 5″ × 8″ × 11″), hence the term "Mini-Modules." Basic applications are outlined by Fig. 10-15. The units are completely solid state, using integrated circuits and transistors.

Courtesy Electronic Engineering Co. of California

Fig. 10-14. EECO video character generator (left) and edit-code reader.

The BE 520 Edit-Code Generator

The BE 520 generates the indexing code needed for efficient editing of video tapes. The code is in the form of an electronic signal recorded on the cue channel or second audio channel and represents real or elapsed time expressed in hours, minutes, seconds, and frames. Normally the edit code is recorded on the tape as scenes are shot, but it can also be added to previously recorded tapes.



(*A*) *Recording* (*code generator*).

(*B*) *Reviewing programming* (*code reader*).

(*C*) *Reviewing programming* (*character generator*).

Fig. 10-15. Basic applications of indexing-editing equipment.

Some of the advantages and options available when video or audio tapes carry the edit-code signals are:

1. Tapes can be previewed and a sqeuence log written to show start and stop times of selected scenes.
2. Subsequent program editing, either manual or computer-automated, can be made more quickly and at less cost than with other methods.
3. Scenes to be shown in a live program can be located more rapidly either manually or automatically.
4. The edit code can be used to synchronize dual-equipment operations.
5. Recordings of significant events carry a permanent time record. Sequences and single frames can be examined in terms of actual time and with split-second accuracy.
6. The edit code can accompany the transfer of video scenes from one type of recorder to another. For example, quadruplex recordings can be copied by a helical recorder. The low-cost equipment can then be used for careful scene reviewing and development of a program sequence log. Subsequent editing of the original quadruplex tapes

can be made with minimum use of production-studio time, including automatic or computer-automated editing equipment.

7. Elaborate computer storage, retrieval, and editing systems are already used for some types of video programs. The edit code is used for reference indexing, storage retrieval, and program sequencing.
8. The edit-code index is never dependent on the original tape length and mechanical footage count. Any section of tape carries its original edit-code identification.

The generator utilizes either the power-line frequency or an externally applied video/sync signal as its reference frequency when generating time at frame rates of 25 or 30 Hz, and the time of day coded into the output time code is then as accurate as the selected reference frequency. At the 29.97-Hz color frame rate, however, the time of day will be in error. This error is due to the fact that the generator counts as if the video frame rate were 30 frames per second, or 1800 frames per minute. However, at the rate of 29.97 frames per second, only 1798.2 frames per minute are generated. Therefore, an error of 1.8 frames per minute (1800 − 1798.2 = 1.8) is induced. Because the basic video frame duration is 1/30 second, or approximately 33.33 milliseconds, the time error is 60 milliseconds (1.8 × 33.33 = 60) per minute. To overcome this error, the generator drops two frame counts per minute for a time correction of 66.66 milliseconds (2 × 33.33). However, this effectively overcorrects the error by −6.66 milliseconds (60 − 66.66 = −6.66). (See Fig. 10-16.) At the end of the second minute, the total error before correction is approximately 53 milliseconds. After the two-frame correction, the total error is approximately −13 milliseconds. The two-frame correction is repeated until after the ninth minute correction, when the total error is approximately −60 milliseconds. Between the ninth and tenth minutes, the 60-millisecond error generated

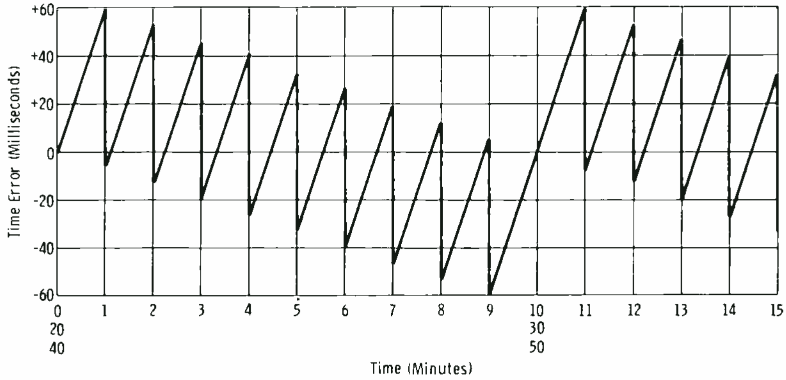


Fig. 10-16. Time-error correction.

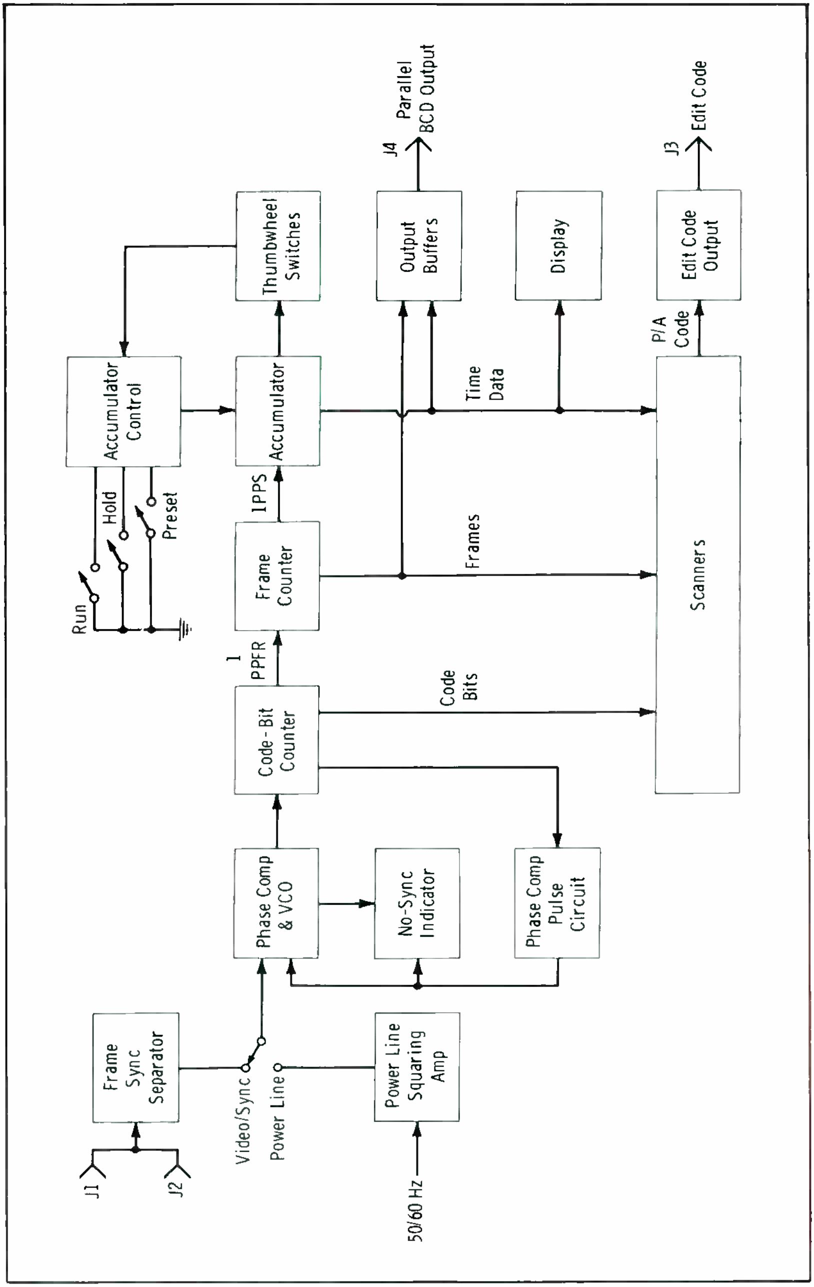


Fig. 10-17. Simplified block diagram of EECO BE 520.

returns the total time error back to 0 milliseconds. Therefore, it is unnecessary to make the two-frame correction at the tenth minute.

Since the color video frame rate is actually 29.97002618 instead of 29.97, there is actually an accumulated error of 0.51 millisecond in ten minutes. This amounts to a total error of 75 milliseconds (0.075 second) per day. If the two-frame error correction were not made each minute (except the tenth), there would be an error of 86 seconds per day.

The generator utilizes either the power-line frequency or an externally applied video/sync signal as its reference frequency. The video/sync signal is applied through either connector J1 or J2 (Fig. 10-17) to the frame sync separator, which separates the sync information from the incoming signal.

The internal power supply operates from either 117 or 234 volts, at 50 to 60 Hz, to provide the necessary dc voltages required by the circuits in the generator. The power supply also generates a 50- or 60-Hz signal (depending on the operating power-line frequency), which is applied to a squaring amplifier. The squared signal is applied to a flip-flop which generates a signal at half the line frequency. The source-switch circuitry selects either the video/sync or ½-power-frequency signal and applies the selected signal to the phase comparator as the reference-source signal.

The phase comparator compares the reference-source signal with an output signal from the phase comparator pulse circuit. The frequency difference, if any, is converted into an error voltage which is applied to the voltage controlled oscillator (vco). The vco is a free-running oscillator the basic frequency of which is changed by the error voltage. A derivative of the vco frequency is fed back to the phase comparator. This forms a phase-lock loop which synchronizes the vco output frequency to the selected reference-source signal. A no-sync indicator circuit gives a visual indication when the vco is not synchronized.

The output frequency of the vco is divided by the code-bit counter, producing various code-bit signals and frame-rate signals. The code-bit signals and clock signals are applied to the scanners to generate the sync-word and frame information for the edit code. A one-pulse-per-frame-rate (1 ppfr) signal is applied to the frame counter to update the frame count. An inverted 64-code-bit ($\overline{\text{64CB}}$) signal is also coupled through an output buffer to J4 as a 1 ppfr output signal.

The frame counter generates frame-count information. When the reference frequency is a 30-Hz video/sync signal, a 29.97-Hz color video/sync signal, or a 60-Hz power-line frequency, the selected frame count is 30. When the reference is a 25-Hz video/sync signal or a 50-Hz power-line frequency, the selected frame count is 25.

The outputs of the RUN, HOLD, and PRESET switch circuits are applied to the accumulator control. The control signals reset all the accumulator outputs to zero, preset the accumulator output at a 50-kHz rate to any desired preset time, advance the accumulator at a 1-pps rate, or hold the accumulator from counting.

The accumulator generates the time of day, 0 to 24 hours, at a 1-second rate. This time is constantly available at the accumulator outputs in parallel bcd (1-2-4-8) form. The accumulator generated time is displayed by numeric indicator tubes. Also, the generated time and the frame count are applied through output buffers to connector J4 as parallel bcd signals.

The scanner receives the time-of-day information from the accumulator, frame information from the frame counter, and signals from the code-bit counter to produce the edit code. The scanner also generates a sync word which is included in the edit code. The edit code is applied to an edit-code output circuit for the necessary amplification, buffering, and impedance matching before being applied to output connector J3.

Space does not permit a detailed description of the circuitry in this equipment. However, a brief analysis of the phase comparator and the vco will assist the reader in becoming acquainted with the type of logic circuitry involved. See Fig. 10-18.

The voltage-controlled oscillator (vco) generates the basic frequency used throughout the generator to form the code bits and clock pulses. The vco is a free-running relaxation oscillator the frequency of which is controllable by the input dc voltage level from the phase comparator. The vco output frequency is divided by circuits in the code-bit counter and then reapplied to the phase comparator at a one-pulse-per-frame rate. Therefore, a phase-lock loop is formed. When the phase-comparison pulses are compared with a one-pulse-per-frame-rate reference-source signal, it is possible for the phase comparator to lock the vco frequency accurately to the incoming video/sync signal or power line.

The phase-comparison signal is a positive-going pulse having a duration of 32 bits and a frequency of one pulse per frame (Fig. 10-19). The positive phase-comparison signal causes Q11 (Fig. 10-18) to conduct at a constant current determined by R47. This constant current causes the potential on C13 to decrease at a linear rate. This forms a negative-going linear ramp with a duration of approximately 400 microseconds. This pulse is applied to the source (S) of FET Q8, through emitter follower Q7.

A narrow reference-source pulse, derived from either the video/sync signal or the power line, is applied to the base of transistor Q12. When the reference-source pulse goes low, the collector of Q12 goes high, thereby back-biasing diode X6. With X6 back-biased, there is no current through resistor R43. Therefore, the voltage difference between the source and the gate of Q8 is zero, causing Q8 to conduct. Capacitor C15 then charges to the voltage at the source (S) of Q8. Because Q8 is turned on at the frame rate (25-30 per second), the voltage level at C15 is maintained and applied to the gate of FET Q9. This FET functions as a source follower, so the voltage level established at its gate also appears at its source.

The oscillator portion of the circuit consists of unijunction transistor Q10, capacitor C17, inductor L1, resistor R35, and potentiometer R37. Capacitor C17 charges through R35 to a level that will allow Q10 to fire.

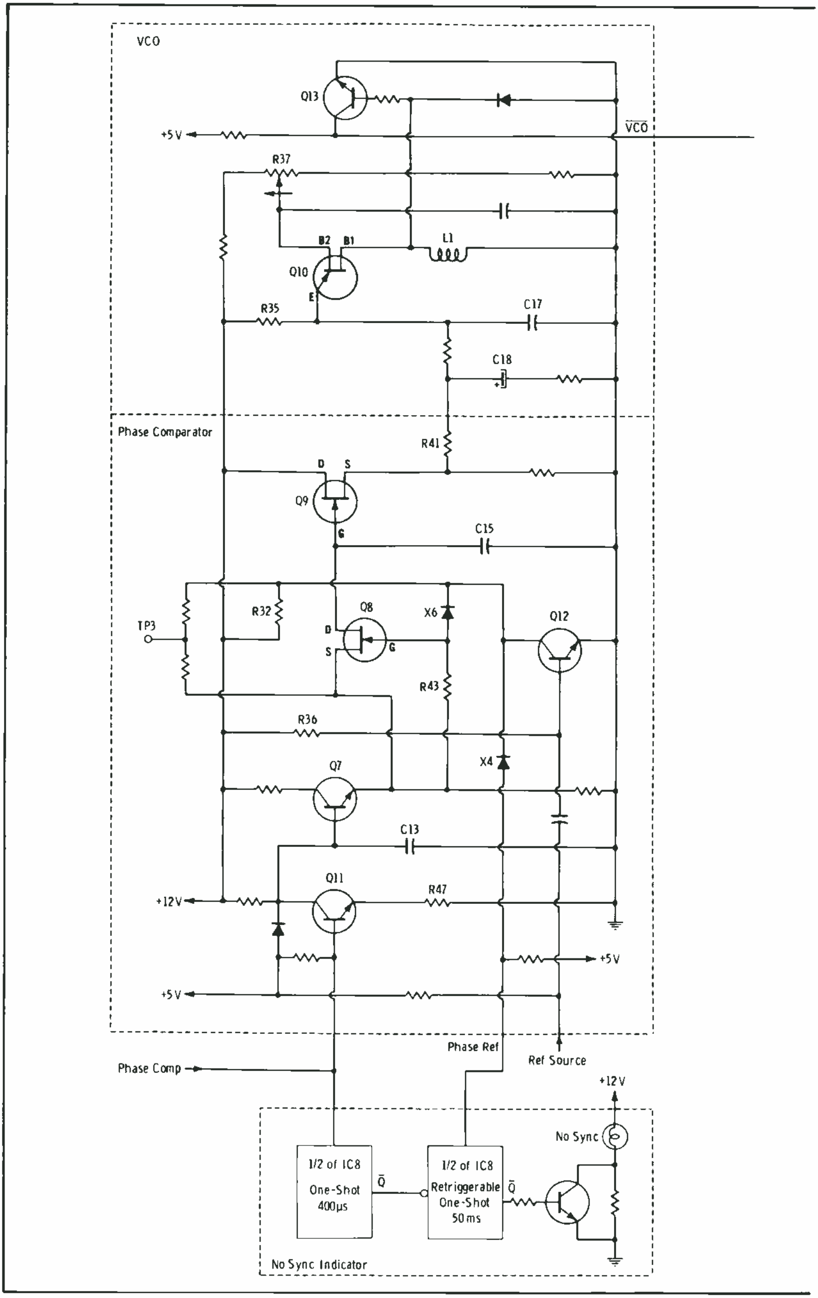
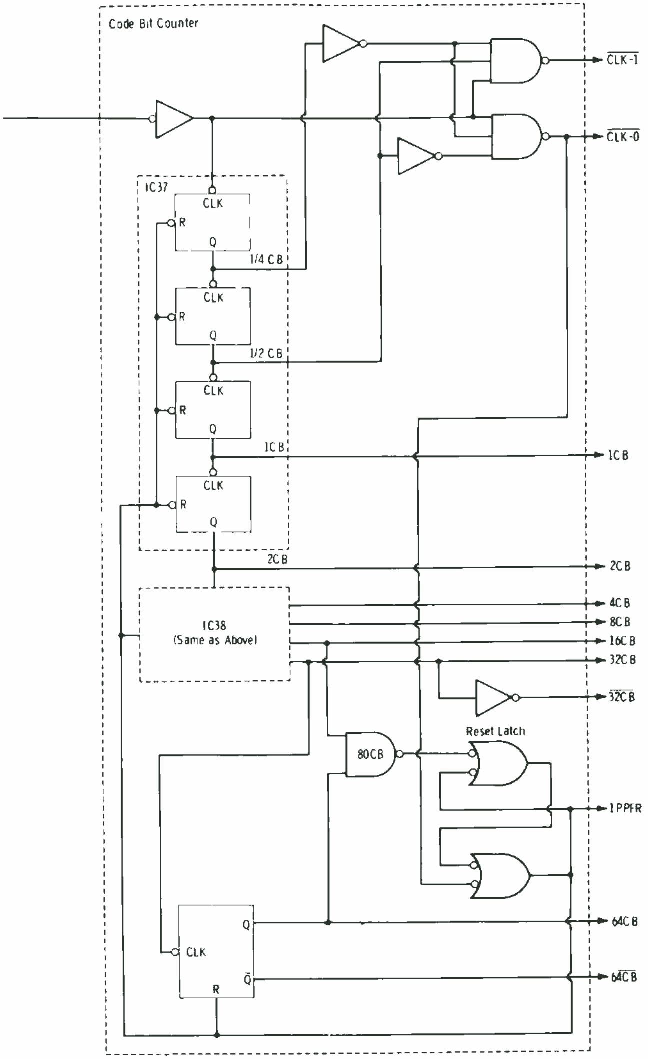


Fig. 10-18. Simplified logic diagram showing



phase comparator and vco section of BE 520.

Capacitor C17 then discharges through Q10 and L1. When the capacitor is discharged sufficiently, Q10 turns off and C17 begins charging again. Potentiometer R37 determines the firing point of Q10 and thereby adjusts the frequency of the oscillator.

Capacitor C17 receives an additional charge through Q9. Therefore, the point on the ramp at which Q8 fires also determines the frequency of the vco. Because a derivative of the vco signal is utilized by the phase comparator, the oscillator is self-compensating and will lock onto the reference-source signal.

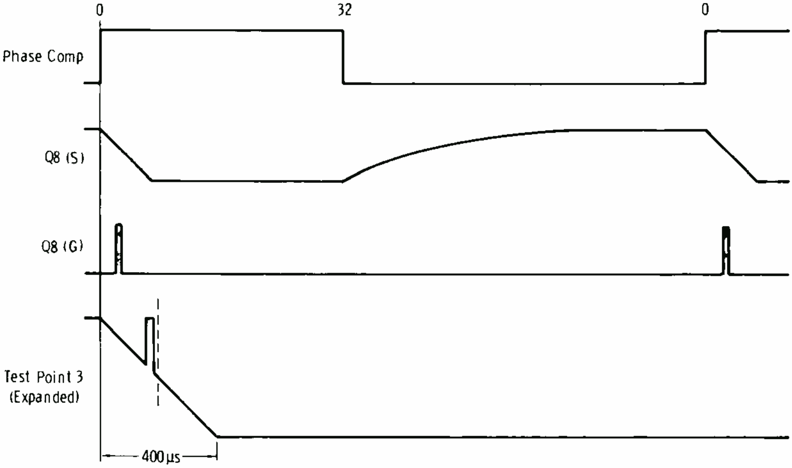


Fig. 10-19. Phase-comparator waveforms.

Test point 3 provides a convenient point for monitoring the adjustment of the vco frequency. With an oscilloscope, both the reference-source pulse and the phase-comparison-signal ramp can be monitored. Potentiometer R37 is adjusted to position the reference-source pulse to coincide with the ramp (Fig. 10-19).

In addition to the actions described above, a phase-reference pulse is coupled through diode X4 to the no-sync indicator circuit.

The BE 420 Edit Time Code Reader

The BE 420 "reads" the standard SMPTE edit code from any source and displays it as real or elapsed hours, minutes, seconds, and frames. This display is available as reference during tape play, rewind, fast forward, or single-frame hold. Scenes from quadruplex or helical tapes may be reviewed and a program sequence developed to show the start and stop times of selected scenes. The program sequence provides an accurate index for manual, automatic, or computer-automated editing of the tapes.

The BE 420 also has helpful supplemental outputs. For example, a field-rate output can be used to keep a multitrack audio recorder in sync with video playback; this eliminates the need for a separate control track in double-system operations (Fig. 10-20). Parallel edit-code outputs are used in computer/automated editing and other equipment controls.

A hold button allows displayed time to be frozen at any point to aid scene identification. Once logged, any scene can be quickly relocated for inclusion in a live broadcast. Significant events can be analyzed in terms of real time.

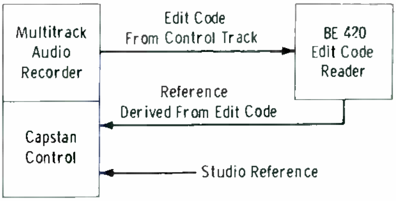


Fig. 10-20. Method of synchronizing audio recorder having control servo.

The incoming SMPTE edit time code is applied through connector J1 to the demodulator (Fig. 10-21). The demodulator utilizes the edit time code to produce two signals, data ones and code clock. The data ones is a series of positive pulses, each being ½ bit count in duration and each occurring when a one transition occurs in the incoming edit time code. The code clock is a series of 80 positive pulses per frame, each with a period of one code bit and a duration of approximately one microsecond. Each code clock pulse is timed so that it occurs just prior to the end of a data ones pulse (if present).

The data ones and code clock signals are applied to a decoder. Both signals are inverted (identified as $\overline{\text{CLK}}$ and $\overline{\text{ONES}}$ in Fig. 10-21) and applied to buffer amplifiers for output signals at J2. Two code-bit signals ($\overline{\text{4CB}}$ and $\overline{\text{64CB}}$) are derived from the code clock and applied through buffers to output connector J2. The sync-word portion of the data ones signal is decoded ($\overline{\text{FRWD}}$) and also applied as an output voltage level at J2 through a buffer. Eight enabling signals (labelled $\overline{\text{1F EN}}$, $\overline{\text{10F EN}}$, $\overline{\text{1S EN}}$, $\overline{\text{10S EN}}$, $\overline{\text{1M EN}}$, $\overline{\text{10M EN}}$, $\overline{\text{1H EN}}$, and $\overline{\text{10H EN}}$ in Fig. 10-21) are produced by the decoder and applied to counter/registers to distinguish properly the various data ones (frames, seconds, minutes, or hours) from each other. The decoder is capable of determining the tape direction (forward or reverse) and, by utilizing a left-right shift register, transferring the decoded serial data (1, 2, 4, 8, and enabling signals) to the counter/register. In addition, field-rate, frame-rate, and read-enable signals are produced, buffered, and made available at output connector J2.

The frames/seconds counter/register utilizes frame and second enabling signals ($\overline{\text{1F EN}}$, $\overline{\text{10F EN}}$, $\overline{\text{1S EN}}$, $\overline{\text{10S EN}}$) and the decoded serial data (1, 2, 4, 8) to produce a set of parallel bcd outputs (labelled BCD

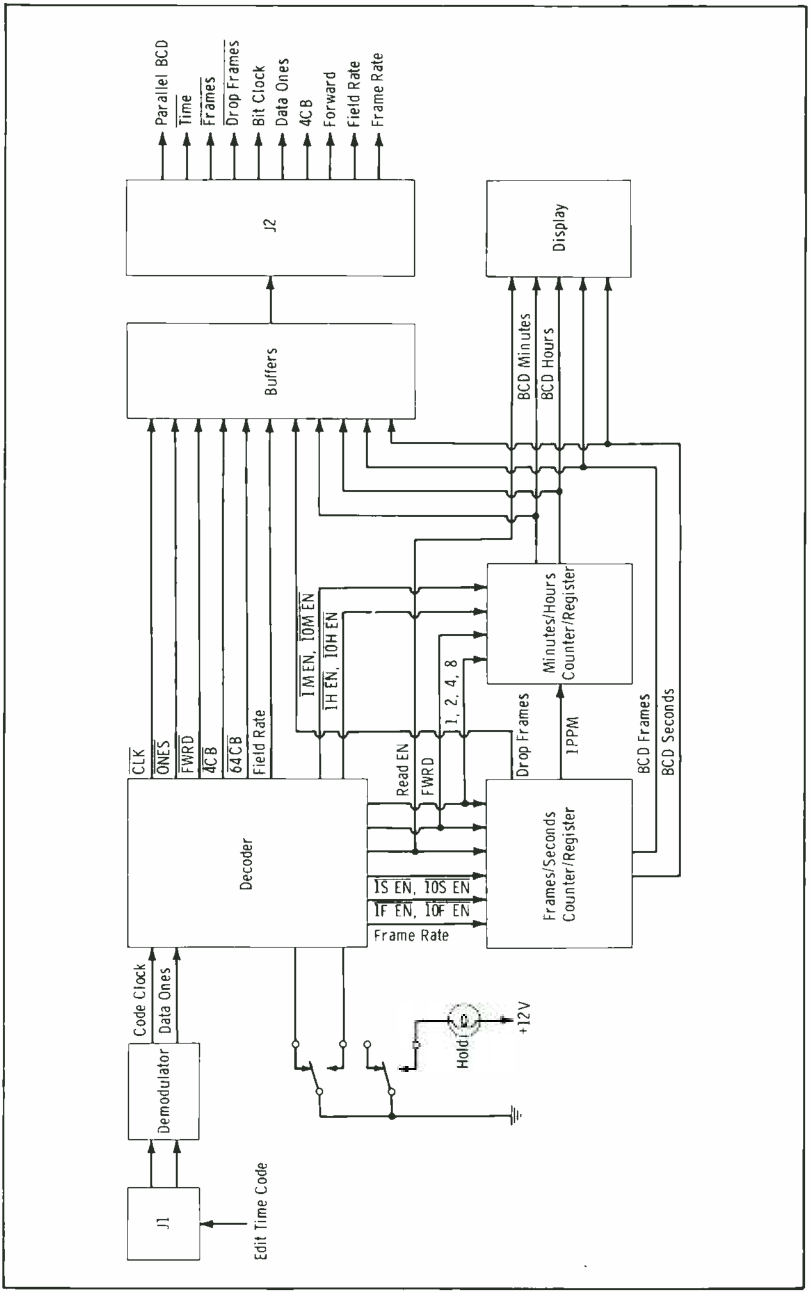


Fig. 10-21. Block diagram of BE 420 code reader.

FRAMES and BCD SECONDS in Fig. 10-21), which are applied to the frames and second display indicators and to buffers for outputs at J2. Other signals used by the frames/seconds counter/register are (as labeled in Fig. 10-21): FWRD, FRAME RATE, and READ EN. A switch in the frames/seconds counter/register selects the frame count (25 or 30) to which the bcd frames are permitted to register before being reset. This switch must be set by the operator to correspond to the number of frames per second in the incoming edit time code.

Similarly, the minutes/hours counter/register produces parallel bcd signals (labelled BCD MINUTES and BCD HOURS) for application to the minutes and hours display indicators and to buffers for outputs.

The HOLD switch activates a latch in the decoder which prevents any further decoding of the ones in the decoder or changing of signals from the counter/register. Therefore, in the hold mode, the display and output signals represent the time and frame count at the instant the HOLD switch was pressed. When the switch is pressed a second time, the latch is released, and the decoder, counter/registers, and display are permitted to update to the time represented in the edit time code. The read-enable signal darkens the frames display by disabling the high voltage to the frames indicators.

The BE 400 Video Character Generator

The BE 400 video character generator converts any number of video monitors into time-code displays. During video play or search, the unit reads the edit code from the tape and generates a corresponding visual time display on the monitor screens. Front-panel switches permit rapid changes in the size and location of the time display, and a black background mask can be added or deleted.

Use of the unit is flexible. It can display the tape edit code (time) on the monitors without affecting the video signals being broadcast or being transferred to another tape. A common option, however, is to add the visual time display to the video signal when it is transferred from a quadruplex recorder to a helical recorder. Scene review is then easy because all scenes, moving or single frame, carry the visual time display.

The features just described make it possible to prepare, with relatively inexpensive equipment, a program sequence log to show the start and stop times of selected scenes. A start-stop time log is useful in a number of operations:

1. Automatic electronic editing
2. Manual electronic editing
3. Computer/automated electronic editing
4. Rapid location of scenes for inclusion in a live program
5. General indexing and filing of taped materials
6. Indexing of computer-stored material

The BE 400 provides a simple method of putting a real-time display on a live video broadcast. It can also provide simultaneous and accurate time references on a number of remote monitors.

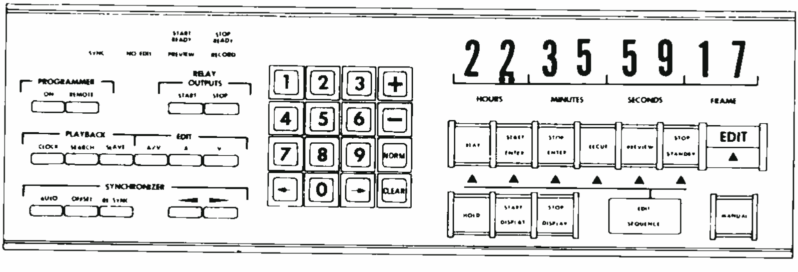
This unit accepts either a standard edit code or parallel time code and frame number input. Control of the output accommodates a wide range of viewing requirements. The BE 400 uses nonadditive video mixing to avoid distortion in video processing channels. Inputs and outputs are TTL, RTL, or DTL compatible.

The BE 210 Electronic Editor Programmer

The BE 210 is the heart of the EECO electronic editing system. It provides precise control of search, cue, and splicing functions, and is designed specifically for use with the RCA TR-60/70 and Ampex VR-1200/2000 series television recorders. This unit provides transport control based on selection of predetermined start and stop points and contains the necessary circuitry for programming the recorder edit electronics and recue functions. This circuitry ensures that the edited scene will be the same as the preview. Features are:

1. Electronic splicing function performed with equal ease for audio, video, or audio and video combined
2. Separate preview and edit functions
3. Automatic frame-by-frame synchronization capability
4. Single sequence control to automate routine editing operation
5. Simple push-button touch entry for edit times and control
6. Keyboard entry and/or modification of start and stop times
7. Human-engineered control panel
8. Backlighted control panel for operation in subdued ambient lighting
9. Single glide recue and search operation

We will go through the basic functions of the BE 210 programmer for the purpose of illustrating how modern electronic editing is computerized. All buttons and switches mentioned are shown in the keyboard drawing of Fig. 10-22.



Courtesy Electronic Engineering Co. of California

Fig. 10-22. Keyboard of BE 210 programmer.

Modification of Times—At any time, as required by the operator, the start and stop times may be recalled and displayed. The start or stop time can be modified by means of a simple front-panel keyboard assembly. The keyboard is enabled by operating either the + or − button. This operation automatically selects the frame number for modification as displayed on the front panel. If modification of the hours, minutes, or seconds is required, the proper digit is selected by operating the left arrow button. The proper digit is indicated by two periods located just below the digit.

Keyboard Time Entry—If times are to be entered from a log, the display register is cleared by operating the CLEAR button. This operation resets the display to zero and places the locating periods below the tens-of-hours digit. As the times are entered from the hours to the frames, the indicator automatically advances to the next digit to the right. Operating the NORM button returns the BE 210 to normal operation of displaying the input code.

Sequence Control—In addition to the normally manual operating controls, an edit sequence control is provided for normal routine edit operation. The normal edit sequence consists of play, start enter (time), stop enter (time), recue, preview, and stop.

Each time the EDIT SEQUENCE button is pressed, the function indicated by a lighted arrow will be initiated. The arrow beneath the next function in the sequence then lights to indicate to the operator the next event in the series. After the stop function has been initiated, the next sequence is recue, preview, stop. This sequence repeats until the edit button is operated. The edit will then be recorded as previewed. The sequence may be interrupted at any point by simply pressing the appropriate function selector.

Limited-Range Synchronizer—The purpose of the limited-range synchronizer is to provide exact frame synchronization of the associated transport to a reference time code. This capability can be used in transfer editing to synchronize the playback transport accurately to the record transport by referencing to the time code from the record machine.

The limited-range synchronizer has an offset mode in which it will lock the stop-time frame number from its own code to the start-time frame number from the reference code. That is, the synchronizer will phase the playback of its own code in such a way that when the code frame coinciding with its start-time frame occurs, the reference code will be at a code frame coinciding with the stop-time frame. The two codes will then be locked in an offset fashion with the offset determined by the respective stop and start times. This assures that the start of action of the playback-machine tape matches the ingoing edit point on the record-machine tape.

The limited-range synchronizer also has a nonoffset mode which disregards the start- and stop-time frames and locks frame 1 of the controlled code to frame 1 of the reference code.

Controls are also provided to advance or retard the capstan servo control circuit manually.

Additional front-panel controls provide the following functions:

PROGRAMMER ON: Activates control functions of the BE 210 to control associated video recorder.

PROGRAMMER REMOTE: Delegates control of BE 210 to remote point.

PLAYBACK/EDIT: Six mechanically interlocked buttons.

PLAYBACK CLOCK: The code at the recorder cue-track input is selected. The time code generator (clock) is normally fed to this point. This selection allows the transport (play and stop) to be controlled from the time-code-generator time.

PLAYBACK SEARCH: The video-recorder cue-track output is selected. The code at this point is one of two. During standby or record, the code at the cue-track input appears at the cue track output through the electronics-to-electronics (E-E) circuit. When the cue track is in playback, the code is reproduced from the tape. This position is normal for tape search and cue. In this mode, the stop time is enabled during recue. The tape may be searched and stopped or cued to any point. A clock or slave code may then be used to place the recorder into play (start). When the recorder is recued, the tape will be rewound to a point (10 seconds normally) ahead of the stop time.

PLAYBACK SLAVE: This external input is used primarily for transport play control and is also the input from the reference machine for the synchronizer. The second input to the synchronizer is from the cue-track output of the local machine.

PROGRAMMER REMOTE overrides any selected playback input. When the BE 210 is placed in remote, the code is selected remotely. When the clock or slave inputs are selected and the recorder is placed into recue, rewind, or fast forward, the code input automatically switches to the VR code input. This is required because the playback code is needed for these operations.

EDIT A/V: Audio-video edit selection. Audio and video edits are made simultaneously. The edit is begun at the start time (ingoing edit) and terminated at the stop time (outgoing edit). In any of the three edit functions, the edit sequencer is operative. When the recorder is recued, the tape is rewound to a point (15 seconds normally) ahead of the start time. A recue time longer than that of a playback machine is required to allow code to be read and a play command to be given to the playback machine at the 10-second preroll time ahead of the edit start time. The A/V function is used to start and stop the preview or record of an audio-video edit. The code from the cue-track playback is used in the edit functions.

EDIT A: Audio-only edits are made. See EDIT A/V above.

EDIT V: Video-only edits are made. See EDIT A/V above.

MANUAL: Operation of the manual edit button allows an ingoing edit to be made using the edit button (after play) and an outgoing edit to be made by operating either play, recue, preview, stop, rewind, or fast forward. Operation of the manual button also resets the edit sequencer to the off condition (no arrows lighted, edit sequence button dim).

START DISPLAY and STOP DISPLAY: Operation of the start (stop) display button transfers the time in the start (stop) storage register into the display logic and displays this time. The time in the store is not altered. This allows stored times to be read and modified. The display is then restored to normal operation by one of three methods. Operation of either the START ENTER, STOP ENTER, or NORM button transfers the display back to the code input selector.

NOTE: The time in one storage register may be moved to another storage register without destroying the time in the first. The NORM button transfers the display to normal operation.

HOLD: The HOLD button freezes the display at the instant of operation. This feature is useful in displaying time without time entry. The display is restored to normal operation with the NORM button. The displayed time may be entered into the start or stop store if required. Either entry button restores the display to normal.

Status Indicators—Indicators are provided on the upper left section of the BE 210.

SYNC: Lights showing that the synchronizer has synchronized local machine to remote code.

NO EDIT: Indicates edit was inhibited.

PREVIEW: Indicates that the video and/or audio monitors have switched to the incoming program.

RECORD: Indicates that the video and/or audio monitors have switched to the incoming program and the machine is recording.

START READY: Indicates that the start time function is enabled.

NOTE: Further editing and animation equipment involving video disc recorders is covered in Chapter 14.

EXERCISES

Q10-1. Why is it not possible to record a new scene into an existing program simply by pressing the record button at the desired time while playing a tape already bearing recorded material?

Q10-2. Describe the basic difference between (A) the insert mode of splicing and (B) the add-on (assemble) mode.

Q10-3. What causes a momentary horizontal "lurch" or "bobble" in the picture at a splicing point?

Q10-4. What controls the capstan servo in the recording machine (machine on which editing is being accomplished) during (A) the insert mode and (B) the add-on (assemble) mode?

Q10-5. Basically, what is "programmed electronic editing"?

CHAPTER 11

Quadruplex Tape System Operations

Television tape systems, now refined to a rather high degree of performance, utilize many unique mechanical and electronic arrangements, each of which makes an important contribution to the final production. Any complex system of this nature requires the development of a certain amount of skill in setup and operation.

Obviously, the degree of skill and knowledge required for operation depends on the operating practices of a particular station. If the tape operator is charged only with threading, selecting the proper video and audio feed, and starting and stopping the system on cue, he will likely not be interested in this book, except out of curiosity or as a means of advancement. However, there are two more common operating practices, which may be listed as follows: (1) In one type of operation, tv tape operators are charged with the responsibility of cleaning, of adjusting modulator frequency and deviation, of calibrating and adjusting video and audio levels, of performing head optimization, of degaussing transport and heads, and of checking out the system with a short trial recording and playback. In this type of operation, maintenance personnel are called to service the equipment in case of abnormal operation and may also be required to carry out more time-consuming functions, such as head optimization, in older tape systems. (2) In the second type of operation, the tv tape operators are charged with all the responsibilities under 1, plus all preventive and emergency system maintenance.

All of the normal operational functions listed under 1 will be considered in this chapter. Chapter 12 will cover preventive and emergency maintenance as well as system performance measurements.

11-1. TERMINOLOGY

The terms most commonly used in tape production techniques may be defined as follows:

Original: The first tape recording of a given program. If multiple machines are used to record this signal simultaneously, then a number of originals exist.

Master: The first tape recording that is complete in all production elements. An original recording which is complete in all production elements can also be the master. A master may also be either of the following:

1. A tape which consists of any number of different originals (or copies) spliced together.
2. A tape which is recorded from any number of other tape-system playbacks (and perhaps from other sources such as film and live inserts) fed through a switching system just as any original production is performed. In this case, all tape systems and any other sources used must be under the control of a common sync generator such as the Ampex Intersync or the RCA Pixlock. This technique eliminates the necessity of mechanical or electronic splicing.

Copy: A recording made from another tape signal, whether a master or a copy. The term *copying master* is sometimes employed for a master tape which has been designated for use in making copies. A *first generation* copy is a copy made from a master. A *second generation* tape is a copy of a copy, etc.

Leader: The portion of a tape immediately preceding program content, usually containing visual and/or aural cues. The term is also applied to a tough protective strip before the leading edge of the recording tape, used to protect the first part of the tape.

Run-Out: The portion of tape following program content, usually containing only sync information to allow fade or cut-out before going to "noise" (tape playback without signal).

Standby Tape: Production term given by the director to cue the operator to get ready to start the tape rolling. In many instances, the operator starts the capstan action (capstan turns without the tape being engaged) on receiving this cue. This is always done when the fast-start method of operation is followed. This method allows only 2 or 3 seconds after the tape is rolling to the actual "take" by the video switcher. The tape-recorder switch for this function is labeled OVERRIDE by Ampex and STANDBY by RCA. This procedure is also sometimes practiced even when the more normal 6-second lapse between roll and take is used, since the system normally stabilizes more quickly when the capstan is already up to speed before engaging the tape.

Roll Tape: Term used by the director to instruct the operator to start the tape rolling by depressing the PLAY button. The capstan engages the tape immediately, and a video signal is delivered from the tape as soon as the vacuum guide engages the tape with the rotating heads. This interval is normally 1½ to 2 seconds, depending on the setting of the associated time-delay relay. (This time may be as long as 4 seconds.)

Cue-In: Method used to enable the operator to stop the tape at the proper point prior to the start of actual program content. Visual or aural cues may be used; the aural portion is either on the regular program sound track or on the cue track. One common visual method is the televising of a second-clock with the second hand started about 15 seconds prior to the program, turning counterclockwise toward zero. The signal is brought to black level 2 seconds before program start to provide a clean take interval for the video switcher.

11-2. THE SYSTEM CONCEPT IN TAPE OPERATIONS

Tape-recording setup and operational techniques become more difficult as the limits of use for which the tape is made are expanded. A program to be recorded one day and run the next day on the same head may be considered a highly limited application of responsibilities. Recorded characteristics may be entirely incompatible with other heads or recording systems but result in entirely satisfactory playback in this instance.

To go a step further, consider the case where a number of spot commercials are to be recorded for use at the same station. Even though the same tape systems will be used for these spots, there is certainly no guarantee that the same head will be used throughout the life of the commercial commitment. Some degree of standardization is now highly desirable.

The next step is interchangeability with other heads and other systems. Important standardizations may be listed as follows:

1. *Video Heads:* Quadrature and gap-azimuth alignment, vacuum-guide position horizontally (controlling tip penetration), and vacuum-guide position vertically (for correct concentricity at the standard tip penetration).
2. *Video Signal:* Carrier frequency, deviation related to 100-percent modulation, type of pre-emphasis, and video bandwidth within limits of good transient response and linear gray scale.
3. *Control Track:* Recorded 240-Hz level, edit-pulse level and phasing, and track width.
4. *Audio Head:* Track width, accuracy of placement, and gap-azimuth alignment.
5. *Audio Signal:* Recorded signal level within limits of distortion components, pre-emphasis, and audio bandwidth.
6. The final and most exacting step is *interspliceability.*

In addition to all of the preceding factors, the control-track signal phasing relative to the reference pulse (hence recorded video tracks) must be standardized. A spliced-in section which is different in control-track phasing relative to the preceding and succeeding sections will need to be manually retracked upon entering and leaving the spliced portion. Even under the most fortunate operating conditions, a disturbing discontinuity will occur.

In order to provide a broad background for the more detailed operating techniques, this section will consider the entire system concept of operations. Following sections will detail actual operating procedures. It is advisable for the reader to review this section after studying the remainder of Chapter 11. Studying in this way will make the chapter contents most effective.

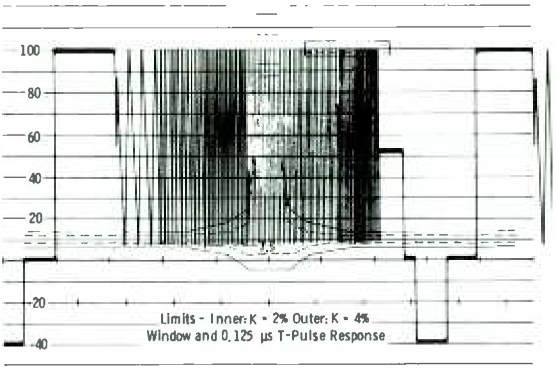
The built-in tape-monitoring oscilloscope will be used as a standard for judging system setup and performance characteristics. Regardless of the type of cro in your particular machine, the Tektronix Type 529, which is popularly used in both the RCA TR-70 and Ampex VR-2000, is a good place to start our discussion.

First, get a clear concept of what you are going to observe. The machine has an "E-E" mode (review Fig. 5-1, Chapter 5) which is quite important in checks and setups, even though this is strictly "back-to-back electronics" with the machine in the stop mode. Here is the basic idea to retain: The E-E circuitry will show signal continuity, levels, and frequency and transient response through the video input amplifier, modulator, demodulator, any time-base-error video amplifiers used (minus the correcting error signals, which must act while the system is in playback), and the output processing amplifiers. System sections and signals you *don't* see with E-E circuitry are the record amplifiers, the fm signal being laid down by the video head in the record mode, the playback preamplifiers, the channel amplifiers (including equalization circuitry), and the switcher output. You should have the E-E circuitry in the best possible operating condition and then make recording and playback adjustments to give a match with the performance of the E-E circuit.

See Fig. 11-1A. This is the multiburst signal as it should appear at the system input. Note that the sine-wave bursts are no longer reduced to 70 percent of white-flag level as was shown by Fig. 5-2. (We are speaking now of the latest high-band/low-band systems, not the older systems. If you are concerned with an older system, keep the proportion of Fig. 5-2.)

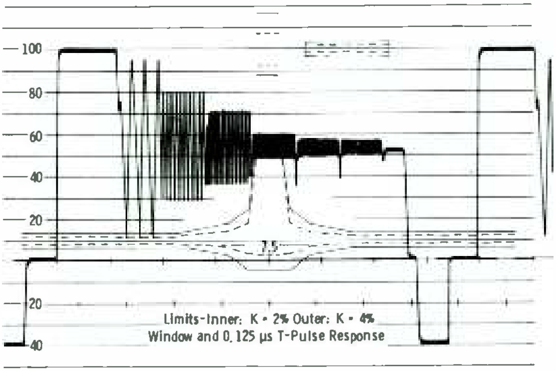
When the selector switch is in the input position, the monitoring cro is actually "looking at" a point after the input-level control in the video input circuitry. This enables you to adjust the input level to a standard 1-volt composite amplitude, regardless of the level being fed from the source. Also in later systems, there may be a high-frequency compensation control as well as an input-level control. This enables you to set the input frequency response for a "flat" multiburst pattern.

At this point let us emphasize that you have not established a standard by which to judge anything! How do you know what any test signal looks like at the actual input to the tape system? You must occasionally check this with an external standard, which, in this case, means an external cro. And if you use a sine-squared pulse test, you cannot use the Tektronix



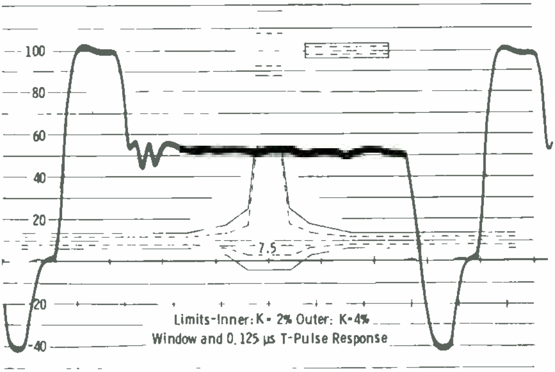
Courtesy Tektronix, Inc.

(*A*) *Flat position.*



Courtesy Tektronix, Inc.

(*B*) *IEEE position.*



Courtesy Tektronix, Inc.

(*C*) *Low-pass position.*

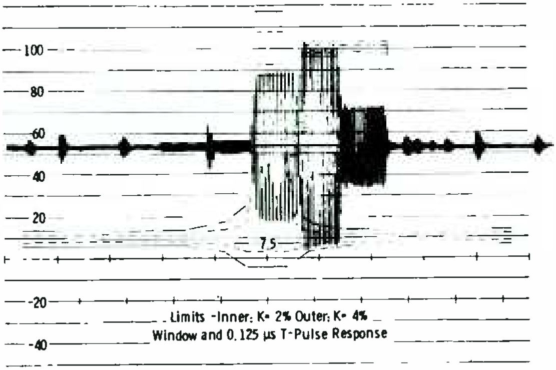
Fig. 11-1. Multiburst

Type 524 scope. This should be made evident as the discussion continues. The recommended Tektronix scopes for modern systems and test techniques are Types 545B, 547, or 453 with Mod 127C.

Thus, the "external standard" will be a scope with a 35- to 60-MHz bandwidth. Use this at periodic intervals to observe the terminated input signal to the monitoring cro. The two should show the same response.

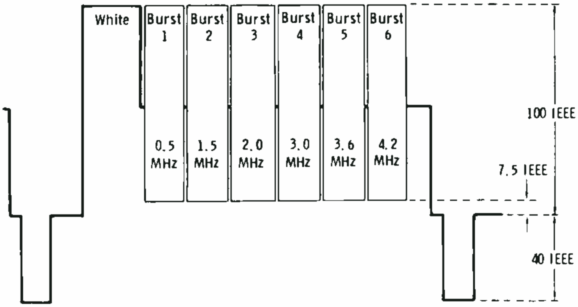
Use the external cro periodically to check the test signal input (actual system input) across the input termination. This should be done for all signal paths feeding the tape system and is particularly important for color tape systems.

Use the multiburst test signal for all these checks. Then switch the monitoring cro to the output and check the response of the E-E circuitry. On modern high-band recorders, you should see exactly what you see at the input. On modern recorders in the low-band E-E mode, you will normally see the last burst (4.2 MHz) slightly rolled off, with a predominant "beat" pattern (moire).



Courtesy Tektronix, Inc.

(*D*) *High-pass position.*



(*E*) *Applied signal.*

responses of waveform monitor.

You should check the remaining response positions of the cro, as shown by Figs. 11-1B through 11-1D. The low-pass position (Fig. 11-1C) is quite important in the following respect. Only the dc axis remains. If there is any "selective clipping," the axis will shift at the burst frequency where this occurs. "Selective frequency clipping" simply means that clipping occurs at one or more particular frequencies. When one side of a sine wave is clipped and then the waveform is restored to a sine wave by filtering circuits, the dc axis is shifted. The pattern of Fig. 11-1C, as well as all other patterns (except Fig. 11-1A in low band), should look the same at the output as it does at the input. (This still concerns the E-E mode.)

> NOTE: This chapter is not intended to give solutions as to what to do in case of troubles. It is meant only to provide the operator with the proper background to *recognize* when maintenance is needed. Maintenance is taken up in Chapter 12.

Fig. 11-1E shows the proper proportion of the multiburst amplitude levels. Remember that when you calibrate the scope for 140 IEEE units equal to 1 volt, then:

Volts/Unit = 1.0/140 = 0.00714

0 to 100 IEEE Units = 0.714 Volt, Blanking to Peak White

0 to −40 Units = 0.286 Volt, Sync Region

Now we will consider the $\sin^2$-window test signal.[1] It is used because it provides a simultaneous measurement of three characteristics which should be grouped together into one *K-factor* for evaluation of system performance. Fig. 11-2A shows a continuous sine wave (top waveform) at a frequency of 4 MHz. One cycle of this wave has a duration of 0.250 μs. If the sine wave is shifted 90°, there is one complete cycle of a 4-MHz *cosine* wave, starting and finishing at its negative peaks. With an added dc component (lower waveform) to raise the negative peaks to the zero axis, the T-pulse for a 4-MHz system is formed. The half-amplitude duration (h.a.d.) is 0.125 μs, or 1/8 μs, or one picture element in a 4-MHz system. The test signal generator normally supplies three selectable pulse durations, as shown in Fig. 11-2B.

Fig. 11-2C shows that the significant energy spectrum of the T-pulse is 50-percent (6 dB) down at 4 MHz, and there is practically no energy beyond 8 MHz. The 2T-pulse is 50-percent down at 2 MHz, with practically no energy beyond 4 MHz. The T/2-pulse is not used for performance evaluation in vtr systems.

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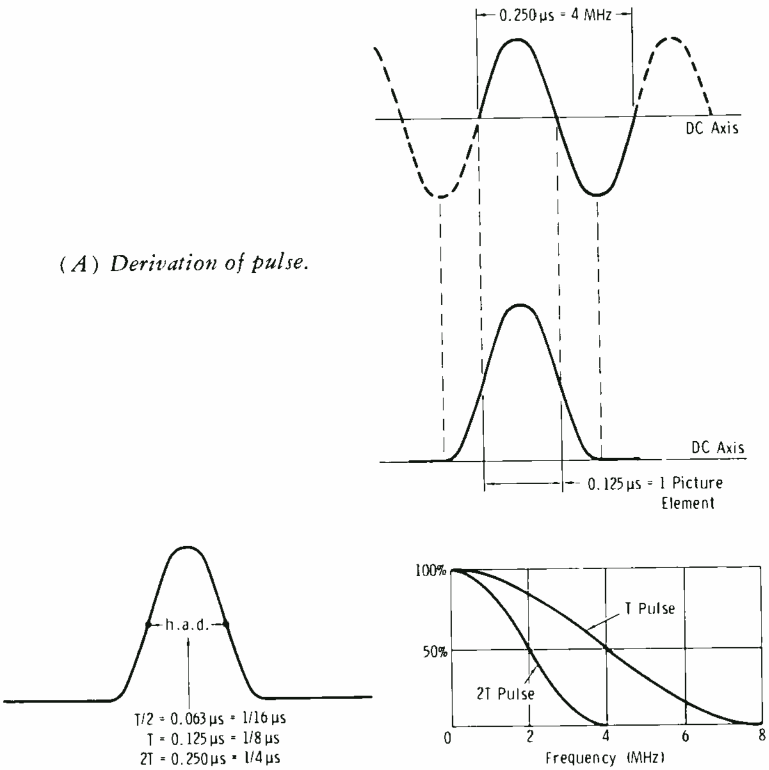
[1] For a more complete development of the $\sin^2$ pulse, see *Television Broadcasting: Systems Maintenance* by Harold E. Ennes (Indianapolis: Howard W. Sams & Co., Inc., 1972), p. 77 ff.



(*A*) *Derivation of pulse.*

(*B*) *Half-amplitude duration.*

(*C*) *Energy spectrum.*

Fig. 11-2. The sine-squared pulse.

This energy spectrum provides a standard for system evaluation, much the same as the standard VU meter was provided for aural gain riding. This is to say that a known frequency spectrum is used. (The square-wave response, formerly used, depended entirely on the rise time of the waveform and was difficult to interpret for transient response.) The window signal has exactly the same rise time as its associated sine-squared pulse.

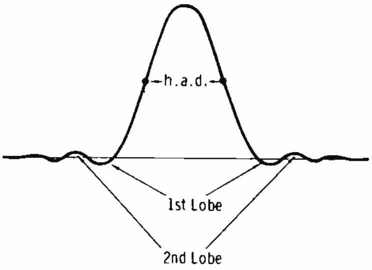
It is necessary to be sure you know how to establish and use this standard. First, study the scope evaluation in Table 11-1. Note in particular that the Type 529 waveform monitor exceeds the specifications of the Type 524 scope to 8 MHz. An external standard must be much better than the monitoring scope to set up and maintain the vtr system properly. Actually, the Types 453 and 547 are the preferred scopes for a studio system. Now note that although the T/2-pulse is not used for the vtr, it is used for checking the specifications of the Type 529 waveform monitor. The T/2-pulse has 50-percent energy at 8 MHz. Theoretically, the scope which measures the pulse should have its −3-dB response at least five

Table 11-1. Tektronix Scope Characteristics

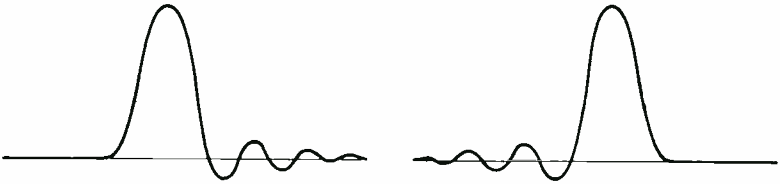
	Response (to —3 dB)	Rise Time
Type 453-TV Scope		
20 mV to 10 V/Div	Dc to 50 MHz	7 ns
10 mV/Div	Dc to 45 MHz	7.8 ns
5 mV/Div	Dc to 40 MHz	8.75 ns
Type 545B		
With 1A1 Preamp		
50 mV/cm	Dc to 33 MHz	11 ns
5 mV/cm	Dc to 23 MHz	16 ns
Type 547		
With 1A1 Preamp		
50 mV/cm	Dc to 50 MHz	7 ns
5 mV/cm	Dc to 28 MHz	13 ns
Type 529 Waveform Mon		
	50 Hz to 6 MHz Within 0.1 dB	
	50 Hz to 8 MHz Within 0.3 dB	
Transient Response:	T/2 Pulse at Least 94 IEEE Units to Window	
Midfreq Response:	Within 1/2 IEEE Unit on Window	

times better; this is 5 × 8, or 40 MHz. If the external scope shows the T/2-pulse at 100 percent of window height, the Type 529 monitor should show at least 94 IEEE units with 100 units of window signal.

The $\sin^2$-pulse measurement through the system under test is made in terms of the first and second lobes (Fig. 11-3A), the amplitude ratios of



(*A*) *Lobe designations.*



(*B*) *Increasing delay with increasing frequency.*

(*C*) *Decreasing delay with increasing frequency.*

Fig. 11-3. Sin^2 pulse with ringing.

the leading-edge and trailing-edge lobes, the h.a.d., and (with the combination window and pulse) the relative heights of the pulse and window.

A rapid rolloff (almost a cutoff) just above the video bandwidth concerned results in practically no effect on the amplitude, but it does produce ringing. The shape of the rolloff and whether the resulting phase shift is leading or lagging is revealed by the distribution of ringing before and after the pulse. See Fig. 11-3A. A fairly rapid rolloff with phase equalizers incorporated to correct the resulting phase distortion will cause the ringing amplitudes to be equally distributed before and after the pulse. The degree and nature of the high-frequency phase distortion is measured by the departure from this optimum response characteristic. In Fig. 11-3B, we have an indication of increasing delay with increasing frequency. In Fig. 11-3C, we have an indication of decreasing delay with increasing frequency.

The system performance K-factor is related to the following (simultaneous) characteristics:

High Frequency: K-factor of pulse
Low Frequency: K-factor of bar (window)
Midfrequency: K-factor of pulse-to-bar amplitude ratio

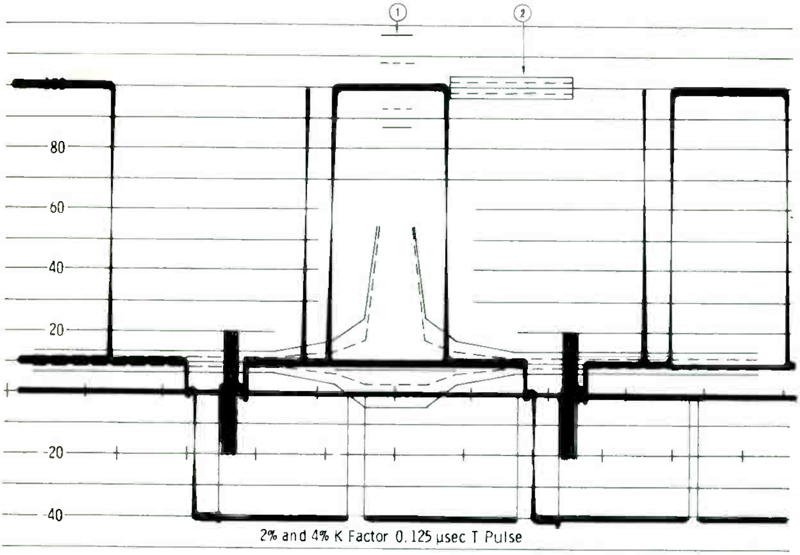
Fig. 11-4A represents the graticule of the Tektronix Type 529 scope with the sin^2-window signal displayed with normal horizontal sweep. The limits for 2-percent K-factor are shown by dash lines, and solid lines indicate the limits for 4-percent K-factor. The limits for the pulse-to-bar amplitude ratio are indicated at point 1. The limits on "tilt" of the bar (window top) are indicated at point 2.

Fig. 11-4B represents the same signal displayed at 0.25H/cm with the ×5 multiplier. Note that the base line is at the 7.5-percent line, indicating standard 7.5-percent setup.

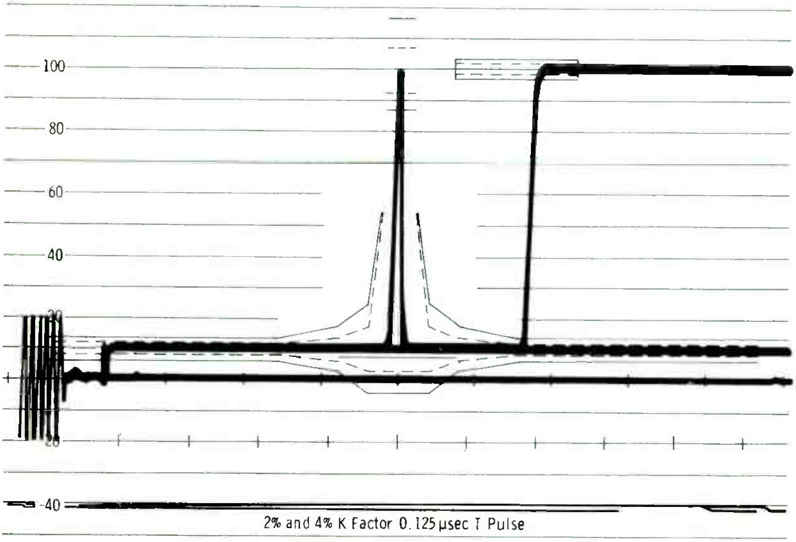
Fig. 11-4C represents the proper display of the pulse (only) to measure h.a.d. and any ringing amplitudes. The h.a.d. point (1) is indicated by the termination of the K-factor lines, accounting for the 7.5-percent pedestal used. When looking at the system output on the cro, remember to adjust the pedestal output so that the base of the pulse is at 7.5 IEEE units. Although the graticule is marked for a T-pulse, the 2T-pulse is measured on the same graticule by proper adjustment of the time base.

With modern high-band systems, you should see no difference on the Type 529 monitor at the input and output for a 2T-pulse in the E-E circuitry. The T-pulse will show a difference between the output and the input. If proper phase correction is employed, an indication something like that of Fig. 11-3A will be obtained. The T-pulse will be somewhat lower in amplitude than the window.

High-frequency rolloff results in loss of amplitude of the pulse. This results in a widening of the h.a.d., since the area of the pulse represents



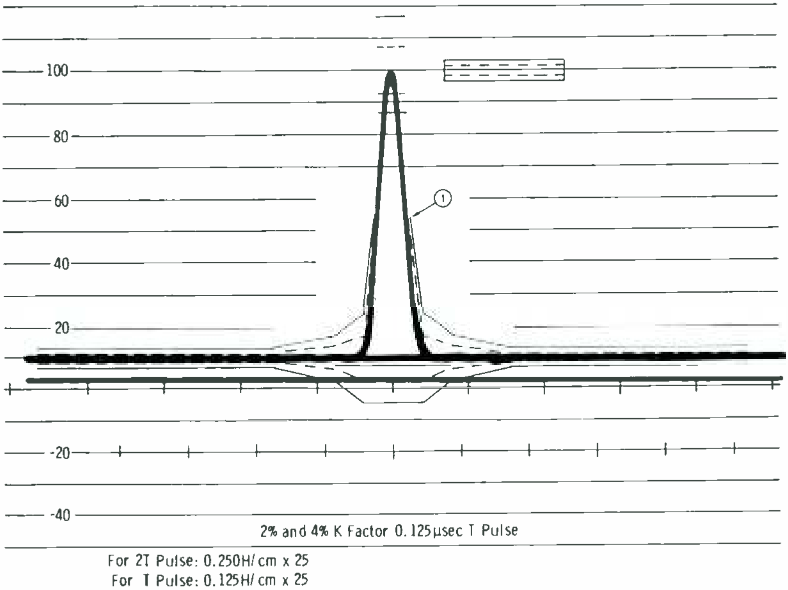
(*A*) *Display with normal sweep.*



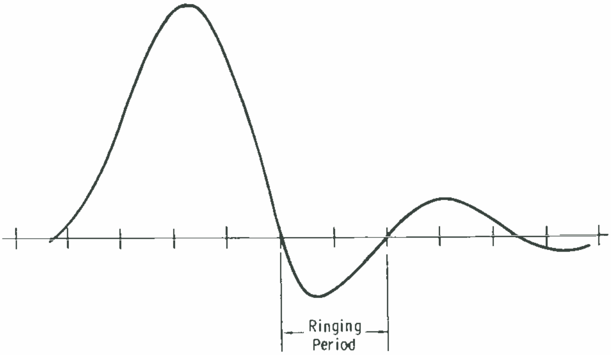
(*B*) *Sweep set for 0.25H/cm × 5.*

Fig. 11-4.

a constant dc component. The energy is simply redistributed. A slow rolloff within the energy spectrum produces a large reduction in amplitude (and increase of pulse h.a.d.) with little or no ringing. A rapid rolloff close to the top of the energy spectrum produces both a reduction (perhaps slight) in amplitude, and ringing. Ringing occurs at the frequency at which the gain dip occurs in the system being measured. The amplitude of ring depends on the sharpness of this gain-dip characteristic.



(*C*) *Display of pulse only.*



(*D*) *Ringing period.*

Waveform displays.

The ringing period (Fig. 11-4D) has the following relationship to the cutoff frequency:

$$R_p = \frac{1}{f_c}$$

where,

R_p is the ringing period in microseconds,
f_c is the cutoff frequency in megahertz.

For example, if the cutoff frequency is 4 MHz, the ringing period is:

$$R_p = \frac{1}{4} = 0.250\ \mu s$$

Then to find the cutoff frequency (in megahertz) for a given measured ringing period (in microseconds):

$$f_c = \frac{1}{R_p}$$

Test Tapes (Low Band)

One of the most convenient methods of overall playback evaluation on an operational basis is provided by the use of the SMPTE alignment tape, based on Recommended Practice RP10. It should be noted that the manufacturer records the standard alignment tape according to the SMPTE specifications; the SMPTE does not manufacture the tape. The customer obtains his alignment tape from the manufacturer of his particular system.

In *Signal Specifications for a Monochrome Video Alignment Tape for 2-Inch Video Magnetic Tape Recording* (SMPTE Recommended Practice RP10), which follows, sequential bands from top to bottom of the raster (each band of 16 to 17 lines representing a single pole-tip sweep across the tape) are identified by numbers 1 through 16. The first band of lines after that which contains vertical sync is identified as band 1; therefore, band 1 is at the top of the raster. Fig. 11-5 correlates the video-head number with the SMPTE band number. This correlation assumes that the capstan tracking is adjusted so that the same head that plays vertical sync also records vertical sync (head 1 for RCA and head 4 for Ampex).

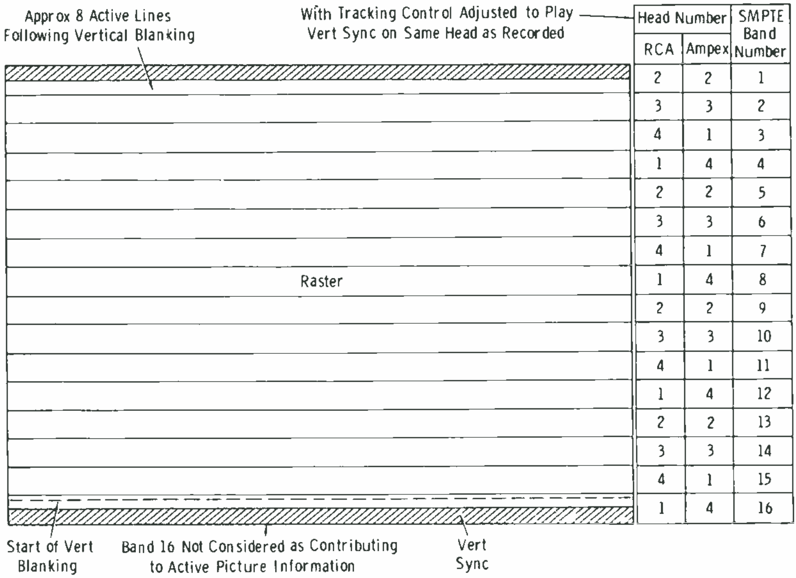
NOTE: Although this test tape is specified as being for a monochrome recording, useful color evaluation is also possible. A high-band color test tape is described later.

SMPTE Recommended Practice RP10

The material in this subsection has been taken from SMPTE Recommended Practice RP10. For convenience, the paragraph numbering has been retained.

1. Scope

1.1. This recommended practice specifies the signals to be recorded on a magnetic video tape for use in evaluating and adjusting the performance of monochrome video-tape recording and playback equipment on a routine operational basis. The characteristics which can be checked primarily are related to the video performance, although a cursory check of the audio channel is included for operating convenience.



Head Number		SMPTE Band Number
RCA	Ampex	
2	2	1
3	3	2
4	1	3
1	4	4
2	2	5
3	3	6
4	1	7
1	4	8
2	2	9
3	3	10
4	1	11
1	4	12
2	2	13
3	3	14
4	1	15
1	4	16

Fig. 11-5. Raster makeup related to heads and SMPTE band number.

1.2. Specifically, the recorded signals on the tape provide a means for checking the following characteristics or adjustments:

(A) Video-head quadrature
(B) Tape vacuum-guide position
(C) Video levels
(D) Video amplitude-frequency response
(E) Video transient response
(F) Video low-frequency tilt
(G) Video amplitude linearity
(H) Video-head playback sensitivity
(I) Relative noise banding
(J) Rf-carrier deviation frequencies
(K) Program and cue-track audio levels
(L) Control-track levels and phase.

2. Recorded Signal Characteristics

2.1. The video signals recorded by the video heads shall occupy sequential bands from top to bottom in the reproduced picture, each band corresponding to a single traverse of a video head across the tape. For the purpose of identification, these bands are designated as 1 through 16. The first band after that containing the vertical synchronizing-pulse interval shall be designated as band 1. (Band 1 will contain fewer active lines than the other bands, because it contains a portion of vertical blanking.) The active picture portion of the horizontal scan shall be divided into 11 equal sections. For the purpose of identification, these sections are designated as 0 through 10. Information shall be recorded as follows:

2.1.1. (Bands 1 through 4) A stairstep signal consisting of a 10-step linear gray scale extending from blanking level to 100 IEEE units, respectively (Fig. 11-6A).

2.1.2. (Bands 5 through 8) A stairstep signal consisting of a 5-step linear gray scale extending from black level to 50 IEEE units, respectively (Fig. 11-6B).

2.1.3. (Bands 5 through 8) A series of 5 sine-wave bursts (Fig. 11-6B) described as follows: The time sequence of the burst frequencies shall be 4.2, 3.6, 3.0, 2.0, and 1.5 MHz. The axis of the multiburst shall be at 30 IEEE units, and the peak-to-peak amplitude shall be 40 IEEE units. Each burst duration will be at least 75 percent of the section width.

2.1.4. (Bands 9 through 15) A window signal at reference white level (100 IEEE units) 3 sections wide and 6 bands high to be positioned horizontally in sections 6, 7, and 8 (as shown in Fig. 11-6C) and vertically between the centers of the ninth and fifteenth bands. The remaining section shall be at blanking level (0 IEEE units).

2.1.5. (Band 16 only) Vertical synchronizing-pulse interval and a portion of vertical blanking.

2.1.6. (Bands 1 through 15) Sine-squared pulses ⅛ microsecond wide (measured at half level) and 50 IEEE units high at horizontal positions corresponding to the center of each of the first six sections. The base level of each sine-squared pulse shall be as follows:

(A) Bands 1 through 8, the same as the accompanying stairstep section level, as shown in Figs. 11-6A and 11-6B.
(B) Bands 9 through 15, at blanking level, as shown in Fig. 11-6C.

2.2. The waveform of the composite signal shall appear as shown in Fig. 11-6D.

2.3. All synchronizing waveforms and signal amplitudes shall conform with EIA Standard RS-170 or the latest revision thereof.

2.4. All video signals shall be within ±1 IEEE unit of specified amplitudes.

2.5. The leading and trailing edges of the window signal shall correspond in shape and rise time to the sine-squared pulse specified in paragraph 2.1.6.

2.6. Overshoot of the stairstep signal shall not exceed 5 percent of the amplitude of transition. An exception is the trailing edge of the stairstep (leading edge of horizontal blanking), which is limited to 2 percent in accordance with EIA Standard RS-170 or the latest revision thereof.

2.7. Multiburst frequencies shall conform with specified values within 1 percent. Total harmonic distortion content of the multiburst frequencies shall not exceed 2 percent.

2.8. The audio tone and cue records shall consist of an audio tone interrupted periodically with voice announcements.

2.9. (A) The audio tone shall be 400 Hz ± 2 percent recorded at a level 10 dB below that corresponding to a 3-percent total harmonic distortion at 400 Hz. (B) The audio response-frequency characteristics shall be as specified in "Proposed American Standard Characteristics of the Audio Records for 2-In. Video Magnetic Tape Recordings" (VTR 16.5) or the latest revision thereof.

2.10. The voice announcements shall be made at 1-minute intervals and shall not exceed 20 seconds in duration. The announcement shall provide identification of the tape as regards the applicable SMPTE recommended practice, the tape issue number, and the manufacturer of the standard tape. Additional identification (such as serial number) may be included at the discretion of the manufacturer.

3. Recording Conditions

3.1. The video-alignment tape shall conform with applicable American standards and SMPTE recommended practices.

Use of the Test Tape

Special care and precautions should be taken in the handling of an alignment tape. The following quotes are from the RCA instructions for the MI-40793 alignment tape (SMPTE):

"Since the tape can be affected by changes in temperature and humidity, extreme changes are to be avoided. The following atmospheric conditions are recommended for the area in which the tape is stored:

Relative Humidity: 40-60 Percent
Temperature: 60-80°F

"Do not attempt to use the tape until it has been stabilized for at least 16 hours at room temperature.

"Take precautions to avoid erasing the tape accidentally. Do not place or store the tape in the region of magnetic fields.

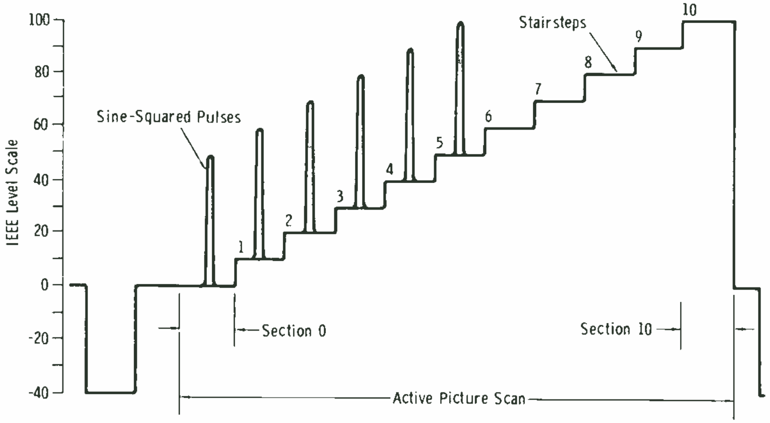
"Make certain that the heads and guides on the recorder are clean before using the tape.

"Check the setting of the reel brakes. Rapid stops with improperly set brakes can damage or distort the tape.

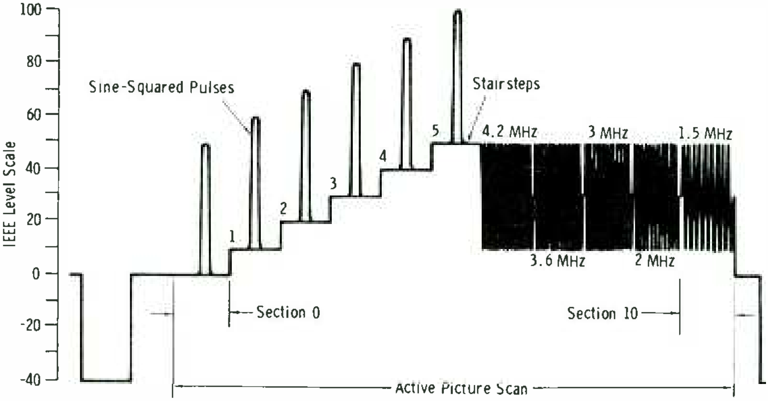
"Be careful to wind and rewind the tape properly; the edge of the tape must not climb up the side of the reel.

"After long usage, short-duration, small pressure changes on the order of 0.0001 inch (0.1 mil) may begin to appear in the tape during playback. However, the tape may still be used by choosing the average vacuum-guide position."

A photograph of the monitor display of the input signal for the SMPTE tape at the time a recording is being made is shown in Fig. 11-7. The bands and sections established by Recommended Practice RP10 are identified on the photograph for convenience. Fig. 11-8 is the oscilloscope dis-



(*A*) *Bands 1 through 4.*

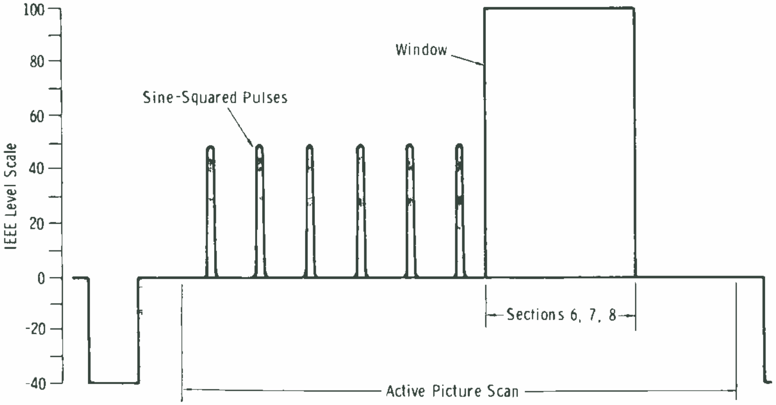


(*B*) *Bands 5 through 8.*

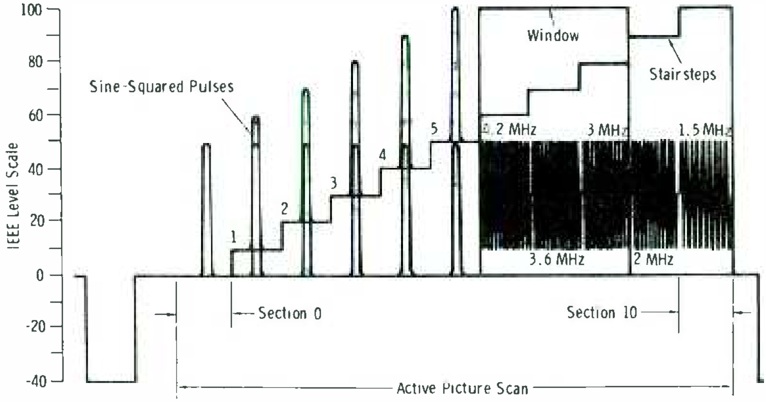
Fig. 11-6.

play (horizontal-rate sweep) of the monitor signal in Fig. 11-7. It is obvious from Fig. 11-7 that adjustments for quadrature and vacuum-guide position may be made to eliminate geometric distortion of the vertical lines, as previously described. Most of the remaining system evaluation is obtained by analysis of the oscilloscope waveform display. Photographs of the output signals taken from an RCA TRT-1B recorder while playing the alignment tape are shown in Fig. 11-9. Since the signals are keyed only onto definite portions of the composite signal, the line-selector trigger must be used on the oscilloscope. By selecting the appropriate sweep speed, any particular line or lines can be displayed. Normal horizontal-rate sweep is used for the composite signal display shown in Fig. 11-9A.

When you have checked the E-E circuitry for proper characteristics, play the SMPTE alignment tape, and observe as closely as possible the T-pulse



(C) Bands 9 through 15.

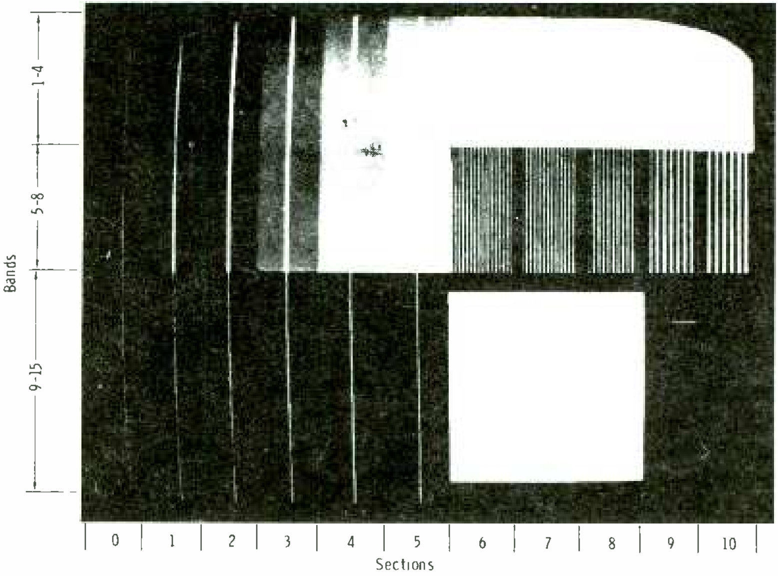


(D) Composite waveform.

SMPTE waveforms.

response in the playback mode. (This tape at present uses the 0.125-μs T-pulse.)

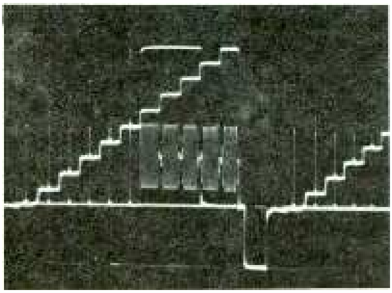
Then it is a simple matter to compare the record mode with the playback mode. Make a recording of the T-pulse and window signal from a properly set up test signal generator. On the latest high-band color systems, the overall performance should be better than the present SMPTE RP10 alignment tape, which is a low-band monochrome test.



Courtesy RCA

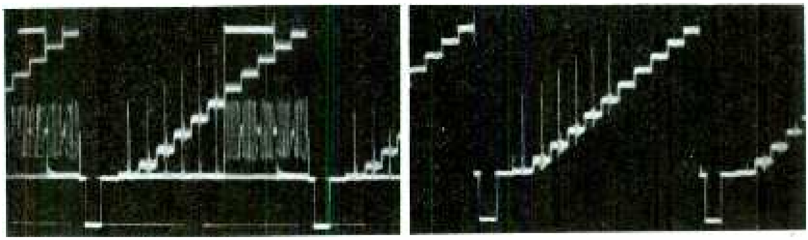
Fig. 11-7. Monitor display of SMPTE input signal at time of recording.

The playback waveform should be within the 4-percent K factor for the T-pulse (on modern systems). The actual specifications are normally given in terms of the 2T-pulse, where the playback should be well within

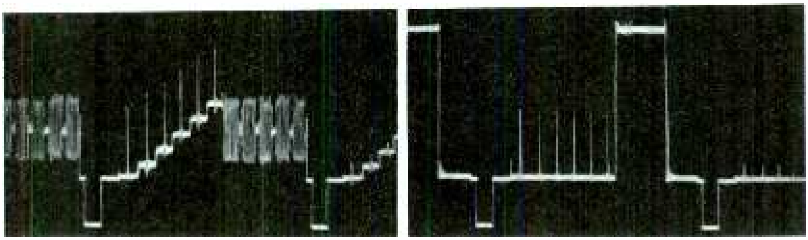


Courtesy RCA

Fig. 11-8. Oscilloscope display of SMPTE input signal at time of recording.



(A) Composite waveform. *(B) Bands 1 through 4.*



(C) Bands 5 through 8. *(D) Bands 9 through 15.*

Fig. 11-9. Playback of SMPTE waveforms.

the 2-percent K rating. This becomes particularly important when dubs are to be made from a master.

Test Tapes (High Band)

At the time of this writing, only one manufacturer (RCA) is recording a high-band test tape which essentially follows SMPTE Recommended Practice RP-43-1971. Ampex is working on such a test tape, which probably will be available by the time this book is in print. Following is a description of the RCA high-band test tape.

The RCA high-band alignment tape, MI-41699, is a reel of 2-inch video tape on which has been magnetically recorded a series of signals to facilitate the adjustment and performance verification of quadruplex video tape recorders. The tape has a minimum playing time of 10 minutes and is intended for use with television systems operating on 525-line, 60-Hz NTSC standards. The signals on the tape are arranged to facilitate the use of the tape either for routine operational checks or for more detailed analysis of recorder performance. A 1000-Hz tone has been recorded at 8 dB below the 3-percent distortion level and may be used to establish the correct record level.

The signals recorded on the tape provide the means for checking the following characteristics and adjustments:

(A) Video-head quadrature
(B) Vacuum-guide position

(C) Video levels
(D) Comparison of carrier frequencies of the video recording system
(E) Verification of level and phase of the control-track recording system
(F) Indication of video frequency-response characteristics of the reproducing system
(G) Video amplitude linearity
(H) Video transient response
(I) Chrominance-luminance delay
(J) Program audio level
(K) Indication of tape speed

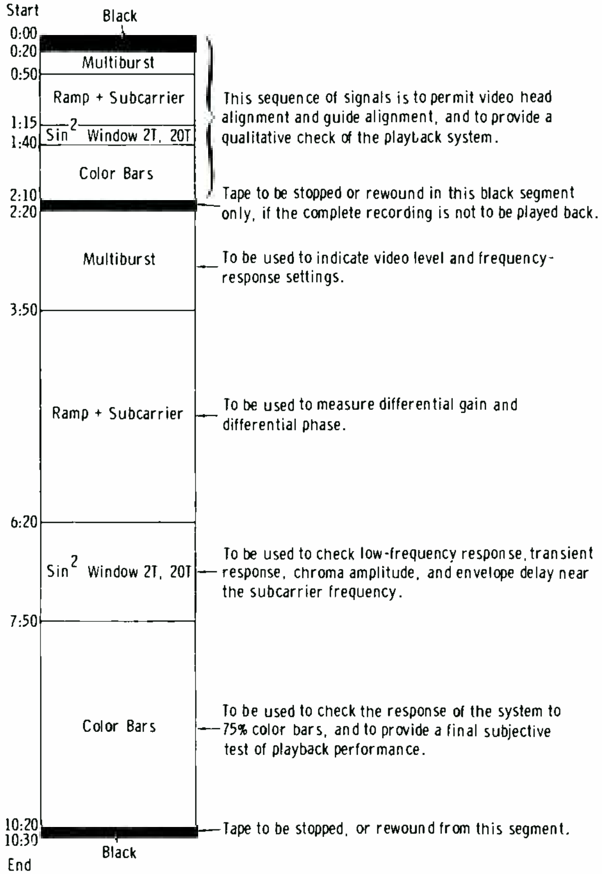
The use of the alignment tape will allow the adjustment of the vacuum guide to the position which will assure interchangeability between tapes made on correctly adjusted equipment.

The contents of this tape, and hence its proper usage, may be best understood by referring to Fig. 11-10. The contents of the tape are shown schematically, and brief notes regarding the intended use of the tape are given. This drawing should be referred to from time to time by the reader as he proceeds through the following paragraphs. (Certain of the waveform photos are included in Chapter 12.)

The tape is divided into two major sections. In the first section, the various alignment signals are displayed in fairly short-duration groups. This section of the tape is intended for quick cursory examination of recorder performance, and can be used by an operator in performing a routine check at the beginning of the day's operation or just prior to making a recording. The second part of the tape presents the same signals, but in segments of much greater duration. This section of the tape is intended for meticulous adjustment or correction of faults in the recorder (Chapter 12).

Since the tape can be affected by changes in temperature and humidity, extreme changes are to be avoided. In the area in which the tape is stored, the relative humidity should be in the range of 40 to 60 percent, and the temperature (Fahrenheit) should be between 60 and 80°. In addition, the following precautions should be observed:

1. Do not store or place the tape in the region of magnetic fields.
2. Do not attempt to use the tape until it has stabilized for at least 16 hours at room temperature.
3. Be sure that the heads and guides on the recorder are clean before using the tape.
4. Check the setting of the reel brakes, capstan pinch roller, and reel tensions.
5. Use a take-up reel having a diameter of 8 inches (same size as test-tape reel) to maintain a proper inertia balance between reels.



Video signals consist of composite sync with indicated test signal.
The tone recorded on the audio track is 1000 Hz at 0 dB.

Fig. 11-10. Diagram of test tape with associated aural identification.

6. Stop or rewind the tape only in the black-signal portions between recordings. Rapid stops, with improperly set brakes, can damage or distort the tape. Observe the tape as it winds on the reel. The edge of the tape must not climb up the side of the reel, or permanent damage may result.
7. Take precautions to avoid erasing the tape accidentally, i.e., by pressing a setup or record button.

NOTE: After long usage, small apparent guide-pressure changes on the order of 0.0001 inch may begin to appear in the tape during playback. However, the tape may still be used by choosing the average guide position.

Errors in quadrature of the video headwheel can be measured with the alignment tape. This tape was made with precision quadrature (30 nanoseconds peak to peak maximum). When a headwheel with errors in quadrature is used to play the precise tape, horizontal displacements directly proportional to the errors in quadrature will be visible in the reproduced picture at the output of the demodulator. These errors will be corrected by the automatic timing corrector, and their magnitude may be measured by observing the error-signal display if the sensitivity is known. In RCA machines, the sensitivity of the display has been set so that 100 IEEE units represent 1 microsecond of error. On RCA high-band headwheel panels, the quadrature has been set very precisely by the manufacturer. It is *not* recommended that the adjustment of quadrature be attempted in the field.

The correct reproduction of the video signal indicates correct positioning of the vacuum guide. The effects of playback with an incorrectly positioned vacuum guide can be separated into two basic types of errors. Combinations of these errors usually occur. An error in vacuum-guide position parallel to the plane of the tape is called *guide height error* and results in the reproduction of vertical bars as a series of scallops or bows. An error in vacuum-guide position perpendicular to the plane of the tape is called *penetration error* and results in the reproduction of vertical bars as a series of zig-zag lines called *skewing* or *jogs* (Chapter 2).

The position of the vacuum guide of the television recorder must be adjusted until the vertical bars of the alignment tape are reproduced as straight vertical bars with minimum horizontal displacements. Adjust the guide height to remove scallops, and adjust the guide penetration to eliminate skewing. Here again, the ATC error signal may be used as a sensitive indicator of the magnitude of the errors, and the guide should be adjusted to minimize these errors (described later). The position of the vacuum guide should be rechecked at 20-hour intervals throughout the life of the headwheel.

Before proceeding with the alignment procedure:

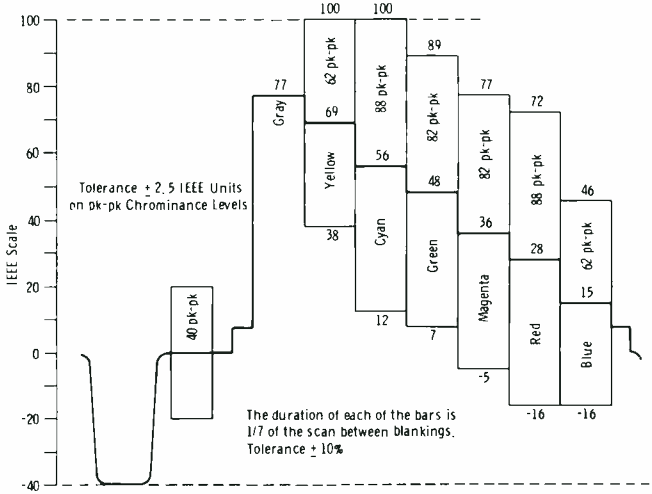
1. Rotate the guide-position control fully counterclockwise for minimum penetration.
2. Observe the output of the demodulator on the picture monitor.
3. Place the recorder in the play mode of operation.
4. Slowly adjust the manual vacuum-guide control knob to minimize vertical misalignment of the picture elements and to avoid overpenetration.
5. Do not stop the tape or rewind except at the point 2 minutes and 10 seconds from the beginning or at the end during the black signal (see Fig. 11-10).
6. Proceed with final guide alignment according to the procedure outlined later, and remember to avoid overpenetration.

WARNING: *Do not stop, initiate forward wind, or rewind in any portions of the tape other than black.* Otherwise the active signal portions of the tape may be stretched. Stretching of the tape will produce distortion of the tape and effectively result in guide-position errors on successive replays.

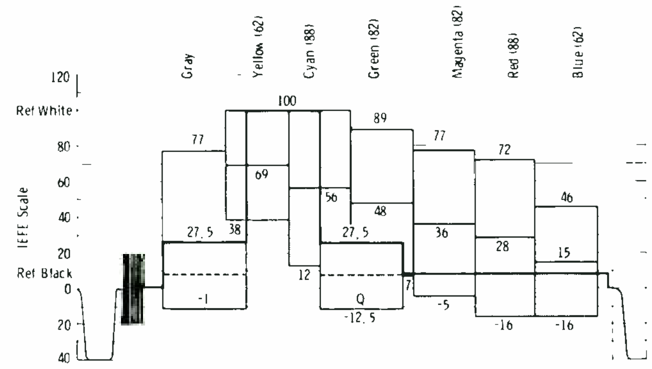
The operational use of this test tape will become evident as this chapter progresses. Use of the tape in maintenance is covered in Chapter 12.

Use of Color Bars

The proper proportionment for a 75-percent color-bar signal is shown in Fig. 11-11A. Note that this incorporates a 7-percent setup. The gray



(*A*) *75% bars, not split-field.*

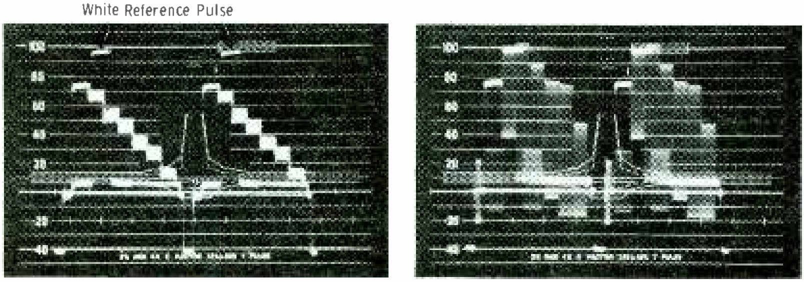


(*B*) *75% bars, split-field.*

Fig. 11-11. Color-bar signals.

bar then, instead of being 70 percent, is properly peaked at 77 percent because of the 7-percent setup. You should adjust the input level so that (providing you have properly adjusted the color-bar generator) this level occurs on the first (gray) bar. Then adjust the input high-frequency compensation (when used) to bring the tops of the yellow and cyan bars to the 100-percent level. This drawing is in detail for the setup discussion later.

The split-field color-bar pattern is shown in Fig. 11-11B. In this case, the white reference is at 100 percent, and the gray is still about 77 percent of peak white (with 7-percent pedestal). Again, adjust the input high-frequency compensation to just fill in the white reference with the chroma of yellow and cyan. You can place the scope on IRE response (Fig. 11-12A) to adjust the white reference to 100 percent. Then with the scope on normal response (Fig. 11-12B), adjust the chroma level to fill in the white reference pulse.



(*A*) *Scope on IRE response.* (*B*) *Scope on wideband response.*

Fig. 11-12. Split-field color-bar patterns at horizontal rate.

Sometimes, you may encounter a tape with a leader that has color bars at 100-percent amplitude. Thus the yellow and cyan peaks are at a level 33 percent over the white reference. This can be confusing on the straight color-bar pattern of Fig. 11-11A and cause you to set the wrong playback level unless you can recognize proper setup. You should always use 75-percent color bars, *not* 100-percent bars. The advantage of the split-field color-bar pattern (Figs. 11-11B and 11-12) is that a white "flag" always exists as a 100-percent reference level, to indicate clearly any difference in luminance and chrominance gain.

First, become familiar with the cro display of your own station color-bar signal. Looking at the input with horizontal-rate sweep, you should see the waveform of either Fig. 11-11A or 11-11B for a properly equalized input.

Now observe the same signal with vertical-rate cro sweep. The top tips of the chroma (yellow and cyan) will occur at 100 IEEE units (Fig. 11-13). Note from the drawings of Fig. 11-11 that the bottom peaks of chroma (red and blue) should occur at −16 IEEE units and the burst bottoms should be at −20 IEEE units.

Since the sweep is at the vertical rate, the chroma signal from −16 to +100 IEEE units results in a rather heavy trace. The space between −16 and −20 IEEE units, since the burst duration is shorter than the other signal intervals, results in a fainter trace. (The graticule illumination was turned off for the photograph of Fig. 11-13 so that the faint part of the trace would be visible.)

A color tape should contain at least two minutes of color-bar recording on the leader. This enables the operator to set the individual channel equalizers properly for playback of the program content.

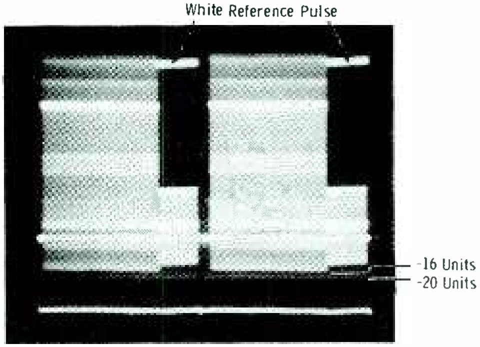


Fig. 11-13. Split-field color-bar pattern at vertical rate and with wideband response.

Setting Playback Equalization

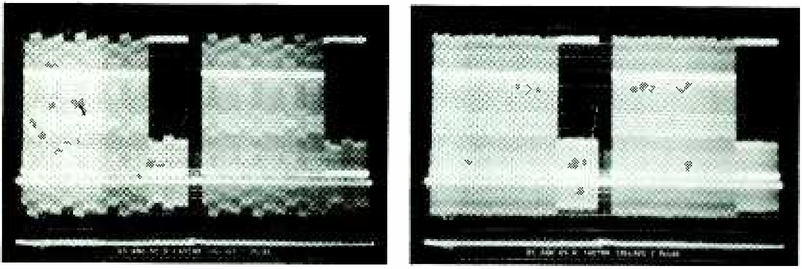
Review Fig. 11-5 carefully. Output from the head which plays back vertical sync (head 1 for RCA and head 4 for Ampex) will appear at the extreme left of the vertical-rate cro pattern. Once each field, this head delivers only a few active lines of picture information, so it provides only about ¾ of the information delivered by the other heads.

The second head (SMPTE band 1) also contains only about half of the normal active picture lines during one pass in each field. So here is a good procedure in setting up the individual channel equalizers on playback:

1. Look at the demodulator output with the scope at the horizontal rate. Adjust the equalizer for the head playing back vertical sync (head 1 for RCA and head 4 for Ampex) so that the green bar (Fig. 11-11) is at the chroma level shown. Of course all of the individual head contributions are being indicated, but you can recognize the individual channel you are adjusting by watching the resulting (faint) trace, within the green bar area, move on the scope pattern.
2. Then change to the vertical sweep rate (Fig. 11-14). Adjust the

remaining channel equalizers so that the chroma peaks are at −16 and +100 IEEE units. *Do not* fill in the space between −16 and −20 units; this should remain a faint trace indicating individual burst levels.

3. After all playback channels have been matched as closely as possible on the cro, observe the output of the system on a good color monitor. Trim the individual equalizers slightly for minimum color banding.
4. On the cro display of the demodulator output at the horizontal rate, the burst amplitude should be correct (40 IEEE units). This is the proper input to the signal-processing amplifiers. An attempt at "overequalization" at this point can result in servo instability.



(A) Channel equalizers not properly adjusted.

(B) Equalizers adjusted for same chroma level.

Fig. 11-14. Demodulator-output displays (wideband scope response).

5. Now change the cro to the system output and again check the color-bar pattern at the vertical rate. In a tape system, the luminance-to-chrominance ratio will be correct with proper equalization, but the burst may not be. This involves a separate control which must be set for proper output amplitude.

NOTE: You can also match all four head-equalizer adjustments by observing the output of the system on a vectorscope (where automatic chroma equalization is not used or is removed for this adjustment). Fig. 11-15 shows the appearance of multiple dots along each vector, showing unequal chroma amplitudes. Fig. 11-17 shows the proper indication for equal chorma amplitudes from all four heads (dots superimposed so that a single dot appears for each vector.) Since each "dot" (vector) in Fig. 11-15 is only ¼ normal brightness, the trace is very dim. For this photograph, the graticule line illumination was turned off, making the IEEE scale more visible than the vector scale. When all dots are superimposed, the trace brightens considerably, as in Fig. 11-17.

Fig. 11-16 is an example of how much improvement over the earlier low-band, monochrome systems has occurred in modern tape recording systems. Fig. 11-16A is the appearance of the multiburst pattern on play-

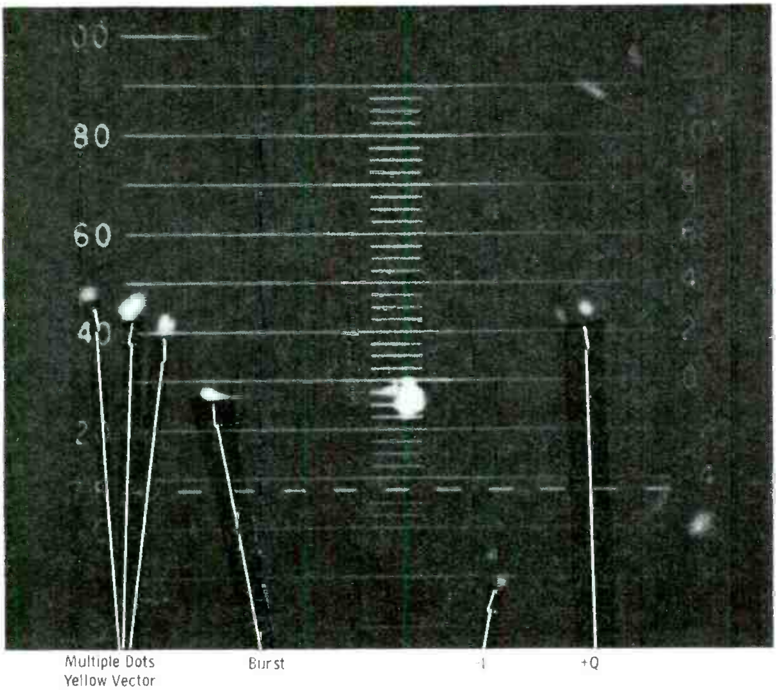
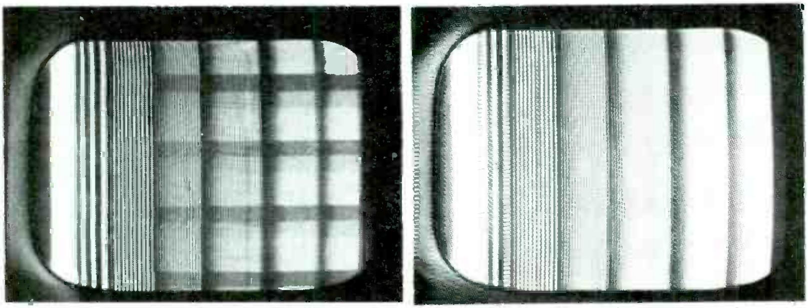


Fig. 11-15. Vectorscope display of color-bar playback with channel equalizers not adjusted for proper match.

back with an early machine (RCA TRT-1A) when the playback head equalizers were adjusted for an optimum picture. In these early systems, it was seldom possible to match response at all discrete sine-wave frequencies, especially on a tape-interchange basis. The best technique at



(*A*) *Best reproduction on older system.*

(*B*) *Best reproduction, modern high-band system.*

Fig. 11-16. Monitor presentations of multiburst playback.

that time was to adjust all channel compensation controls for the best match (no banding) on the first two burst frequencies (normally 0.5 MHz and 1.5 MHz). Most of the average picture content of normal programs (in monochrome) is in the spectrum up to 1.5 to 2.0 MHz maximum. Thus, although a test signal such as the higher frequencies in a multiburst pattern would show some banding, the usual monochrome picture content was satisfactory.

For a color signal, there is a very different situation. The chroma content lies in sidebands of the 3.58-MHz subcarrier. Therefore, optimum response up through the highest frequency of the multiburst pattern (normally 4.2 MHz) is extremely important. Fig. 11-16B is a photograph of the playback of the same multiburst pattern as that of Fig. 11-16A, except that it was recorded and played back on a modern high-band color recording system. For a properly operating high-band system, it is necessary to get extremely close to the monitor presentation to observe any "noise" at all on the multiburst signal. On modern low-band systems, some slight moire and noise will be visible on the last burst (4.2 MHz) of the pattern.

Adjusting Monochrome and Color ATC Error Gains

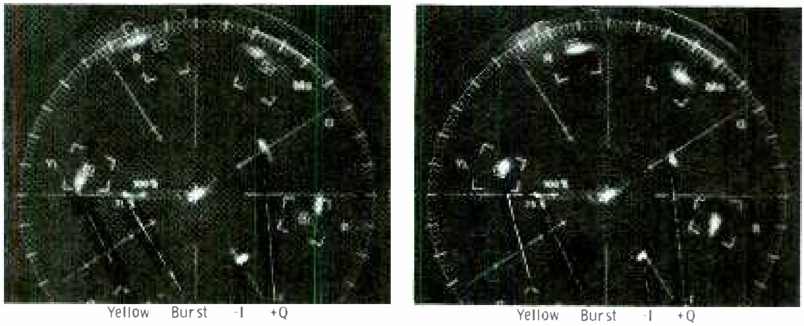
Never play the monochrome and Color ATC error gains against each other while watching a color monitor for transients and best "effect." If you do, you may have trouble with a spliced-in portion or the next color tape. There is really only one proper method for each:

(A) For monochrome time-error gain: Put the guide servo in the manual position, and while observing the demodulator output on the picture monitor, insert about a microsecond of error. Then switch the picture monitor to the output, and adjust the monochrome time-base-error gain to correct all geometric error exactly. Return the guide servo to minimum error as observed at the demodulator output.

(B) The color error gain should be adjusted while observing the vectorscope on color-bar playback. Adjust this gain for minimum jitter of the yellow vector. Yellow immediately follows the time of correction, which occurs during horizontal blanking, and is most influenced by the correction.

Observe the yellow-vector dots and the I and Q dots in Fig. 11-17. Note that these dots have wider excursions in Fig. 11-17A than is true for Fig. 11-17B. You will note that the proper error-gain control setting is most evident by observing only the yellow, I, and Q vector dots. If the color-bar signal does not contain I and Q signals, observe only the dot for the yellow vector.

Always recheck the burst-phase setting with the vectorscope after adjustment of the Color ATC error-gain control.



(*A*) *Dot displacement* (*jitter*). (*B*) *Adjusted for minimum jitter.*

Fig. 11-17. Optimization of Color ATC error gain control.

System Phase and Burst Phase

Be sure you understand the difference between "system phase" and "burst phase" in color operation. See 11-18A. The color error detector receives a reference 3.58-MHz signal from the local generator and a burst from the tape playback signal gated on by a horizontal pulse. If the phase of the reference signal is changed in this path, the reference that is compared with the tape-signal burst to obtain an error signal is changed. Hence all the vectors are rotated, as in Fig. 11-18B.

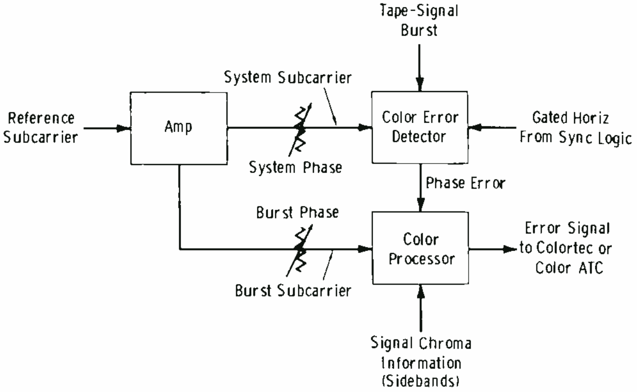
The color processor receives the same reference subcarrier, and also signal chroma (sidebands) from separated high-frequency video information. (The luminance information and chrominance information are separated to provide individual clamping and processing.) If the phase of the reference signal in this path is changed, the burst vector is rotated relative to the signal chroma information, as indicated by Fig. 11-18C.

It makes no difference to the color monitor or receiver what system phase it "sees." It synchronously demodulates the color information in accordance with the relationship between the burst and the picture sideband information. So if you change the *burst* phase, you change flesh tones, hues of color bars, etc.

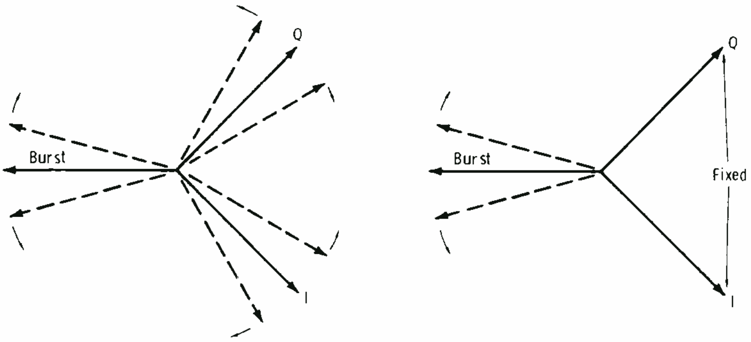
You can vary system phase from one limit to the other, and the color monitor will *not* change hue if it is connected to the output of the tape system. This control must be used in matching the phase of the color tape signal with other local color sources, as when special-effects equipment must be used. The special-effects amplifier will pass only one burst source at a time. Therefore, if you mix color tape with a local color signal, any difference of system phase will result in mismatched colors.

To adjust system phase properly, feed the output of the special-effects amplifier to a color monitor. Feed color bars (reference) to one input, "wipe in" the color tape signal which also contains color bars, and rotate the system-phase control on the tape system to obtain a match.

When you do not use special effects or other mixing equipment, your only concern in phasing is burst phase. The best way to adjust this (other than using a vectorscope) is to have a color monitor which can be switched between the regular program-line output and the tape-system output. When the monitor is adjusted for proper reproduction on the program-line output, switch it to the tape-system output and adjust the tape burst-phase control for proper color.



(*A*) *Block diagram.*



(*B*) *System phase.* (*C*) *Burst phase.*

Fig. 11-18. Phasing of color vectors.

Normally this is done on the color-bar leader of the tape to be played. It is nearly always necessary to readjust slightly for proper flesh tones in the program content. The burst-phase setting is rather broad on color bars (unless a vectorscope is used) compared to the much more subtle phase adjustment required to obtain good flesh-tone reproduction on a color monitor.

11-3. PRELIMINARY SETUP PROCEDURE

At the start of the operating day, before the tape is threaded on the transport, ample time should be scheduled for the operator to carry out the following procedures. (The cleaning procedure should be exercised before every recording and before playback of programs more than 5 minutes long. Once a day is normally sufficient for the other procedures.)

Cleaning

Naphtha, Energine, and Freon TF are the most widely accepted cleaning agents for video and audio heads and all other metal contacts on the tape transport. Chlorothene may also be used, but only with the utmost caution. This agent (although cheaper than Freon TF in bulk quantities) will soften the oxide binder of the tape if ample time is not allowed for it to dry thoroughly. Denatured alcohol is also used for all items other than audio and video heads.

Use lint-free tissue (such as Kim-Wipes) or a soft brush (camel's hair) moistened with the solvent to clean the following items:

A. Supply tension arm
B. Supply idler
C. Video (master) erase head
D. Rotating-head panel (headwheel or drum, pole tips, vacuum guide, nylon bearings under vacuum-guide block, vacuum-guide screw contact with the movable servo arm, control-track head)
E. Audio and cue heads (and simulplay audio and control-track heads)
F. Take-up idler
G. Capstan and capstan pinch roller
H. Counting roller
I. Take-up tension arm
J. Take-up and supply reel hubs

The video heads should be cleaned by hand-rotating the shaft while holding a moistened tissue against the heads and rotating with a slight circular motion. Use the agent on the tape-supporting surface of the vacuum guide while the vacuum pump is working, and inject a little of the agent into the slots with an eye dropper or hypodermic injector. Inject a slight amount into the slip-ring assembly (on RCA heads) on the head panel, and rotate the shaft by hand to clean the brush assembly. Inspect each brush to be certain that the slim spring contact arm is properly seated in the brush groove. A cotton applicator or tissue dampened with a solvent is handy for cleaning the control-track head.

Degaussing

As a precautionary measure, the tape transport should be demagnetized at least once daily. Fig. 11-19 shows the usual tell-tale indication in the switched rf output at the switcher unit when magnetic paths exist. A tape which was originally good can be harmed by this condition.

> NOTE: The pattern in Fig. 11-19 is observed on the Ampex A scope when the selector switch is in the SWR RF Output position. This monitors the off-tape rf signal from each of the four video heads. It is also as observed on older RCA systems at the FM Level or SWR Out monitoring position. The RCA TR-70 fm level pattern is different, as illustrated in Section 11-6.

The small hand degausser which is normally purchased with the equipment should be energized at least 4 feet from the tape transport and brought slowly up to the panel. Keep the unit slowly rotating in a small circle while going over the entire tape path from supply reel to take-up reel; be sure to include the master video erase head. Start the video heads rotating (push the OVERRIDE switch on the Ampex machine or the STANDBY or SETUP switch on the RCA machine) as the degausser is passed over the rotating-head panel. Degauss the audio heads with the conventional audio-head unit. Slowly pull the degausser away from the panel and de-energize after the unit is at least 4 feet away.

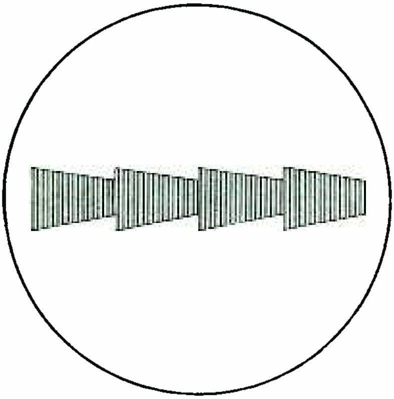


Fig. 11-19. Oscilloscope presentation of switcher rf output, indicating magnetic path.

The fact that no magnetic tools, such as screwdrivers, wrenches, etc., should be stored near the transport or tape is often forgotten. Always degauss tools before using them on the equipment or storing them in nearby shelves.

11-4. LEVEL CHECKS

Always check to see that the monitoring oscilloscope is properly calibrated before setting levels. The usual sequence is as follows:

1. Input: 1 volt (peak-to-peak)

2. Demodulator output: 1 volt peak-to-peak (This is also the input to the ATC system and processing amplifier.)
3. Processing amplifier: 1 volt peak-to-peak with 5- to 10-percent setup (interval between maximum picture black and blanking level), and 0.4 volt from blanking to sync tip. These controls are all included in the processing amplifier.

When it is certain that a 1-volt peak-to-peak level exists at the input, the deviation control for fm modulation should be set by the means provided in the system. For example, Fig. 11-20 shows how the deviation control is adjusted on the RCA TR-70.

11-5. HEAD-ALIGNMENT AND SELF-CHECK PROCEDURES

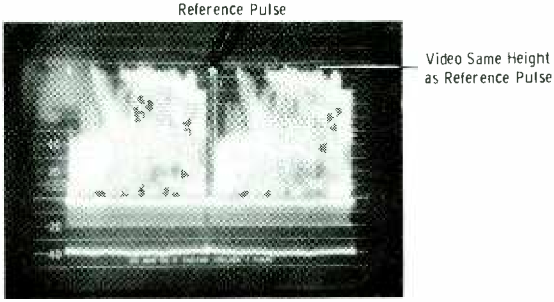
The normal sequence of checks (and adjustments where required) is: vertical (height) alignment of vacuum guide for maximum concentricity, horizontal alignment of the vacuum guide for proper tip penetration of the particular rotating head assembly, and electronic or mechanical alignment for quadrature (in older systems). These checks, and other self-check procedures which are not a normal operational procedure unless questionable conditions exist (such as a doubtful alignment tape or temporary loss of such tape), are described in the following paragraphs.

Vertical (Scallop) Adjustment

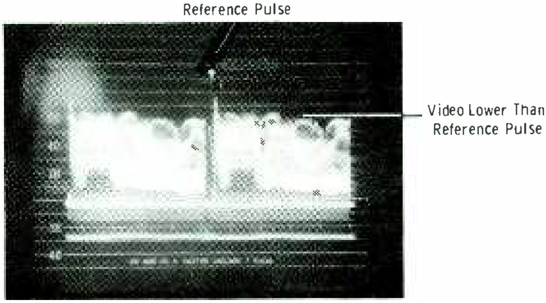
See Figs. 2-17 and 2-18 for monitor displays of an alignment tape when the vacuum guide is too high or too low. When the guide is properly set, the video head tips exert the same degree of tape stretching (resulting in the same relative velocity) throughout the entire arc of contact. This indicates maximum concentricity of the vacuum guide with the arc described by the pole-tip radius of rotation.

A. Thread the manufacturer's alignment tape, usually containing vertical lines recorded under precise laboratory measurements, onto the tape transport and place the system in the play mode.
B. Place the vacuum-guide servo in the automatic mode of operation so that the tip penetration is somewhere near standard. NOTE: With a new or rebuilt head assembly, a rough *skew* or *jog* adjustment (next subsection) may need to be made before the height adjustment. The need is apparent if the tips are obviously not contacting the tape, or if the pole tips are obviously digging too deeply (overloading the servo system). In either case, the tape will not play.
C. While watching the monitor, turn the guide-height or scallop-adjustment screw to eliminate any scalloping of the vertical lines. The alignment points are shown in Figs. 2-22 and 2-24.
D. One method of rapid self-check without the alignment tape is to

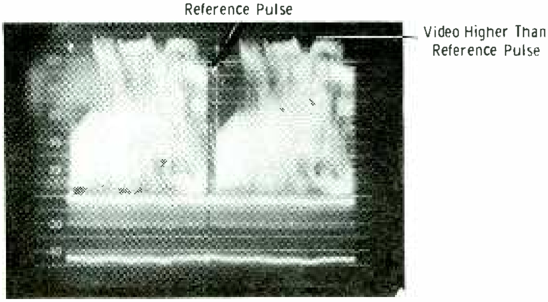
use the principle that there is normally some slight eccentricity of the vacuum-guide center of curvature with the axis of the rotating heads. This means that as the guide is moved farther away from the pole tips, contact is first lost at the center of the tape (Fig. 2-13B). With the scope looking at an individual head playback-channel output, back the vacuum guide away from the heads, by means of the electrical tip-projection control with the guide servo placed in the manual mode of operation, so that contact exists only



(*A*) *Proper deviation.*



(*B*) *Underdeviation.*



(*C*) *Overdeviation.*

Fig. 11-20. Demodulator output displayed at vertical rate.

at the edges of the tape. Fig. 11-21 shows a typical pattern obtained under these conditions. If the guide is perfectly concentric to the pole-tip rotation (the same pressure at top and bottom of tape), the height of the pulses will be equal. Adjust the height-adjustment screw until the pulses are as nearly equal as possible. Then return the tip-projection (guide position) control to normal.

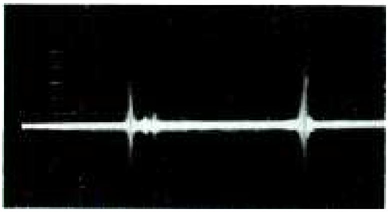


Fig. 11-21. Single-channel playback waveform with guide adjusted to barely contact tape.

E. A more accurate method of self-check for height adjustment is to make a recording consisting of vertical lines, such as a grating-pattern generator signal, and simultaneously to feed the control-track signal to the audio track. Let the tape run through to the take-up reel and *do not* rewind the tape. Simply place the take-up reel with the run-off tape onto the supply-reel hub and thread in the normal manner. It is now obvious that the tape is reversed—the audio track (which also contains the control track in this case) is at the bottom instead of the top, and as the role tip sweeps across the tape in playback the signal will be reversed from the recording mode. Thus, playback of the tape will reveal scalloping if the vacuum-guide height adjustment is improper. This self-check method is accurate but time-consuming. Use the simplest nonsynchronous playback mode for a more stable picture.

Horizontal (Skew or Jog) Adjustment

Horizontal adjustment is normally required only on the initial installation of a new or rebuilt head assembly. When the vacuum guide is once set to the standard distance from the headwheel axis, the heads will record and play back tape interchangeably over a wide range of head wear without resetting.

A. Place the vacuum-guide servo in the manual mode of operation. With the standard alignment tape threaded, place the system in the play mode. Remove all high-frequency post-emphasis (where used) to avoid possible geometric distortions of the vertical lines from transient effects on leading and trailing edges.

B. Set the guide-position (electrical) control on the control panel to the position designated by the manufacturer for standard.

C. Adjust the penetration-range adjusting screw on the head panel for straight vertical lines. (See Figs. 2-14 and 2-16 for time errors resulting from improper horizontal positioning of the guide.)

Keep the time-base concept of this velocity error in terms of the picture-signal components. This will serve well in the future. We will discuss now one practical application, determining pole-tip projection remaining on a head.

Thread the SMPTE alignment tape on the machine. Observe the picture at the demodulator output. Place the guide on manual operation (remove automatic circuitry), and operate the guide-position knob so as to move the guide *away* from the head.

See Fig. 11-22A. The highest-frequency burst packet is at 4.2 MHz. This is sufficiently close to 4 MHz to make a point. If the guide is backed off so that the first bar of band B is aligned with the fifth bar of band A (4 cycles displacement), the time displacement is 1 microsecond. (One cycle at 4 MHz is $1/(4 \times 10^6) = 0.25$ μs, and since the displacement is four of these cycles, the error is 1 μs.

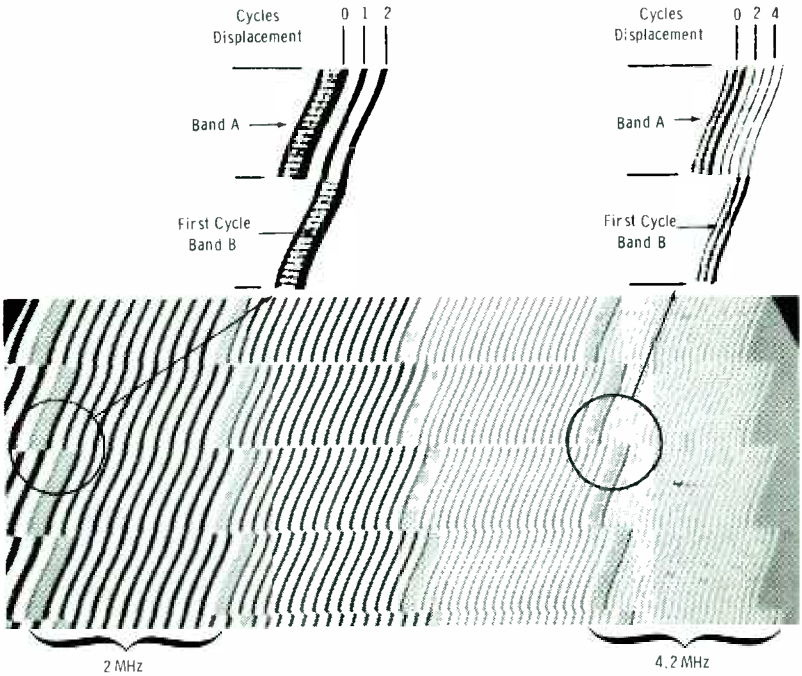
With this same adjustment, observe the 2-MHz burst. Since one cycle at this frequency is 0.5 μs, the 1-μs error will show alignment with the third black line (2 cycles displacement). There will be a slight difference because the 4-MHz reference is actually 4.2 MHz.

Now, if you were able to measure the actual radius of the pole-tip arc, you would find it 1 mil too large. The rule of thumb is that 1 mil = 1 μs, 0.5 mil = 0.5 μs, etc.

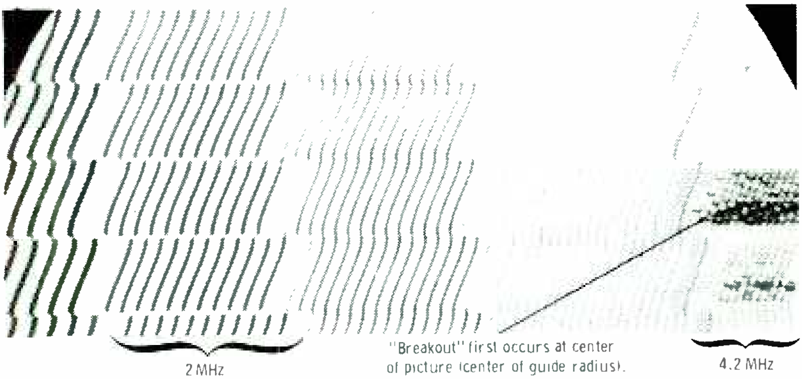
Fig. 11-22B shows the same amount of displacement, but playback is on a headwheel with slightly less than 1 mil of tips remaining. Note that the 4.2-MHz sine waves are "breaking into black," indicating a loss of signal at this frequency. A headwheel assembly is normally returned (exchanged) for a new assembly when the tips reach 1 mil.

Still another timing check you can demonstrate to yourself with the SMPTE alignment tape is shown by Fig. 11-23. Observe the demodulator output on the monitoring oscilloscope while you adjust the guide farther away from the head from zero alignment error, on the portion of the tape containing the $\sin^2$ pulse.

Note that both the sync pulse and the $\sin^2$ pulse move to the right in a faint trace. For example, assume you are using the Tektronix Type 529 cro. The time base is set for 0.125H, and the 5-times multiplier is used. Thus the sweep rate is 0.025H/cm, or $(0.025)(63.5) = 1.59$ μs/cm. So a 1-μs displacement is $1/1.59 = 0.62$ cm (approx). This means that the faint trace at the trailing edges of sync and the $\sin^2$ pulse will *move to the right* by 0.62 cm when the guide is moved *farther* from the headwheel. This will occur at the same time that the picture monitor shows the first cycle of band B aligned with the third black line (second cycle) of band A on the 2-MHz burst packet (Fig. 11-22).



(*A*) *Guide backed away 1 mil.*



(*B*) *Heavy breakout at 4.2 MHz.*

Fig. 11-22. Guide back-away method of estimating remaining head-tip projection.

This particular procedure will serve as an excellent "warning flag" of usable tip projection remaining on the head. For example, if the video head is worn down to near the 1-mil minimum projection, the 4.2-MHz bursts at the center of the picture will tear out with "whites" going to black. This tells you that the head is starting to "break out" at this frequency, and the head is nearing the end of its useful life.

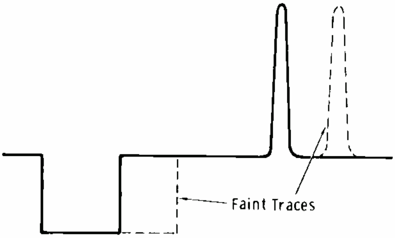


Fig. 11-23. Conversion of microseconds of error to mils of tip projection.

Many heads can be used down to about 0.8 mil before discarding, but only at the risk of excessive clogging, noise, and lowered resolution. Also, the recording-current drive (in the record mode) becomes rather critical in "head optimization" for proper recording and playback (next section).

To avoid any confusion in your mind, answer the question, "what is standard tip penetration?" The tip penetration is equal to the tip projection. This is to say that if the vacuum guide is adjusted to minimize skewing, when playing back the SMPTE standard alignment tape, the penetration of the video tips into the tape (tip penetration) will be equal to the video tip projection. Therefore, the tip penetration is greater with a new head than when this head is worn down. There is a greater rate of tip wear with maximum tip penetration. At the same time, the greater penetration serves as a "self-cleaning" agent for heads (minimum clogging from tape oxide particles) and gives greater freedom from dropouts.

Note: The following information is included for a more complete understanding of tip projection but is not normally employed by the operator in practice.

If the operator has a basic understanding of what constitutes standard position of the vacuum guide, he can set this position without the standard alignment tape, but not with the same laboratory precision. In practice, the following information can be used to obtain a reasonably approximate setting of the guide. (See Fig. 11-24.)

1. The distance from the axis of rotation of the heads to the center of curvature of the vacuum guide is 1.0334 inches.
2. The nominal tape thickness is 1.4 mils.
3. The minimum radius of rotation of the magnetic-head pole tips is 1.0329 inches and the maximum is 1.0356 inches.

4. The vacuum guide is adjusted to the standard recording radius, which is calculated as follows:

1.0334	inches (distance to guide)
−0.0014	inch (nominal tape thickness)
1.0320	inches

   This figure (1.0320 inches) is necessary to find the "departure point," or the distance from the axis of rotation at which the pole tips just touch the tape surface. This distance also defines the radius of the pole-tip rotation.

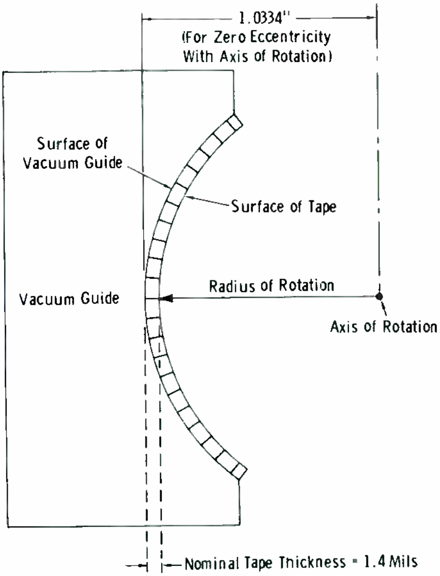


Fig. 11-24. Relationship of standard recording radius to departure point.

5. Measure the diameter of the drum rim with a micrometer, and divide this by 2 to obtain the radius.
6. Measure the actual tip projection above the drum rim with the tip-projection gauge that is provided with the system.
7. Add the tip projection to the radius of the drum to obtain the radius of pole-tip rotation.
8. With any prerecorded tape threaded, place the machine in the play mode and back the guide away from the heads until the signal is just lost, as revealed by zero rf output at the switcher.
9. Subtract the standard recording radius of 1.0320 inches from the total pole-tip radius of rotation. Move the guide in from the departure point by this amount, as measured with the tip-projection gauge jigged to the vacuum-guide block. This places the guide to the standard tip projection within the tolerances of measurement.

Two examples follow:

Example 1:

$$\begin{aligned}
\text{Drum Diameter} &= 2.064 \text{ inches}\\
\text{Radius} &= 1.032 \text{ inches}\\
\text{Tip Projection} &= 2 \text{ mils}\\
\text{Radius of rotation} &= 1.032 + 0.002\\
&= 1.034 \text{ inches}\\
\text{Move in from departure point} &= 1.0340 - 1.0320\\
&= 2 \text{ mils}
\end{aligned}$$

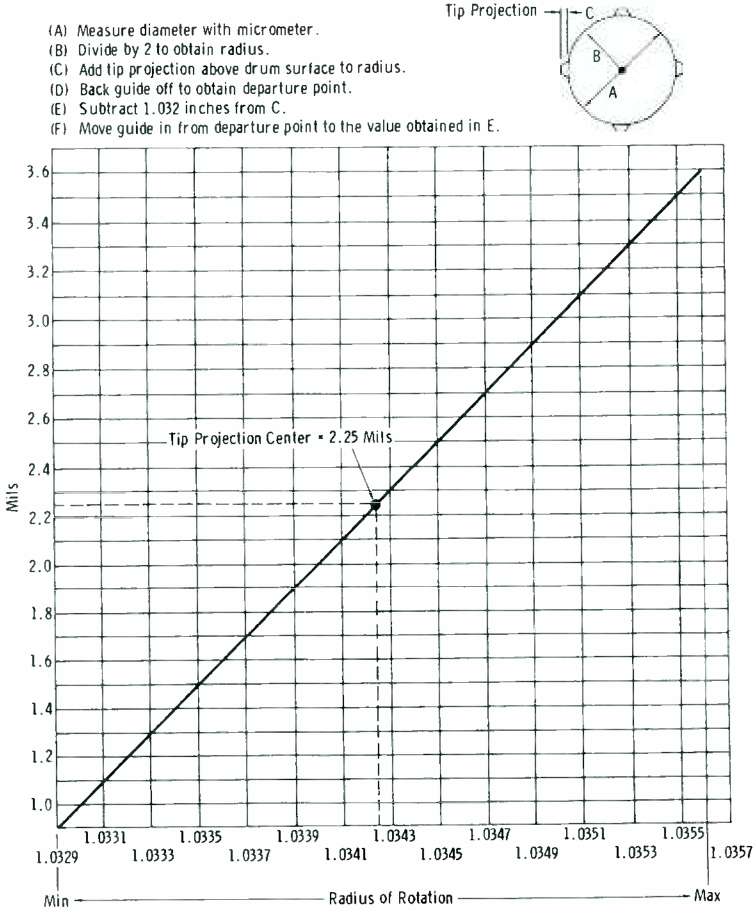
Example 2:

$$\begin{aligned}
\text{Drum Diameter} &= 2.062 \text{ inches}\\
\text{Radius} &= 1.031 \text{ inches}\\
\text{Tip Projection} &= 2 \text{ mils}\\
\text{Radius of rotation} &= 1.031 + 0.002\\
&= 1.033 \text{ inches}\\
\text{Move in from departure point} &= 1.033 - 1.032\\
&= 1 \text{ mil}
\end{aligned}$$

Note that in both cases the measured tip projection was 2 mils, but the tolerances in the head drum resulted in a 1-mil difference in the radius of rotation. The foregoing procedure places the vacuum guide to the standard, but actual *tip penetration* depends on the effective radius of rotation, and not on tip projection alone.

Fig. 11-25 illustrates the foregoing procedure and gives the proper adjustment from the departure point over the normal range of rotation radius.

NOTE: Some stations employ a *dual standard* positioning of the vacuum guide. Tapes to be used *only* by the local station can be recorded at lighter-than-standard tip pressures for new heads until the heads are worn to the point where standard SMPTE projection can be used. This increases tape life and results in less head wear per hour, if not carried to extremes. A head assembly is normally retired (returned to manufacturer on an exchange basis for a rebuilt assembly) at 1-mil measured tip projection. This is due to the fact that the pole-tip gap widens somewhat below this projection and is apt to become useless during a recording or playback. However, if too little recording radius is used, the tape may not play back on a tip projection of, for example, less than 1.3 mils. This would require premature retirement of the head assembly and be more costly in the long run. The dual standard should not be used on an interchange basis, since recordings are not completely interchangeable between heads at different points on the head-wear curve.



(A) Measure diameter with micrometer.
(B) Divide by 2 to obtain radius.
(C) Add tip projection above drum surface to radius.
(D) Back guide off to obtain departure point.
(E) Subtract 1.032 inches from C.
(F) Move guide in from departure point to the value obtained in E.

Fig. 11-25. Instructions for move-in from departure point.

Quadrature Adjustment

Electronic delay correction is employed in both the record and play modes by RCA. Ampex supplies a delay equalizer as optional equipment for the play mode only. In the following procedure, Steps A, B, and C apply to Ampex; Steps D through J are for RCA.

> NOTE: On the latest Ampex and RCA systems, quadrature adjustment is strictly a factory procedure in headwheel assembly. The description herewith applies only to older systems, a number of which are still in use at the time of this writing.

A. Reproduce the test pattern recorded on the alignment tape and identify channel 1 by reducing the channel-1 gain control on the switcher unit. Outputs appear in the picture in a 1, 4, 2, 3 order; that is, channel 4 is directly below channel 1, channel 2 is directly below channel 4, etc.

B. Observe the relative position of the four bands of information as they appear horizontally on the picture, and choose a band which occupies a mean position. Hereafter, use that band as a reference. Assume here that channel 3 is the reference. With respect to channel 3, channels 1 and 2 are early; that is, they are displaced to the left on the monitor. Channel 4 is late, displaced to the right on the monitor.

C. The angular position of the Ampex 1000-series head can be changed by adjusting the tapered Allen-head screws. To advance a head, it must be moved in the direction of rotation of the head drum; conversely, to retard a head, it must be moved in the direction opposite to the direction of rotation. To advance a head (in our example the channel-4 head), first loosen the tapered screw leading the head, and then tighten the tapered screw following the head. (This simply shifts the quadrant which contains the head in the direction of rotation of the head drum.) To retard a head (in our example channels 1 and 2), first loosen the screw following the head and then tighten the screw leading the head. Make these adjustments in small increments (not more than ⅛ turn of the adjusting screws), checking with the alignment tape after each adjustment. The head which corresponds to a given channel can be identified by marks scribed on the Bakelite hub of the slip-ring assembly just forward from the terminals where the head leads are connected.

NOTE: Where the playback-delay amplifier unit is employed in the Ampex system, playback adjustments may be made with this unit, and the relative calibrations of the individual channel knobs may be read for a direct indication of which segments need to be adjusted and the direction of adjustment. This unit also permits proper playback of any tape made from another source which may have quadrature errors relative to the Ampex head.

Steps D through J apply to RCA machines.

D. Place the guide-position switch on the control panel in the automatic position.

E. Install the alignment tape, and place the tape recorder in the play mode.

F. Adjust the control-track phase control to produce the optimum picture. Set the four high-frequency compensation controls to zero.

G. Set all four delay knobs on the playback-delay amplifier to zero, and observe the picture. The presence of steps in the vertical lines (Fig. 2-19) indicates that the heads are not exactly in quadrature (90° apart). Identify the head which produces an average amount of horizontal displacement with respect to the other heads (steps about halfway between the extreme left and the extreme right), and leave the delay knob corresponding to that head at zero. Adjust the other three delay controls to minimize the horizontal displacements.

NOTE: Since the delay steps are quite small, this adjustment must be made with care to insure optimum alignment of the vertical bars. In addition, penetration and scalloping adjustments should be retouched to achieve the best results.

H. The quadrature relation of the heads is the same for record or playback, except that the relative sense (lag or lead) is reversed. Consequently, the delay controls on the record-delay amplifier should be adjusted as follows:
   (1) Note the channel on which the delay control is set to zero on the playback-delay amplifier. Set the delay control for the same channel to zero on the record-delay amplifier.
   (2) Turn each of the other three delay knobs on the record-delay amplifier to the same numeral as that of the corresponding playback delay knob, but in the opposite direction from zero. (For example, if the delay knob on the playback-delay amplifier is set to +3, set the delay knob on the record-delay amplifier to −3.)

I. Remove the alignment tape from the machine.

J. Record a test pattern or other test signal with vertical lines; playback of this recorded signal should produce vertical lines. In addition, when the control-track phase knob is turned to another track position, the vertical lines should contain a minimum of horizontal displacements. Large displacements indicate that the corrections should be rechecked.

NOTE: The video heads can be self-checked for quadrature quite simply, but only after head optimization, as described in Section 11-6, is followed. The reason for this is that one head that may be overdriven with fm signal in the record mode will play back with a slight effective quadrature. The procedure is to make a recording of vertical lines and play back with the tracking control adjusted sequentially through all four head-tracking positions, while the operator watches the playback monitor. For example, if head 1 recorded vertical sync, and tracking is adjusted so that the same head plays back vertical sync, no quadrature error will be apparent even though it may exist. However, if tracking is adjusted so that each of the four heads picks up the track recorded by the adjacent head, quadrature error between any two heads will be revealed.

11-6. OPTIMIZING THE VIDEO HEADS

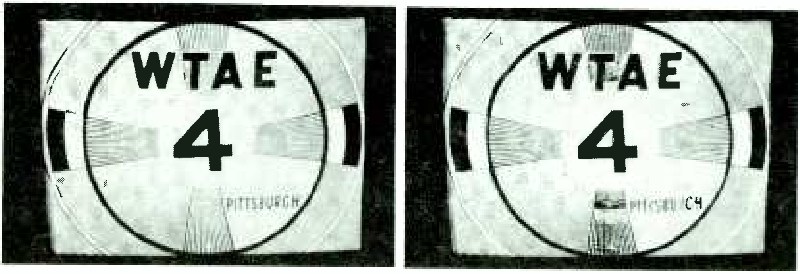
The record currents for each of the four video heads must be separately adjusted (by means of record-channel gain controls) for optimum results.

Fig. 11-26A illustrates the playback of a test pattern with proper deviation and head optimization in the recording process. Fig. 11-26B shows breakout into black of white areas following black-to-white transitions; this can be caused by overdeviation of the modulator (excessive level) with properly optimized heads, or by normal deviation but with one or more heads overdriven with fm signal. (This effect can also be produced by improperly adjusted playback-channel equalization controls.)

The result shown by Fig. 11-26B is inevitably called *overdeviation,* even though this is not necessarily the case. In fact, this photograph was made from the playback of a tape with the test pattern recorded with exactly the same deviation as that used for the tape of Fig. 11-26A. The difference is in the levels fed to the heads during the record mode. Since the optimum record currents change with head wear (heads may wear unequally), optimization procedures must be carried out at frequent intervals. Wear is greatest during the first hours of operation of a new head assembly; therefore, checks should be made approximately every 10 operating hours for the first 30 hours, then after every 20 hours of use. Poor signal-to-noise ratio or banding (bands or unequal color and contrast) usually indicate the procedure is past due, regardless of hours.

When heads wear, there is less shunting effect of the pole tips, and less signal is required for optimum recording. This is the reason why tapes sometimes play back with what appears to be overdeviation, even though normal video levels are maintained. Tapes which are very objectionable in this effect can sometimes be greatly improved by removing all high-frequency equalization (where used) in the playback channels. The resulting picture may be *soft* (lacking in fine detail), but such softness is normally less objectionable than the severe white-level noise. On a color signal, this procedure cannot be carried to the point where there is insufficient chroma and burst level for proper handling in the color processing system.

Video-head optimization procedures have become well standardized as follows:

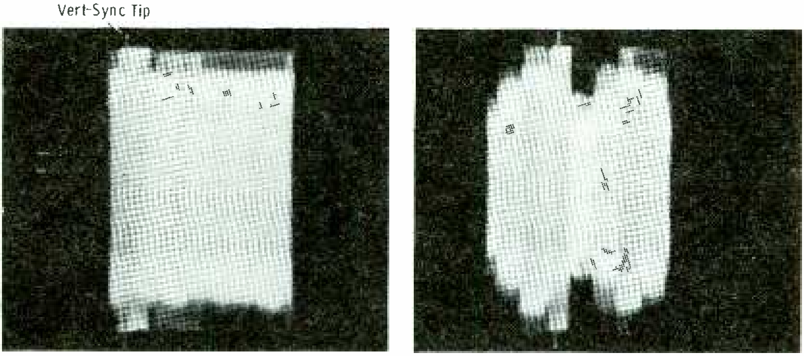


(*A*) *Properly adjusted.* (*B*) *Improperly adjusted.*

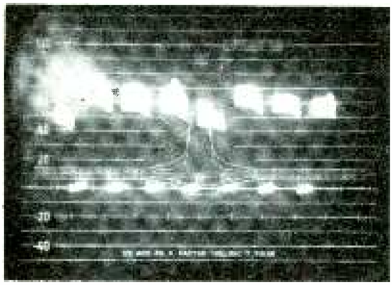
Fig. 11-26. Effect of adjustment of record-channel gain controls on playback of tape recorded with test pattern.

1. Feed a signal with a large-area white reference (such as a monoscope or window signal) to the system. Check to see that the deviation is normal.
2. Place the system in the record mode. Speak into the microphone, and identify channel 1 by turning the channel-1 record gain control fully counterclockwise (to zero). For example: "This is channel 1 on zero."
3. Rotate the gain control clockwise, stopping momentarily on each dial number to identify this number aurally. When the maximum clockwise position is reached, reverse the gain, and again identify each dial number at the momentary stops. When finished, return the gain control to midpoint.
4. Carry out the same procedure for channels 2, 3, and 4. Rewind the tape to the start of the recording.
5. With the scope set on the wideband-response position and connected to the switcher-unit output, play back the recording. Remove any high-frequency compensation that may exist in the playback circuits. Keep the playback-channel gains and scope gains low enough that there is no chance of rf compression.
6. Track the playback so that the same head which records vertical sync is playing back vertical sync. Watch the scope display of the switcher output. Monitor the voice identification of the channel-1 gain. At some point, the rf envelope of channel 1 will cease to increase as the gain is raised. Make a record of this point. A further increase in record current causes the playback level to decrease.
7. Repeat Step 6 for each of the remaining channels.
8. Set the record gain control for each channel to the point at which the gain for that channel was maximum. Make a new recording. Rotate the head record-current meter switch to each channel in turn, and make note of the current readings for reference. When this recording is played back, should any banding be apparent, identify the head(s) causing the banding, and repeat the procedure of optimization for these channels. Be sure all playback-channel gains are equal, as shown by Fig. 11-27A. (Ignore the vertical-sync tip in setting gains.)

NOTE: With regard to the rf patterns of Figs. 11-27A and 11-27B, the level controls should be adjusted for equal levels as in Fig. 11-27A if the pattern of Fig. 11-27B is observed. For the pattern of Fig. 11-27C, the point of observation is before agc action, and no manual gain controls are provided. For optimization, the individual head record currents are still adjusted for maximum level of each individual head on playback. Actually, the record current should be increased just slightly past the point of reaching maximum playback level. (In Fig. 11-27C, the rf envelope is chopped to ground reference to indicate each individual channel.)



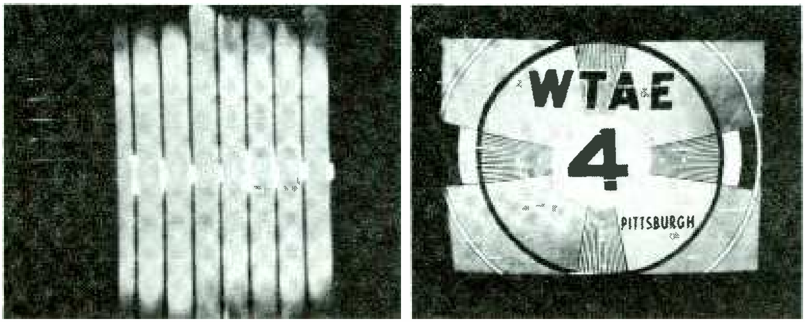
(*A*) *Equal gains.* (*B*) *Unequal gains.*



(*C*) *TR-70 system.*

Fig. 11-27. Switcher-output rf waveforms.

9. Fig. 11-28 shows the oscilloscope and monitor displays if the switcher phasing is improperly adjusted (switcher phasing on Ampex, 960 delay on RCA). Adjust for the elimination of holes on the scope display and white streaks in the picture. The white



(*A*) *Switcher output waveform.* (*B*) *Monitor presentation.*

Fig. 11-28. Switching pulse misphased.

streaks are similar to dropouts, except that switcher phasing error is synchronous, whereas dropouts are random.

10. It should be common practice during any of the preceding record modes to check the phasing of the control track relative to the edit (hence reference) pulses. Proper adjustment is shown in Fig. 11-29. If two tapes are spliced together with slightly different control-track phase relative to the recorded tracks, the effect in Fig. 11-30 will occur. If the phase difference is large, complete loss of signal may result, as the heads are between tracks. It is then necessary to readjust the tracking control manually immediately following a splice. (On the RCA TR-70 system, the monitoring cro presentation of the record control track shows the edit pulse inverted, but proper polarity actually exists at the head.)

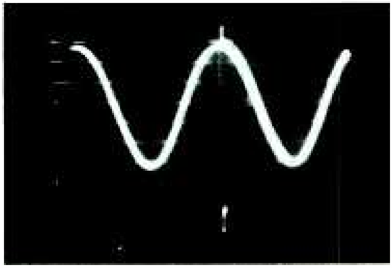


Fig. 11-29. Waveform-monitor display showing proper phasing of control-track signal with edit pulse.

Fig. 11-30. Monitor display of poor signal-to-noise ratio caused by slight mistracking.

The operator is now ready to make a short trial recording as a double check on system operations. All of the preceding procedures, of course, are not necessary before each recording. The entire setup procedure has been described in the interest of completeness. Experience with a particular installation will dictate the setup scheduling for optimum results on a consistent basis.

11-7. CHECKS DURING RECORDING

The following checks should be made periodically during a recording:

1. Control-track meter (or cro presentation) for normal current
2. Master-oscillator meter (or panel light) for proper erase current
3. Record-current meter for proper head currents as called for in the optimization procedure
4. Head-servo waveform for stability
5. Capstan-servo waveform for stability
6. Audio-head erase meter for proper erase current

7. Audio-recording level on VU meter
8. All warning lights for any indication of malfunction

11-8. CHECKS BEFORE PLAYBACK

The following procedure should be followed before playback of a tape:

1. If the recording was made on the same head used for playback, adjust the control-track phase (tracking) control so that the same head that plays the vertical sync also records the vertical sync (head 1 for RCA and head 4 for Ampex). This procedure will result in optimum match of heads. However, if the recording was made with a different head, the capstan tracking should be adjusted to obtain maximum rf output from the switcher unit. This normally indicates the best match of heads.

NOTE: Where Intersync or Switchlock is used, a given head must play back vertical sync for proper operation, depending on the particular system and mode of operation.

2. For playback of any tape, the guide servo is normally placed in automatic control so that skew is eliminated. If the automatic circuitry should fail to work and time is not available to repair it, simply place the servo in manual operation and adjust the position (tip-projection) control to eliminate skew at the demodulator output, so that the burden on the ATC system is minimized.

NOTE: It is important to bear in mind that the mechanical adjustment *should not* be changed from standard. The worst condition that can exist is that scalloping can be so noticeable in the picture (which may be a recording made elsewhere) as to require guide-height adjustment, which *must* be done mechanically. If the mechanical adjustment for skew has not been tampered with, it is normally a simple matter to give the height adjustment a slight turn to eliminate the scallop. When this is necessary, remember to recheck the height adjustment with the standard alignment tape before making a recording.

3. Adjust the playback-channel gains for equal outputs, as shown in Fig. 11-27A (rf indication, and where gain controls are provided).
4. Adjust the individual-channel high-frequency compensation controls (where used) for the "snappiest" picture without transients, and for best match of individual head response for contrast (minimum banding).
5. Adjust the processing-amplifier controls for proper video, setup, and sync levels to the line output.
6. Set the audio-output level control for standard level.
7. Rewind the tape and cue in to the proper roll point.

11-9. EMERGENCY OPERATIONS

We will now take up color-tape problems in general—what to do when you have trouble getting even a semblance of "lock-up" on a color tape for purposes of setting it up for proper playback.

The color mode of operation demands the tightest tolerance in video and servo functions. If the system will not find stable lock, *temporarily forget color!* Go back to the "loosest" servo mode, tonewheel for RCA, or normal for Ampex. If the system has switchable time-base error correction, turn it off (bypass). Reduce all playback equalization to a low level. Sometimes high-frequency transients from accumulated errors will prevent servo lock-up. You can always bring these back to normal after lock-up has been achieved.

The idea is to remove all feedback information from the demodulated tape signal into the servos. This enables you to minimize all errors of the head itself to match the tape to be played back.

Remember that time-base error circuitry is stable only over a limited range. If accumulated errors exceed about 1 μs, the resulting variable-delay modulation exceeds the practical range of Z_0 of the voltage-variable delay line, "kicking" the servos and preventing lock-up.

As soon as you have obtained stable lock in the simplest form of servo mode, you must make the head match the tape as closely as possible (scallop and skew). You observe the demodulator output on the picture monitor to do this. Include quadrature adjustments if these are provided.

Then activate the ATC or Amtec (while still in the nonsynchronous servo mode, no tape-signal feedback), and observe the error signal remaining on the cro at the ATC or TEC error monitoring point. After considerable practice, you can actually go through all the head adjustments to obtain minimum error signal on the cro at this point.

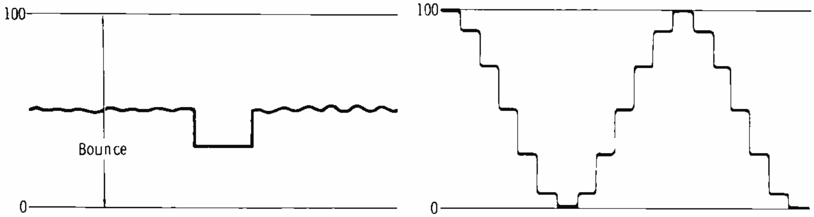
If the calibration is correct, the time-error correction signal will show 100 IEEE units (0.7 volt) peak-to-peak for a 1-μs error. If this is exceeded, chances are that you will not be able to use synchronous servo modes of operation; hence there will be no color lock. It is still better to play the program in monochrome than to lose the show entirely.

For a color tape to play properly, the accumulated errors (including recording jitter) must be less than 1 μs. Select the ATC or TEC position of the monitoring scope. On the latest systems, the error waveform may appear as in Fig. 11-31A. The "line" of errors may bounce up and down. If the range of bounce is greater than 100 IEEE units, the trouble may have been in the initial recording.

On older systems, you may obtain the waveform of Fig. 11-31B. This is a "locked error" simply showing the excursion of the time-error correcting signals. Again, this must be under 1 μs, or 100 IEEE units.

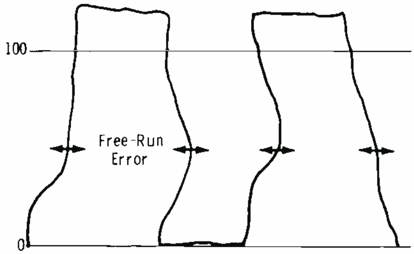
In the case of a "random" walk of error signals as in Fig. 11-31C, the waveform will "float" at an unlocked rate. (When the cro selector switch is in this position, the cro is externally synchronized to a 240-, 480-, or 960-Hz sweep).

Let us consider an example. If you have an early Ampex VR-1000A, or an RCA 1A without time-error correction circuitry, make a recording on this machine. Then make a dub of this on your latest system designed for color, with the machine which made the recording supplying the dub signal source. Chances are, in playback of this dub you will obtain the waveform of Fig. 11-31C, and you cannot go to a synchronous mode of servo operation such as Pixlock (automatic) or Linelock (horizontal). Early servos were quite "loose," particularly without time-base error video correction circuitry.



(*A*) *Waveform with bounce.*

(*B*) *Locked error.*



(*C*) *Free-run error.*

Fig. 11-31. ATC or TEC error waveforms.

There is a way you can check your system to differentiate between playback stability and jitter in the initial recording. Think of it this way: If you place the picture monitor on external sync (local sync) and play back the tape in a nonsynchronous mode (tonewheel or normal), then you observe the total jitter of recording and playback. Maintaining this same type of operation, superimpose the tonewheel or stability dots onto the picture monitor. These are pulses from the head tachometer; therefore the motion of these dots relative to the picture itself is an indication of *playback* jitter only. Now put the picture monitor on internal-sync operation. This means the sync from the video-tape playback is separated and used to sweep the monitor. Therefore the *playback* jitter is taken up automatically in the monitor, and the tonewheel or stability dots will now indicate *recorded* jitter only. It makes no difference whether you are operating the tape system in a nonsynchronous or synchronous mode.

Caution: Some systems automatically switch the picture monitor to external sync in going to the synchronous mode of operation, so it is best to leave the tape system in the tonewheel or normal mode if you are not sure. But check this for your particular system as soon as possible so that you know your system.

The tachometer dots superimposed on the picture should never be so "rapid" as to cause a "double-dots" appearance. If this shows up, either in playback jitter or record stability, the chances are that you will not obtain synchronous operation. A wide excursion (several inches), if at a slow rate, is *not* an indication of jitter.

Obviously if this jitter shows up only as a recorded jitter, you cannot do much to save the program, except to play it in a nonsynchronous (monochrome) mode. If jitter shows up in the playback check, the servos need attention. There is no substitute for the manufacturer's instruction book here, but Chapter 12 will help give you a better understanding of servo setup and troubleshooting.

After you have matched the head as closely as possible to the tape in nonsynchronous operation (minimized errors as much as possible), you can then try synchronous operation (with ATC or TEC on). If you can now achieve lock-up, readjust the individual channel equalizers and go on from there.

The important thing to know is what was just described, how to tell whether a particular tape is suitable for synchronous operation. You also need to be able to tell whether the servos are at fault (playback jitter) or the fault is in the particular tape recording involved.

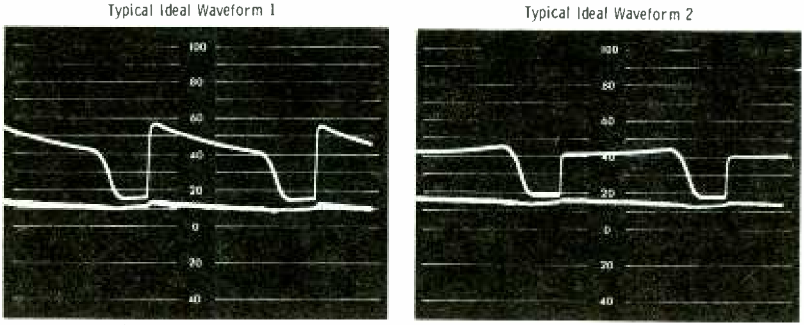
Some erratic conditions, such as video tear-out on a certain head or heads, can often be blamed on improper head antiresonance adjustments in the latest systems where this feature is included. This adjustment (or adjustments) compensates for the resonance of the head during playback and is made by operating reactance (usually a capacitor) and resistance controls on each channel playback amplifier while observing a sweep pattern (injected by a special probe on the headwheel) at the fm switcher output. For example, the procedure for the RCA TR-70 is as follows:

1. Place the machine in the stop mode, and remove the tape from the headwheel panel and audio heads (rewinding the tape is not necessary).
2. On the switch panel just above the modules, set the TEST SELECT switch to Res (resonance) and the CHANNEL SELECT switch to 1.
3. Remove the head resonance probe from the HD RES PROBE socket on the switch panel above the modules by rotating the probe clockwise approximately 45° and pulling the probe out. (Later RCA headwheels have a built-in probe.)

4. Insert the extruded portion of the head resonance probe into the slot provided for it on the headwheel panel, so that the U-shaped wire loop is close to the headwheel.

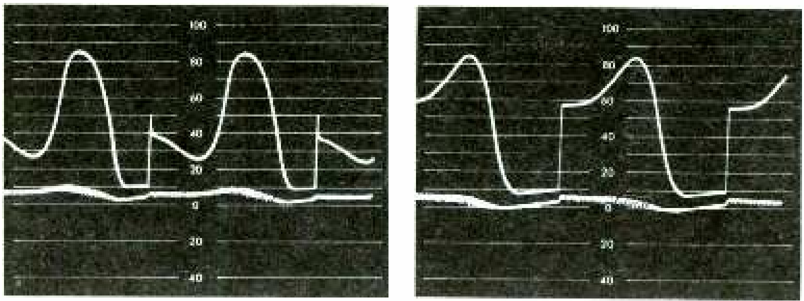
NOTE: The HD RES PROBE socket contains an interlock switch that prevents the machine from being placed in any operating mode when the head resonance probe is removed from the socket.

5. Push the TEST switch/indicator on the switch panel above the modules.
6. Press the FM LEVEL button on the cro switcher panel.



Typical Ideal Waveform 1 — Reactance and Resistance Controls Set Correctly

Typical Ideal Waveform 2 — Reactance and Resistance Controls Set Correctly



Reactance and Resistance Controls Set at Minimum

Reactance and Resistance Controls Set at Maximum

Fig. 11-32. Head antiresonance adjustment.

7. Manually rotate the tonewheel so that the notch on the tonewheel is lined up opposite the tonewheel head. Observe the cro presentation of head 1, and slowly rotate the tonewheel for maximum amplitude on the cro presentation.
8. Alternately rotate the RESISTANCE and REACTANCE controls on the playback amplifier 1 module in either direction to obtain a smooth or linear section on the waveform just prior to its rapid drop in amplitude (Fig. 11-32).

NOTE: The smooth or linear portion of the waveform may slope in either direction. Proper adjustment results in the desired smooth portion regardless of direction of slope.

9. Move the CHANNEL SELECT switch to position 2.
10. Manually rotate the tonewheel one-quarter turn in a clockwise direction (looking from the tonewheel end of the headwheel panel) so that the tonewheel notch is located at the top of the headwheel motor, which is 90° from the tonewheel head. Observe the waveform presentation on the cro, and position the tonewheel for maximum amplitude from head 2.
11. Repeat the procedure described in Step 8, except that now the procedure is for the antiresonance adjustment for head 2 on playback amplifier 2.
12. Move the CHANNEL SELECT switch to position 3.
13. Manually rotate the tonewheel one-quarter turn in a clockwise direction so that the tonewheel notch is located 180° from the tonewheel head. Observe the cro, and position the tonewheel for maximum amplitude from head 3.
14. Repeat the procedure described in Step 8, except that now the procedure is for the antiresonance adjustment for head 3 on playback amplifier 3.
15. Move the CHANNEL SELECT switch to position 4.
16. Manually rotate the tonewheel one-quarter turn in a clockwise direction so that the tonewheel notch is located 270° from the tonewheel head. Observe the cro, and position the tonewheel for maximum amplitude from head 4.
17. Repeat the procedure described in Step 8, except that now the procedure is for the antiresonance adjustment for head 4 on playback amplifier 4.
18. Press the STOP switch on the record or play panel to release the test switch-holding circuit.
19. Replace the head resonance probe by inserting the probe into the HD RES PROBE socket and rotating the probe 45° in a counterclockwise direction.

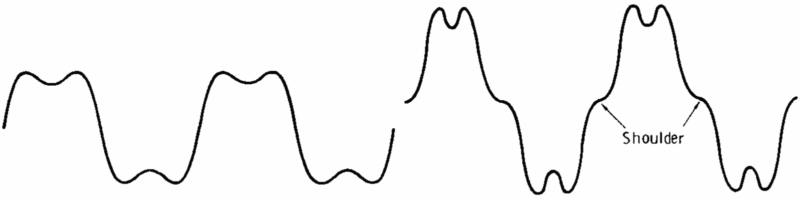
Erratic tracking problems are sometimes due to insufficient control-track level on the recorded tape. The peak-to-peak level of the control-track waveform is *not* an indication of either proper or improper control-track level. Note from Fig. 11-33 that the proper control-track level is indicated by a slight shoulder at the zero axis of the distorted sine wave. This amplitude is originally set as follows:

1. With the machine in the master record mode, the control-track playback button on the monitoring cro is depressed to observe the

simultaneous control-track playback presentation during the record mode.

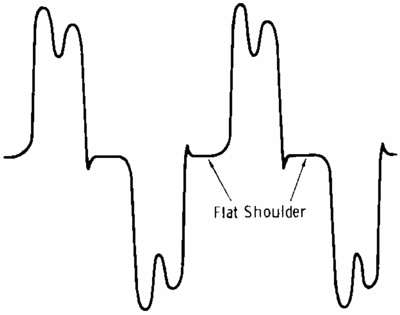
2. The control-track record-level control is then adjusted until the simultaneous control-track signal just begins to show saturation, as in Fig. 11-33B.
3. While still recording, change the cro monitoring selector push button from control-track playback to control-track record. Adjust the frame-pulse amplitude to 1.5 times the sine-wave amplitude, as in Fig. 11-34 (waveform A). Note that with this amplitude, it appears that the frame pulse is not exactly at the peak of the sine-wave. To properly judge this, however, it is necessary to reduce (temporarily) the frame-pulse amplitude and adjust the frame-pulse phase control for exact centering, as shown by waveform B of Fig. 11-34. Then when the pulse is readjusted for proper amplitude, waveform A results.

NOTE: It was previously mentioned that the frame pulse is a negative-going pulse starting from the crest of the current waveform. It was also mentioned at that time that the RCA TR-70 monitoring position shows a polarity the reverse of what actually exists at the control-track head. For this reason, the frame pulse is shown starting from the valley rather than the crest of the waveform, and it is positive-going. This is immaterial to proper adjustment but is important to understanding the subject.



(*A*) *Current too low.*

(*B*) *Proper current.*



(*C*) *Current excessive.*

Fig. 11-33. Simulplay waveforms for adjustment of control-track record current to proper level.

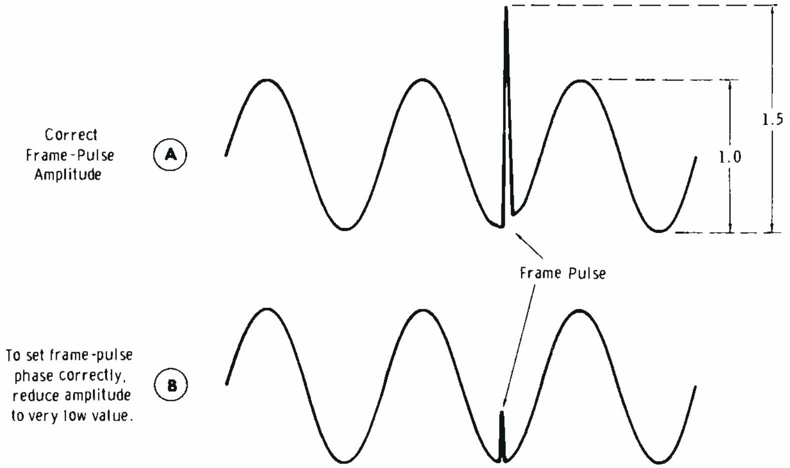


Fig. 11-34. Control-track record waveforms for RCA TR-70 recorder.

11-10. ELECTRONIC SPLICING

The following basic outline serves as a guide for preparing to do an electronic splicing job:

1. Determine what is to be accomplished.
2. Determine the relative timings. (Where are they to occur?)
3. You might desire to utilize the cue track for splicing information. (The splice must be initiated ½ second ahead of the actual cut. This is because there is ½ second, or about 15 frames, between the master-erase and video heads.)
4. Should the audio track be retained?
5. Make certain that the machine is operating properly and that the tapes used have edit (frame) pulses on the control track. Without these pulses, the electronic splicer will not turn on.
6. Make a few practice splices on spare tape to become familiar with the technique.
7. If a second tape recorder is used as a signal source, it must be adjusted to appear as a line feed as follows:
   - A. Servo mode in Pixlock.
   - B. Burst phase adjusted to give proper flesh tones.
   - C. Horizontal phase (in the splicer) adjusted to give exact leading-edge coincidence at the input to the splice recorder.
   - D. If inserts or wipes are anticipated, set the system burst phase of the feed machine correctly to match the burst phases of other sources at the switcher-system input.

Following is a brief outline of the RCA electronic splicing technique. This information is included here to acquaint the reader with the operations involved.

1. Put the machine on which the splice is to be made in the Switchlock mode.
2. Select the proper splice mode. (Insert retains the old control track; Add-On puts down a new control track.)
3. Select the proper audio mode (audio off to retain old audio).
4. On the monitor selector switch, press both VID IN and DEMOD buttons. (On the TR-70, use PULSE CROSS.) With the switch in the E-E mode, note the normal phasing horizontally between the superimposed signals in the sync region (Fig. 11-35).
5. Play back the tape on which splicing is to be done. Punch the ATC button on the cro and adjust the head for minimum errors.
6. For the add-on mode only, perform capstan adjustment as follows: Punch the CAPSTAN button on the cro. With the tape playing, put the switch on the splice logic module in the Capstan Adj position, and adjust CAPSTAN ADD ON ADJ (same module) for minimum shift of the sampling pip on the slope. (Switch between Capstan Adj and Fixed TW and adjust until the shift of the pip is zero.) Be sure to return this switch to Var TW.
7. While still playing back the tape, adjust SPLICE RECORD H PHASE (on splice timing module) until the phasing on the monitor (looking at VID IN and DEMOD OUT superimposed) is the same in playback as in the E-E mode (Step 4). In Fig. 11-35, the delayed signal is the demodulator output. To set the splice record horizontal phase control, adjust this control so that the playback gives no vertical displacement and has the approximate horizontal position shown. (The heavy, or darkest, portion of the hammerhead is the overlap interval of the two signals.)

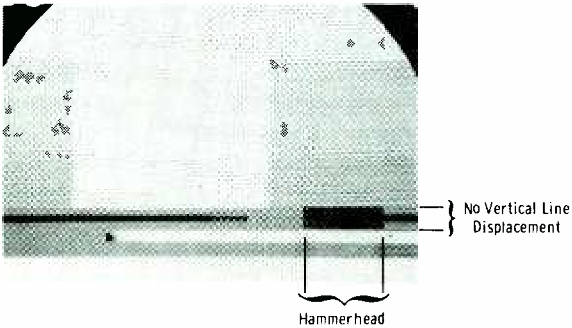


Fig. 11-35. Simultaneous presentation of video input and demodulator output with pulse-cross display on picture monitor.

8. Go into regular splice operation. The REC button must be pressed ½ second before the splice is to be made. Then the PLAY button must be pressed ½ second before the end of the splice. Remember that you must go into the play mode before the record mode; otherwise, the machine will make a regular recording, ignoring the splice mode.

NOTE: This section has discussed only the basic technique of electronic splicing. The use of more refined automatic editing programmers varies considerably with every make and is beyond the scope of this book. The operator familiar with Chapter 10 and this chapter will be able to master those techniques more quickly by following the operational outlines accompanying the equipment.

EXERCISES

Q11-1. Where should the master equalizer control be set?

Q11-2. Why was the setting of individual playback levels not mentioned?

Q11-3. If the individual channel equalizers are adjusted for even "tops" across all heads as observed at the demodulator outputs, and the "bottoms" are unequal, what does this mean?

Q11-4. What is the proper way to adjust monochrome and color time-base-error gains?

Q11-5. When the demodulator gain is adjusted for proper output in the E-E circuit mode, should this level be the same for any tape playback?

Q11-6. Assume the demodulator balance control is set in the E-E mode, but on playback of a tape, it is necessary to readjust this balance for minimum rf in the blanking and sync regions. Is this normal? (Usually occurs only on older low-band systems.)

Q11-7. When you are checking signal inputs on an external scope without the IRE (IEEE) graticule, what is the proper voltage proportion for video and sync?

Q11-8. If you have a 0.2-μs ringing period of a sine-squared pulse, what is the cutoff frequency?

Q11-9. What are the specific K-factor characteristics to look for in the (A) low-frequency, (B) high-frequency, and (C) midfrequency region?

Q11-10. When it is necessary to use special-effects mixing on a color tape playback, which should be adjusted first, system phase or burst phase?

Q11-11. If you make a recording of the sine-squared pulse-window test signal for checking system performance, how do you differentiate between recording and playback characteristics?

Q11-12. What is the gamut of rf frequencies covered in modern high-band tape-recording systems?

Q11-13. In either the RCA or Ampex high-band tape systems, the video processing amplifier can be operated in one of two modes, the external-reference mode or the regenerated-sync mode. What is the difference?

Q11-14. Does a "standard test tape" serve as a standard for both new and worn heads?

Q11-15. What is the minimum tip projection normally allowed on heads before they are returned to the factory for exchange?

Q11-16. Is it advisable to reduce tip penetration below the "standard" to obtain greater life of the headwheel?

Q11-17. How do you lap-dissolve between a studio camera and a tape machine or between two tape machines?

Q11-18. What can be wrong if no movement of the tape occurs in a play mode but everything is actually working properly on the machine?

CHAPTER 12

Quadruplex Tape System Maintenance

This chapter concerns general testing and maintenance techniques as applied to any quadruplex recording system. Lubrication schedules recommended by the manufacturer for the specific system used should be faithfully executed. This is of extreme importance due to the electromechanical nature of the tv tape system. Complete service records of work performed or adjustments made, correlated with the elapsed-hour meter, are invaluable for increasing efficiency in tests and maintenance.

12-1. OVERALL PERFORMANCE EVALUATION

An overall performance evaluation of a television-tape system helps to pinpoint the need for maintenance in specific areas. A professional job of cleaning the tape transport and video-head assembly is of vital importance before testing or maintenance procedures are conducted.

Major troubles that can result from lack of cleanliness may be summarized as follows:

1. Dropouts (white flashes) due to oxide accumulation between heads.
2. Dots at a 960-Hz rate as a result of scratches on the coated surface of the tape caused by oxide accumulation.
3. Oxide in the vacuum guide or hose, causing scallop or skew due to lack of concentricity with the tape. A wandering type of skewing can be caused when oxide which sheds into the vacuum guide alternately clogs and clears the air path. This effect can also be caused by an alignment tape with many hours of use—or even after only a few hours if the transport tensions are such as to cause excessively rapid stops or jerking of the tape when the STOP button is depressed. Another cause is bent reels which place undue stress on the edges of the tape.

4. Contamination of the nylon bearings under the vacuum-guide block or a contaminated screwhead contact with the arm that is actuated by the guide servo (to position the vacuum guide). This can result in a slightly different tip penetration each time the tape is stopped and restarted.
5. Erratic tracking caused by tape slippage resulting from a contaminated capstan or capstan pinch roller.

CAUTION: New tape from the factory will often exhibit what seems to be an excessive number of white flashes (dropouts) when the first recording is played back. When tape is first received, a spot check should be made (recording sync only for about the first 5 minutes, 5 minutes near the middle, and 5 minutes near the end of the reel) to observe the playback raster. If dropouts are numerous, the tape should be polished by allowing the entire reel to run through the heads two or three times. A worn head is best for this polishing operation. This is not quite so important when a dropout compensator (Chapter 8) is employed.

Overall evaluation can be an evaluation of the recording and playback functions on a routine operational basis considering only the composite video signal, or it can be an evaluation which also includes the following items:

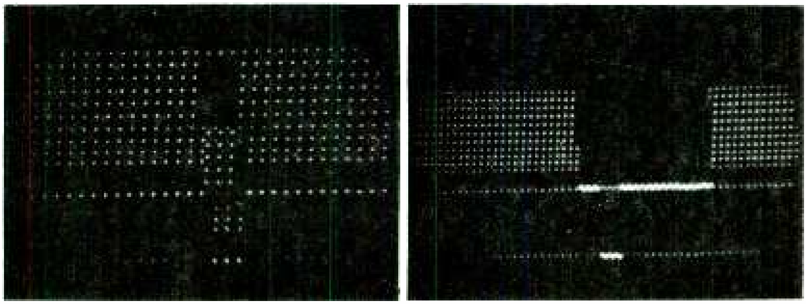
1. Time required after tape roll time for complete stabilization of the servos.
2. Maximum input level to the video-processing amplifier tolerable before clipping occurs, and minimum input level tolerable before sync gating and/or sync formation is affected. This is a means of anticipating trouble before the unit ceases to function properly over the normal operating range.

NOTE: The trademark of a qualified maintenance man is knowing his *safety margins.* When the safety margin begins to slip, he goes to work. In fact, most of the effectiveness of any preventive-maintenance schedule is in knowing and using the safety margin.

3. Evaluation of adjustment control ranges. Some controls are normally set at one extreme (cw or ccw). Others, however, such as frequency controls, pulse-widths controls, and video-level controls (including blanking and sync) should be checked to determine if proper operation is obtained near an extreme end of the range.
4. Modulator-demodulator amplitude linearity range, the extent of overdeviation possible before amplitude compression occurs or the picture plays back with visible transients in black-white transitions. NOTE: The video heads must first be checked for optimization (proper driving currents) before this evaluation (described in Chapter 11).

5. The playback signal-to-noise ratio of a recording made by the system concerned. This is an excellent indicator of any system degradation other than amplitude-frequency response. (Amplitude-frequency response is usually revealed by evaluation of the composite video signal.

The maintenance engineer should bear in mind that any standard test tape such as the one described in Chapter 11 is a check of the playback function *only*. For overall record-playback checks, it is necessary to have access to the necessary test-signal generators. Conventional signal-analysis techniques are used when dealing with individual test signals. The test-signal input to the recorder *must* be a standard composite signal. Some older test-signal generators contain only horizontal sync so that clamping circuits will function properly. Fig. 12-1A is the vertical-rate display of the output of a typical older stairstep generator; this display indicates that horizontal pulses are contained in the vertical-sync interval. A television tape recorder will not make a satisfactory recording of this signal. The same signal fed through a unit (such as a monoscope amplifier with external input provision) with keyed blanking so that horizontal pulses are eliminated during the vertical interval is shown in Fig. 12-1B. This type of signal is necessary to make a recording on television-tape systems which generate a reference pulse at a specific time in the vertical-synchronizing interval (all recorders after the Ampex 1000). The vertical pulses are not only integrated, but they are also effectively differentiated so that a particular time reference is available for generation of the reference pulse. When a signal such as that in Fig. 12-1A is fed to the system in the record mode, no reference pulse is generated (or if it is generated, it will be erratically keyed), and playback may be either erratic or impossible. NOTE: See Section 12-4 for special test procedures employing noncomposite signals.



(A) Direct output, showing horizontal-rate pulses in vertical sync.

(B) Output of unit which inserts keyed blanking and sync pulses.

Fig. 12-1. Vertical-rate display of typical stairstep-generator signal.

12-2. THE VIDEO-HEAD ASSEMBLY

Maintenance of the video-head assembly involves primarily cleaning, proper positioning of the vacuum guide, and video-head optimization. All of these items have been covered previously.

If the head clogs easily, measure the tip projection as described in Chapter 11. Heads should normally be retired when they become worn down to a 1-mil tip projection, as a slight widening of the gap is apt to occur at any point below this value. The gap is quite easily clogged by iron-oxide particles from the tape and may become useless on the passage of a splice. NOTE: If a rolling-through amplitude change occurs during a program as observed on the rf envelope from the switcher (with resultant degraded and banded picture), try holding a very soft brush (moistened with Freon TF) *lightly* against the rotating pole tips while they are in motion. Some operators grasp the vacuum guide gently with the thumb and middle finger to steady the hand while extending the forefinger (in the direction of head rotation) and lightly grazing the pole tips as they rotate. While this method must be used with extreme care to avoid injury to the finger, a clogged head is almost immediately cleared.

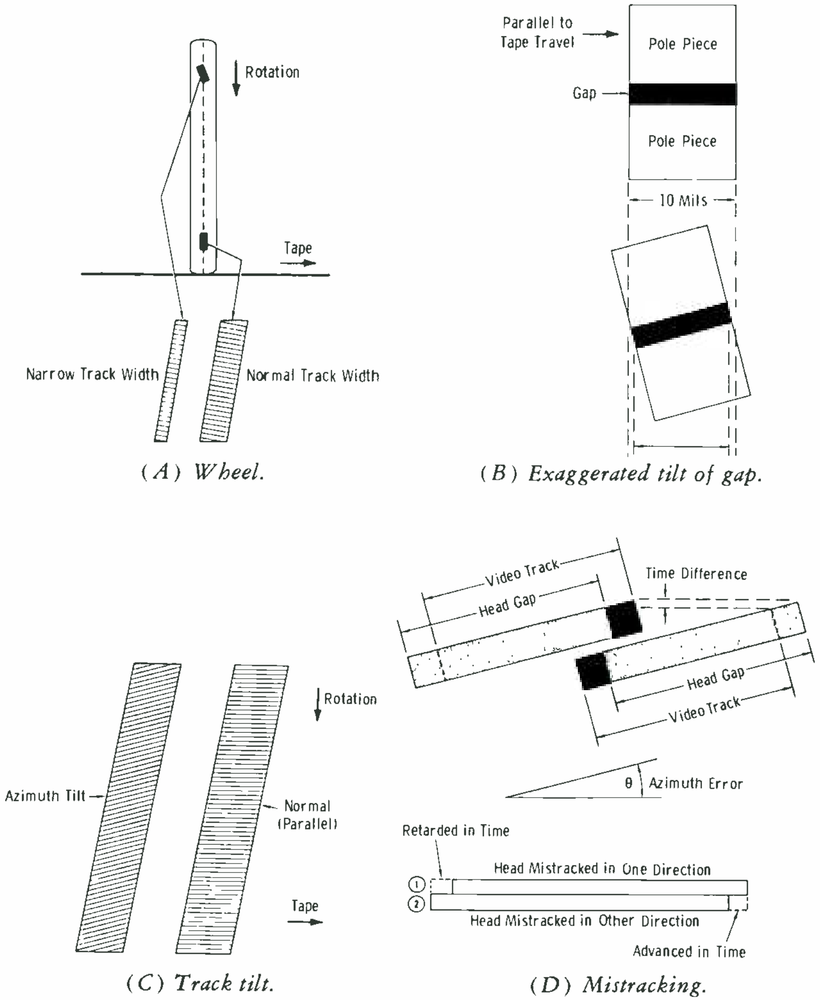
There are two head faults over which the operator has no control: azimuth alignment and axial position (see Figs. 2-20 and 2-21). However, it is possible to check the heads for these conditions; such checks should normally be made by the maintenance engineer immediately on receipt of a rebuilt head assembly.

Check for Azimuth

A head with gap tilt lays down a narrow track, as shown in Fig. 12-2A. This results in a loss in amplitude, bandwidth, and signal-to-noise ratio. An exaggerated azimuth error is shown in Fig. 12-2B to illustrate how the recorded track is narrowed. This is equivalent to widening the playback gap of a normal head. The tilt of tracks recorded when the gap is not parallel to tape travel is shown in Fig. 12-2C, and the method used to detect this error is given in Fig. 12-2D. Make a recording of vertical lines. Playback should be done with the tracking adjusted so that the same head that plays vertical sync also recorded vertical sync. When tracking is perfect, the head gaps are directly over the recorded tracks. By slightly mistracking on each side, any apparent quadrature effect will reveal azimuth error. Mistracking in the direction of 1 (Fig. 12-2D) will retard the band in time, and mistracking in the direction of 2 will advance the band in time. If the lines are parallel to tape travel, no error will occur. The head assembly must first be optimized and aligned properly, as outlined in Chapter 11.

Check for Axial Position

As shown by Fig. 2-21, axial misalignment of a head results in nonstandard spacing for one band of 16 lines. After the heads have been



(*A*) *Wheel.* (*B*) *Exaggerated tilt of gap.*

(*C*) *Track tilt.* (*D*) *Mistracking.*

Fig. 12-2. Azimuth alignment check.

optimized, make a recording of a suitable signal (a test pattern is best) and play the tape back with the tracking control adjusted so the head that records vertical sync plays it back. The playback picture should be optimum under this condition. Now change the tracking by one head. (This is done simply by moving the tracking control either clockwise or counterclockwise until lock-in is again achieved.) If axial misalignment exists, one band will become noisier than the rest. This will result for three out of four head trackings. In many cases, an effect known as *half-banding* occurs; this simply means that approximately one-half of a given band is noisy. Half-banding results when the pole tip scans properly across a portion of the track, but the remaining portion of the track is curved relative to the standard track. Thus, a uniformly high noise level throughout one band indicates that one head is not in the same vertical plane (axial position) as the other three heads. Half-banding results when the plane of pole-tip rotation is not perpendicular to the tape. In either case, the manufacturer will allow full rebate on such a head assembly if it is returned within the first 10 hours of operation. (Check your manufacturer on this, as this "free time" may be lengthened.)

Tip Ringing

In color, if three or four bands of lines (indicating one of the four video heads) show excessive moiré, this may be caused by *tip ringing.* Assuming the playback level and equalization for the particular head in question have been properly adjusted, tip ringing can cause a color interference pattern (moiré) even when not very noticeable in monochrome.

Tip ringing is a head pole-tip fault caused by deterioration of the magnetic-gap material. The tip can actually dig into the tape in a severe instance of this condition and cause excessive tape shredding with possible tape damage.

12-3. OPTIMIZING THE LOCAL SYNC GENERATOR

Requirements for certain characteristics of the local sync generator are more exacting for integration with tv tape systems than for other studio equipment. Optimizing the station sync generator indicates neither a different adjustment nor a nonstandard adjustment to make it compatible with the tape recorder. It does, however, indicate more critical adjustment of frequency and more thorough maintenance of stability of counters, afc circuits, and pulse distribution. This is particularly true of older sync generators and tape systems.

After the sync generator has been adjusted according to the manufacturer's instructions, perform the following check:

Set the master oscillator in the free-running mode. Insert the scope probe to observe any 60-Hz signal (such as counter-chain output, vertical drive, or blanking) with the scope trigger selector on the 60-Hz line position. This reveals any slip of the vertical-frequency generator output with respect to the line frequency. Adjust the master-oscillator frequency so that the trace is stabilized with the line frequency; this provides a fine adjustment of the oscillator frequency, provided that the counters are properly functioning and centered. A very slight drift back and forth may occur, but no sudden changes should exist.

Setting the master oscillator control to line-lock should immediately stabilize the trace after the initial phase slip to lock. If this does not occur or if the trace becomes unstable on the line-lock position, the afc circuitry is in need of service. When individual counter stages employ adjustable controls, always check to see that such controls are centered in the range midway between the extremes where proper countdown is lost.

With the sync-generator frequency adjusted, no difficulty should be experienced in tape-system operation using local sync as the playback reference. The same is true when the Ampex Intersync or RCA Pixlock mode is employed with the local sync generator in the Linelock position. However, both Ampex and RCA recommend using crystal control for the local sync generator in the latter case for maximum playback stability. When, for any reason, it is desirable to operate in the Linelock sync position, the preceding fine tuning of the master oscillator along with stable afc circuitry will normally result in satisfactory operation. Modern systems, of course, employ "color lock" only.

Sync cross talk is another problem. This term applies either to cross talk within the sync generator itself or to the "windshield-wiper effect," similar to the horizontal motion resulting from cochannel interference on a home receiver.

Cross talk within the generator itself is usually caused by very small leakage of any of the counter frequencies to the master oscillator. This trouble is most evident on video monitors employing pulse-width (*Synchroguide*) horizontal circuitry. Cross talk produces a slight horizontal-line displacement at the vertical raster edges and vertical lines in the picture. The engineer can check by observing any pattern consisting of vertical lines (such as a grating signal or keyed-burst signal driven from local sync), preferably on a Synchroguide-type monitor. The frequency of any existing cross talk can be determined by considering the number of horizontal line displacements occurring from top to bottom of the raster, as follows:

Frequency	*Number of Displacements*
4500 Hz	70
900 Hz	14
180 Hz	3

Thus, cross talk from the 900-Hz output of one of the counters results in 14 displacements, which is quite close to the 16-band (960 Hz) raster construction of a tape-recorder output. Sometimes a scallop effect, which can cause the operator to misadjust the vacuum-guide height adjustment in an attempt to eliminate an error, is actually caused by the local sync generator. However, this effect will be observed at the input to the tape system when cross talk exists. Certain types of master monitors employ a synchronization which, for all practical purposes, results in line-to-line sync. This tends to start each active line of picture information at the same spot following horizontal sync and minimizes any effect of line displacement that normally would be quite apparent on an average-sync monitor (and on most modern home receivers). For this reason, the station should monitor tv-tape systems with an averaging-sync monitor.

When "synchronous-type" cross talk is found, the indicated counter should be additionally shielded or the wiring rerouted until the interference is eliminated.

A more prevalent type of sync cross talk occurs between two nonsynchronous sources, such as local and network signals or local and videotape signals. This trouble is evident as a vertical bar or line moving nonsynchronously back and forth horizontally on the video monitors when the network or television-tape signal is fed to the program line. (Of course, this will not occur if the tape is operated in the Intersync or Pixlock mode, because the tape output then is in phase with the local sync generator.) The condition is caused by cross talk between the local sync and the nonsynchronous tape or network signal.

This trouble is usually the result of ground loops. A ground loop in an otherwise well designed installation is most often the result of an open or intermittent ground at one end of a coaxial cable. When an open occurs, the signal at the open-shield end must obtain its ground return through a number of racks. Each cable should be disconnected from the sending end and checked with an ohmmeter from center conductor to shield to determine if the termination resistance is obtained. If the shield is open, no continuity will exist. Always twist both the sending and receiving connectors while making this check so that loose, intermittent, or high-resistance connections will be made evident.

More recent sync generators, particularly those of modern digital design, are normally quite stable and trouble-free compared to the older types. The stability of the color-subcarrier generator is many times better than that of older systems, and this is particularly important for second- and third-generation dubbing on color tape systems.

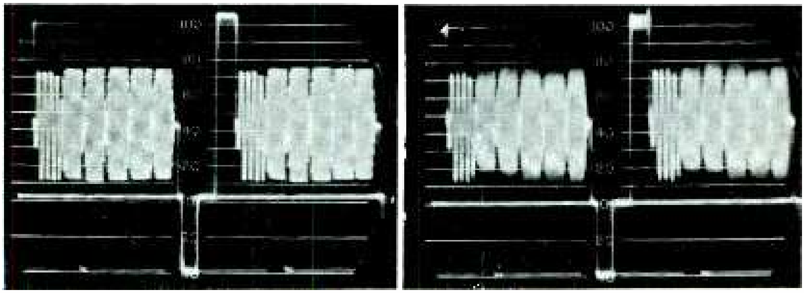
12-4. CHECKING VIDEO CHARACTERISTICS

Knowing the normal gains of individual amplifiers (such as preamplifiers, modulator video stages up to the frequency-modulated stages, rf stages from modulated stage to modulator output, demodulator unit, etc.) is an important factor in preventive-maintenance procedures. This step in preventive maintenance will help in keeping the system signal-to-noise ratio within specifications and, in tube-type systems, will indicate when the need arises for carrying out tube-transconductance checks and making replacements.

As a specific example, measure the video-head output (with a scope directly at each commutator brush) on playback of a standard tape such as the alignment tape. This rf output is normally from 2 to 5 millivolts. Then measure the output of the individual head preamplifiers, and compare this peak-to-peak value to the normal value, determined when the system is known to be properly functioning. All of these values should be recorded and available to the maintenance personnel.

The general condition of the video-processing amplifier can be interpreted if the normal range of input level is known. An example of a specific tabulation follows:

Normal input: 1 volt (p-p)
Minimum input: 0.5 volt (p-p) for same signal-to-noise ratio
0.25 volt (p-p) just above sync breakout



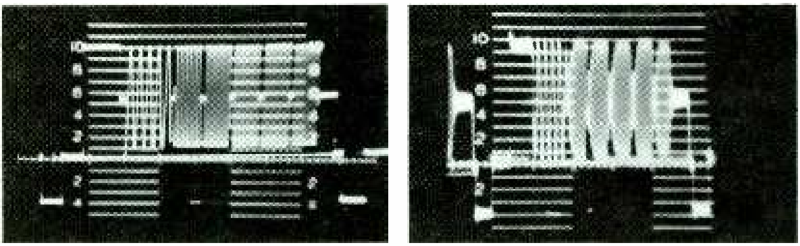
(A) Proper proportionment at input. *(B) Acceptable reproduction of A.*

Fig. 12-3. Multiburst signal as proportioned for older tape systems.

Use of Test Signals

The need for attention is most quickly checked with the keyed-burst signal, as illustrated in Fig. 12-3. On all older tape systems, care should be taken to proportion the amplitudes of the single-frequency bursts as shown for the input signal of Fig. 12-3A. The energy of frequency components in the normal monochrome picture is quite low above 1.5 MHz. If sine waves are fed into the system with the higher frequencies at the same amplitude as the white-pulse reference, considerable high-frequency power exists, and high-frequency overload of the modulator due to the previously discussed pre-emphasis may occur. The same type of overloading occurs in the demodulation process due to natural limitations in high-power, high-frequency linearity. The response obtained from such adjustment of the input signal will indicate some loss of higher frequencies as compared with Fig. 12-3B. Also, a shift in the ac axis occurs, indicating selective-frequency clipping. This type of input signal exceeds the normal limits of the modulation-demodulation process and is of little value, except as a safety-margin check. The multiburst signal generator should be carefully designed so that it does not have a second-harmonic content. The pattern will give the appearance of poor frequency response on playback at any frequency where the second-harmonic content is high. Many professional multiburst signal generators employ a 4.5-MHz filter at the output, where the highest burst frequency in the signal is 4.2 MHz.

The above situation does not hold true for modern low-band and high-band systems, such as the Ampex VR-3000 and AVR-1 or RCA TR-70 systems. The normal multiburst test signal is used for these systems, as illustrated in Fig. 12-4. The extended system capability is brought about by the use of double sidebands in the fm-video system and modulation-demodulation process.



(A) Full-amplitude multiburst signal input for recording.

(B) Playback of recorded signal on low-band color standards.

Fig. 12-4. Normal multiburst test signal.

NOTE: It is important to remember, however, that in the interest of minimum phase distortions and maximum signal-to-noise ratio, the actual video output response may be down as much as 3 dB at 4.5 MHz relative to 1 MHz. This is due to the critically shaped response of the filtering networks in modern tape systems.

Fig. 12-4B shows the output of a modern low-band color tape system. The reproduction of the full multiburst test signal by a modern high-band system is practically indistinguishable from the input signal in a photograph.

If a video sweep is used for fm circuit alignment, remember that the highest video frequency (4 MHz) is represented by a carrier frequency of 1 MHz (lowest carrier frequency). Thus, peaking the carrier at the lower end increases the response at the higher video frequencies.

When it is necessary or desirable to insert a test signal into the video preamplifiers, use a wideband video pad such as the one shown in Fig. 12-5.

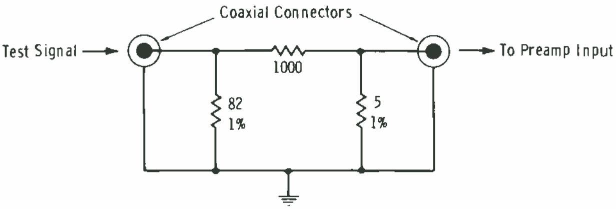


Fig. 12-5. A 46-dB video pad.

The pad is inserted between the test signal generator and the preamplifier input by means of short coaxial cables. The test signal generator should be adjusted for a signal output of no more than 0.5 volt (p-p), to insure that the 46-dB attenuation will prevent any possible overloading of the preamplifier.

Inability to bring a tube-type video amplifier into proper amplitude-frequency response specifications by adjustment of the appropriate peaking circuits may be due to any one or a combination of the following faults:

1. Changed plate load. An increase in the plate load will reduce the response at higher frequencies. A decrease in the plate load will reduce the gain and increase the response at higher frequencies.
2. Defective peaking coil or swamping resistor across the coil.
3. Low-transconductance tubes. (However, in certain types of negative-feedback amplifiers, loss of highs may result from tubes that show normal transconductance on a tube checker. *Always* replace tubes in negative-feedback amplifiers before making further checks for troubles when video-response checks indicate loss of high-frequency response.)

Always bear in mind the turn-around in fm peaking circuitry due to the nature of the modulation system. In this case, for example, an increase in plate load, causing reduced response at the higher carrier frequencies, results in a loss of low-frequency video and an increase in high-frequency video.

The evaluation of low-frequency response is important in determining absolute values of picture streaking. It is important to understand that the degree of streaking observed on a picture monitor depends not only on the monitor-amplifier characteristics, but also on the ratio of the brightness- and contrast-control settings. There is almost always some visible streaking when a window signal, or any other white bar on a black background, is displayed if the bar extends over an appreciable portion of the scanning line. This was the primary reason for development of the white-window test signal, so that a truly accurate measurement can be obtained from the cro presentation in quantitative terms.

The phase characteristic related to the low-to-high frequency response ratio is closely related to the absolute measurement of the low-frequency response. The shape of the passband response curve determines the transient response of the system. Depending on the rise time of the window signal, an indication of transient response may be determined to some degree, but this characteristic is more accurately shown by the $\sin^2$ pulse.

> NOTE: The makeup and practical measurements of the $\sin^2$-window signal and the 20T modulated test signal were covered in Chapters 2 and 8 of *Television Broadcasting: Systems Maintenance,*[1] and will not be re-

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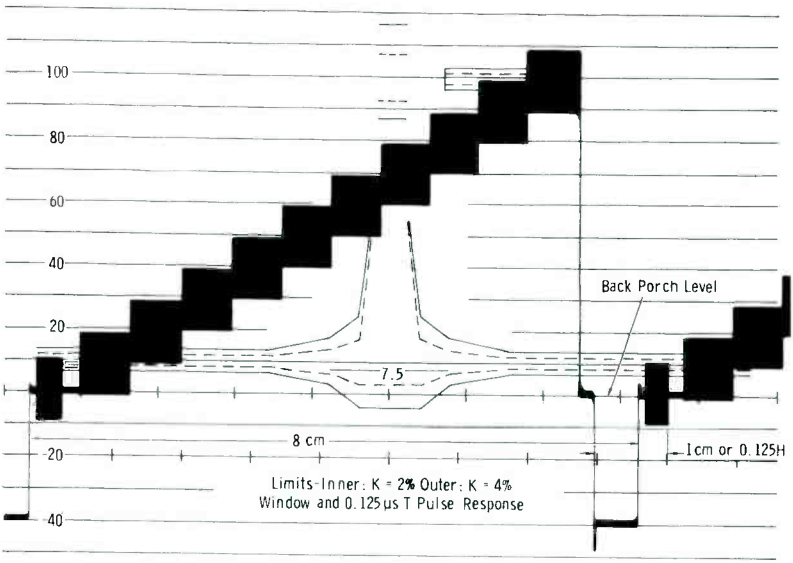
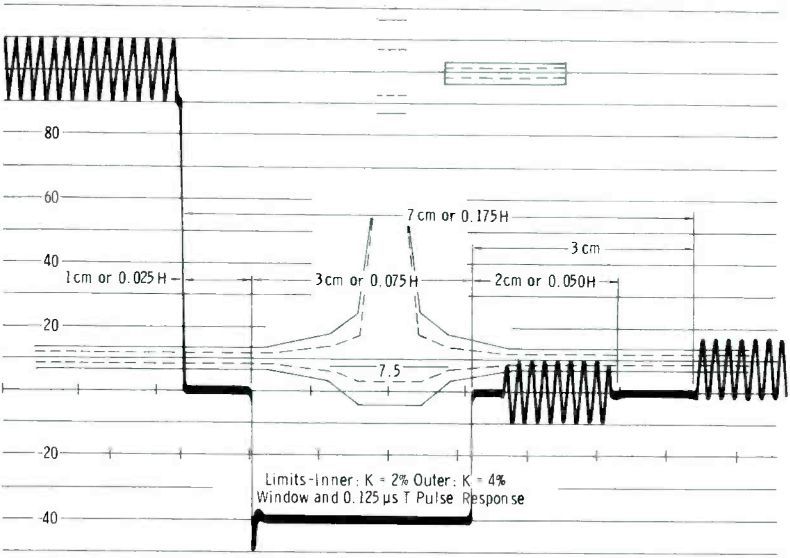
[1] Harold E. Ennes, *Television Broadcasting: Systems Maintenance* (Indianapolis: Howard W. Sams & Co., Inc., 1972).



(A) 0.125H/cm sweep rate.



(B) 0.025H/cm sweep rate.

Fig. 12-6. Use of sweep magnification

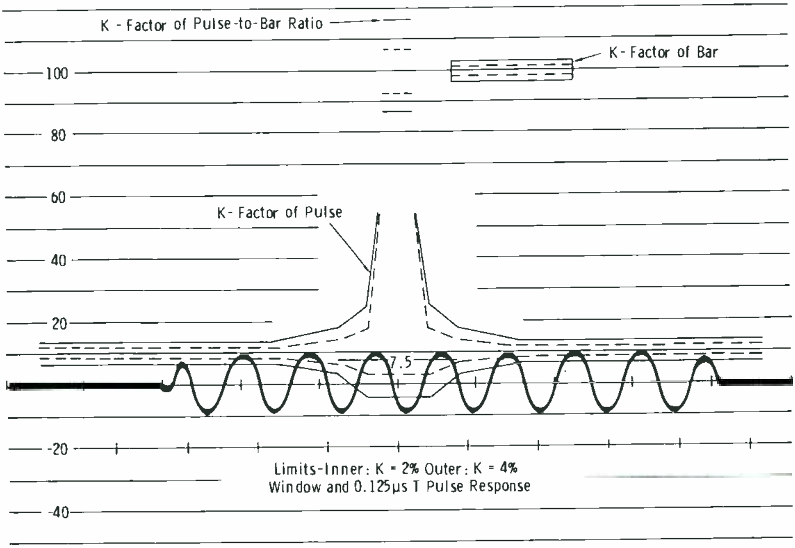
peated here. The student or practicing engineer not familiar with such techniques should review this material at this time.

In any case, the Tektronix Type 529 waveform monitor is commonly used in all vtr installations, and we will briefly cover the use of this monitor before proceeding.

When the DISPLAY switch is set to 0.125H/cm, horizontal-sync timing is measured in terms of H (the time between horizontal-sync pulses, or the time from the start of one horizontal line to the start of the next line). When the (HORIZ) MAG switch is set to ×1, one complete horizontal line is displayed in a sweep length of 8 cm (see Fig. 12-6A). In addition, refer to Table 12-1, which lists the sweep-time relationship between H/cm and microseconds/cm.

> NOTE: The 2 Field position is the only position of the DISPLAY switch for which a free-running trace can be obtained in the absence of a trigger signal. Thus, the 2 Field position is useful for determining whether the video signal is absent.

For pulse measurements at 0.125H/cm, one centimeter equals 0.125H. For example, in the NTSC signal specifications, 0.125H is the minimum time interval between the leading edge of the horizontal-sync pulse and the end of the color burst.



(C) 0.005H/cm sweep rate.

in display of horizontal waveforms.

Table 12-1. Sweep-Rate Settings

(Horiz) Mag	DISPLAY Switch Setting	
	0.125 H/cm[1]	0.250 H/cm[1]
×1	0.125 H/cm	0.250 H/cm
	7.94 μs/cm	15.9 μs/cm
×5	0.025 H/cm	0.05 H/cm
	1.59 μs/cm	3.18 μs/cm
×25	0.005 H/cm	0.01 H/cm
	0.318 μs/cm	0.635 μs/cm

[1] Also applies to the Line Selector settings of the DISPLAY switch.

If the (HORIZ) MAG switch is set to ×5 when the DISPLAY switch is at 0.125H/cm, the time-base sweep rate is 0.025H/cm. This sweep rate is used, for example, to make horizontal-sync pulse-waveform measurements such as those shown in Fig. 12-6B.

If the (HORIZ) MAG switch is set to ×25 when the DISPLAY switch is at the 0.125H/cm position, the sweep rate is 0.005H/cm. This sweep rate is useful for measuring the rise time and fall time of the horizontal-sync pulses, to count the cycles of color burst (Fig. 12-6C), and to examine portions of a complete line.

The 0.25H/cm position of the DISPLAY switch is another calibrated sweep rate which is useful for making horizontal line and sync-pulse waveform measurements. In the ×1 position of the (HORIZ) MAG switch, approximately 2½ horizontal lines are displayed. Table 12-1 lists the sweep-time relationship between H/cm and microseconds/cm for each magnifier switch position.

When the DISPLAY switch is set to either of the Line Selector positions and the LINE SELECTOR control is used, it is possible to range into the top of the picture to examine any one or two lines, depending on whether the DISPLAY switch is set to the 0.125H/cm line selector or 0.25H/cm line selector position. Also, the LINE SELECTOR control can be set so the portion of the vertical-blanking pulse which may contain vertical-interval test signals can be examined in detail. The 0.25H/cm line selector position, in particular, is useful for observing $\sin^2$ pulses.

The range of the LINE SELECTOR control is such that any portion of field 1 or field 2 can be examined. Either field 1 or field 2 is selected by means of the FIELD switch. A special bright-up circuit in the Type 529 increases the crt writing rate in either of the two line selector positions.

The graticule lines noted in Fig. 12-6C are used to measure the $\sin^2$-window signal. The K-factor evaluation is a simultaneous measurement of three characteristics, as follows:

1. K-factor of pulse measures high-frequency characteristic.
2. K-factor of bar (window) measures low-frequency characteristic.
3. K-factor of pulse-to-bar ratio measures midfrequency characteristic.

The outer limits in each case are marked with solid lines and designate a K-factor of 4 percent. The inner limits for each case are marked with dash lines which indicate a K-factor of 2 percent.

Although the graticule specifies a 2-percent and 4-percent K-factor for a 0.125-μs T-pulse, the same graticule is used for the 2T pulse by selecting the appropriate time base on the Type 529 monitor. A time base of 0.125H/cm ×25 is used for the T pulse, whereas the 0.25H/cm ×25 time base is used for the 2T pulse. The 2T pulse (0.250-μs half-amplitude duration) is normally used for video-tape systems measurements. Fig. 12-7 illustrates the reproduction of the 2T-window test signal of the high-band test tape mentioned in Chapter 11. For proper measurement, the $\sin^2$ pulse should be adjusted by scope gain to reach the top of the bar signal (100-percent reference amplitude) as shown. The pulse should then fit well within the 2-percent K-factor lines (dash lines) on a properly functioning high-band tape system.

Fig. 12-7. Waveform-monitor display during playback of 2T-pulse, high-band standard.

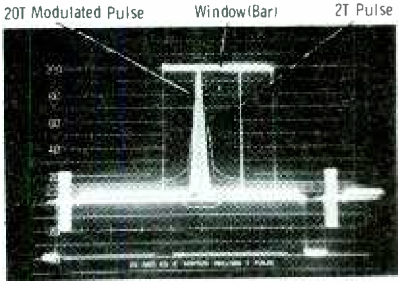
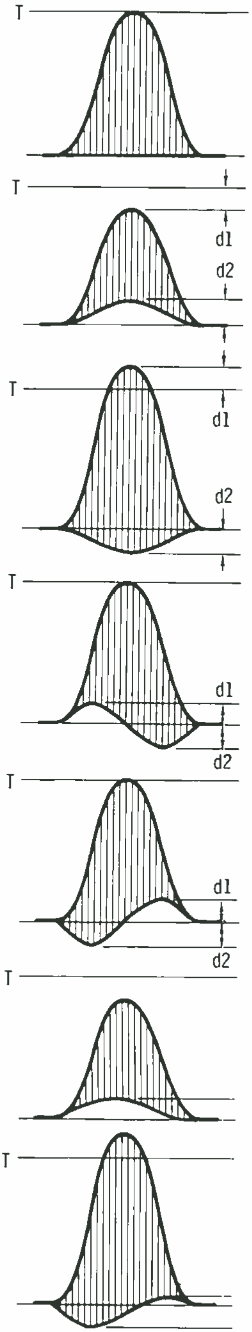


Fig. 12-8. Playback of 2T-pulse, 20T-pulse, and window signal from high-band test tape.

Fig. 12-8 shows the reproduction (playback) of the 2T pulse, 20T modulated pulse, and window signal of the high-band test tape described in Chapter 11. A somewhat expanded time base was used here to make the reproduction of the 20T modulated pulse more apparent. The T and 2T pulse graticule does not measure the 20T modulated pulse by K-factor lines. In general, the reproduction of a properly operating high-band tape system should have response to a 20T modulated pulse within 2 percent of the undistorted waveform of Fig. 12-9A. (In Fig. 12-9, T indicates the top of the window signal.)

Pure linear amplitude distortion is shown by Figs. 12-9B and 12-9C, and pure delay distortion is shown in Figs. 12-9D (3.58-MHz component delayed) and 12-9E (3.58-MHz component leading). Note that in all four



(A) Undistorted modulated 20T-pulse.

(B) Decreasing amplitude with increasing frequency.

(C) Increasing amplitude with increasing frequency.

(D) Increase in group delay with increasing frequency.

(E) Decrease in group delay with increasing frequency.

(F) Simultaneous amplitude decrease and increase in group delay at 3.58 MHz.

(G) Simultaneous amplitude increase and decrease in group delay at 3.58 MHz.

Fig. 12-9. Typical distortions of modulated 20T-pulse.

waveform distortions, d1 = d2. However, when both amplitude and delay inequalities occur simultaneously, the resulting baseline distortion is not a linear addition of the two components, as shown by Figs. 12-9F and 12-9G.

Techniques for rf and video sweeping are thoroughly outlined elsewhere.[2] In tracking down amplitude-vs-frequency troubles or transient-response problems in the modern tape system, the techniques are the same, but the equipment required is different. As described previously, the fm portion of a high-band recording system requires a sweep width to at least 30 MHz as compared to the more conventional 10 MHz used for normal video sweeping procedures. In addition, all modern tape-system fm and filtering circuitry has factory-adjusted components that are sealed after alignment. Unless proper equipment is available, the field service department of the tape-system manufacturer should be contacted for rf-video alignment adjustments after necessary replacements of critical components. Playback of the test tape, followed by recording and playback of appropriate test signals as previously outlined, will reveal whether such alignment is necessary.

For differential-gain and differential-phase measurements, either the stairstep with a superimposed 3.58-MHz signal is used (as in Fig. 12-6A), or the sawtooth with 3.58-MHz signal (Fig. 12-10A) is employed. Fig.

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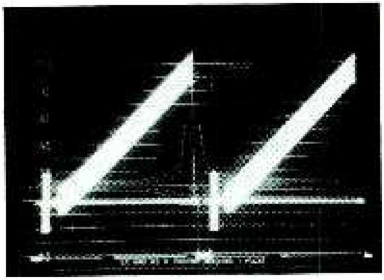
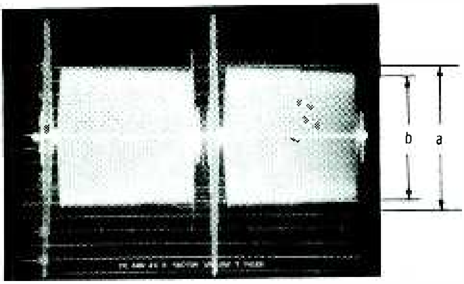
[2] Harold E. Ennes, *Television Broadcasting: Systems Maintenance* (Indianapolis: Howard W. Sams & Co., Inc., 1972).



(A) Without high-pass filter.



(B) Through high-pass filter.

Fig. 12-10. Playback of sawtooth portion of high-band test tape.

12-10A shows the crt presentation for playback of the high-band test tape mentioned in Chapter 11. Fig. 12-10B shows the same presentation with the Type 529 monitor placed in the high-pass position, with additional gain used to bring the maximum portion of the envelope to 100 IEEE units. Thus if a = 100 and b = 95, there is 5 percent differential gain at 3.58 MHz, white compression.

> IMPORTANT NOTE: A rather complete study of differential gain and differential phase at 3.58 MHz, as well as techniques for using the vectorscope for differential-phase measurements, was presented in Chapter 8 of *Television Broadcasting: Systems Maintenance.*[3] Techniques and interpretations are identical for the television tape system. Tests should be run at 10-, 50-, and 90-percent APL for both differential gain and differential phase, as fully covered in the above-mentioned reference. In video tape systems, differential gain and phase can be caused by the head or head-resonance adjustments. In the Ampex AVR-1 system, differential gain controls are included in the playback amplifiers.

An example of a handy form to be used for differential-gain and differential-phase measurements is presented in Fig. 12-11. In this example, three record/reproducers are included in the complete system. The test signals are first recorded on machine A, and then played back on all three machines. The performance is recorded on the form. This process is repeated for all three machines. This technique gives the maintenance technician a good indication of performance of each system, as well as verification of having all machines adjusted to a "standard" of operation.

Record On	Playback On	$\Delta G\%$			$\Delta\theta^0$		
		APL			APL		
		10%	50%	90%	10%	50%	90%
A	A						
	B						
	C						
B	A						
	B						
	C						
C	A						
	B						
	C						

Fig. 12-11. Example of form for differential gain and phase measurements.

Signal-to-Noise Ratio

One video measurement now remains: the video signal-to-noise ratio. Measurement of recording-playback signal-to-noise (S/N) ratio is a good indicator of the need for a complete run-through on tube replacements (on older tube-type systems, or in modern record-playback amplifiers using

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[3] Ennes, *loc. cit.*

tubes), amplifier gains, input source and output lines, and demodulator limiting circuitry. Some modern systems still employ vacuum tubes in the record function as head drivers, and in the playback function as the first preamplifier stages where nuvistors may be employed. All other circuitry is normally solid-state.

Three generally satisfactory methods of measuring video-tape S/N ratio will be described: (1) the oscilloscope method, (2) the vtvm method, and (3) the Rohde & Schwarz UPSF video noise meter method. Method 1 is less time consuming and most convenient, but less accurate than methods 2 and 3. Method 3 is the most accurate and is now being used by the equipment manufacturers for factory tests.

The Oscilloscope Method—The tape used should not be completely new and unpolished, nor old and worn or scratched; a tape should be used that is in the condition employed for normal satisfactory recording and playback in the daily schedule. The heads should be optimized, the demodulator properly balanced, and critical (optimum) tracking adjustments made. To make the readings significant, the signal-to-noise ratio should be determined on a peak-to-peak video to rms noise basis.

A. The test signal can be a "doorstep" (three steps: one at black, one at gray or midway between the black and white peaks, and one at reference white level) or the standard stairstep signal described before. Many prefer the "one-line-in-six" stairstep signal (Fig. 12-12A) adjusted for a 50-percent duty cycle. This signal provides a convenient method of swinging the modulation over the reference frequencies to provide the reference level, while simultaneously providing for a gray-step measuring point.
B. With the system optimized for recording, make about 5 minutes of recording of the test signal.
C. With the system optimized for playback, connect an oscilloscope at the demodulator output, and observe the playback of the preceding test signal.
D. Fig. 12-12B illustrates a typical playback of the test signal of Fig. 12-12A. Note the additional thickness of the gray step. Adjust the video output level to obtain the standard 0.714 volt (p-p) of video.

NOTE: Measurements of S/N ratio are made at any point *ahead* of the ATC and processing amplifiers, to avoid false readings from regenerated sync and spurious signals from any random ATC operation.

E. Expand the vertical deflection by using maximum scope gain. Read the peak-to-peak excursion of the noise (at the 50-percent steps) with the scope on wideband (10-MHz) response, if the Tektronix Type 524 scope is used. Assume for the moment that the measured peak-to-peak value is 100 millivolts (0.1 volt).

F. To convert the 100 millivolts from peak-to-peak to rms value, multiply by 0.35:

$$100 \times 0.35 = 35 \text{ millivolts}$$
$$= 0.035 \text{ volt}$$

G. The voltage ratio is now 0.714/0.035, or 20.4. The dB equivalent for a voltage ratio of 20.4 is 26. This is on a peak-to-peak video to rms noise basis.

H. To convert the 10-MHz bandwidth reading to a 4-MHz bandwidth, which is the useful passband of the video information, add 7 dB to the above computation:

$$26 \text{ dB} + 7 \text{ dB} = 33 \text{ dB}$$

If a 4-MHz scope amplifier or preamplifier is used, delete Step H. The bandwidth is given in terms of the 3-dB-down point. Note also that from the analysis, 100 millivolts of noise is approaching the maximum allowable to meet specifications for a 35-dB signal-to-noise ratio. Thus, the 100-millivolt (p-p) noise level becomes the warning flag on older low-band systems. Newer systems achieve an S/N ratio of 40 to 46 dB. Also, when later Tektronix scopes, such as the Type 547 (50-MHz bandwidth), are employed, the correction factor becomes 12 dB rather than 7 dB.

Due to the limitations in accuracy of reading the noise peaks on the oscilloscope trace, the preceding method is subject to a variable error, depending entirely on the operator's care and his familiarity with his particular scope-amplifier characteristics. The result under optimum conditions should be within a few dB of the actual signal-to-noise ratio.

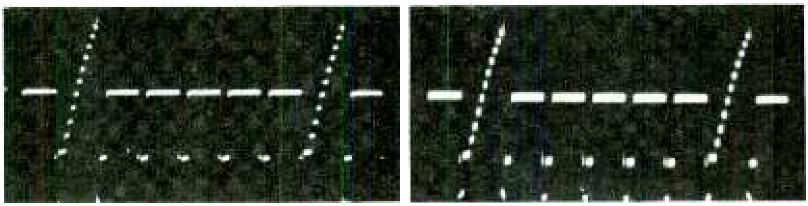
The VTVM Method, Older (Low-Band) Systems—The vtvm method described here is more accurate than the scope method and is limited only by the accuracy of the instrument used.

(A) The equipment required includes a bandpass filter (Fig. 12-13 or equivalent) and a 4-MHz vtvm, such as the Hewlett-Packard Model 400D or 400H, the Balantine 314, or equivalent.

(B) Adjust the detector balance control on the demodulator for maximum rejection of carrier 10-MHz ripple, with the modulator carrier frequency set to 5 MHz and the deviation set at zero (modulator input level control completely counterclockwise). Then raise the input level control for Step C.

(C) With a standard window or stairstep signal applied to the input of the modulator, set the carrier frequency and deviation in accordance with the proposed SMPTE recommended practice, i.e., 5-MHz carrier frequency corresponds to blanking level and 6.8 MHz corresponds to peak white (low-band).

(D) Record a two-minute section of window or stairstep signal, and rewind the tape to the beginning of the recorded section.



(A) Input to tape recorder. *(B) Demodulator output.*

(C) Expanded portion of 50% point.

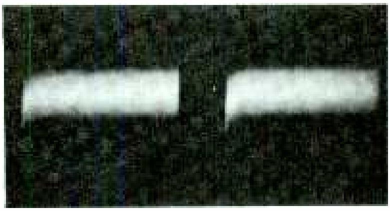


Fig. 12-12. One-in-six stairstep signal, 50% duty cycle.

(E) Place the machine in the reproduce mode and adjust the video output level control on the demodulator for an output level of 0.7 volt peak-to-peak video, not including sync.

(F) Remove the video input cable from the input to the modulator in order to disable clamping. Set the carrier frequency control for a carrier frequency of 6.0 MHz, corresponding to a medium shade of gray.

(G) Record a two-minute section of undeviated 6.0-MHz carrier and rewind the tape to the beginning of this recording.

(H) Remove the video cable from the demodulator output, and connect the special bandpass filter to the output of the demodulator. Connect the output of the filter to an rms-measuring vtvm.

(I) Place the machine in the reproduce mode; set the scope-selector switch on the left-hand control panel to the switcher output position, and adjust the tracking control for maximum amplitude of the scope presentation.

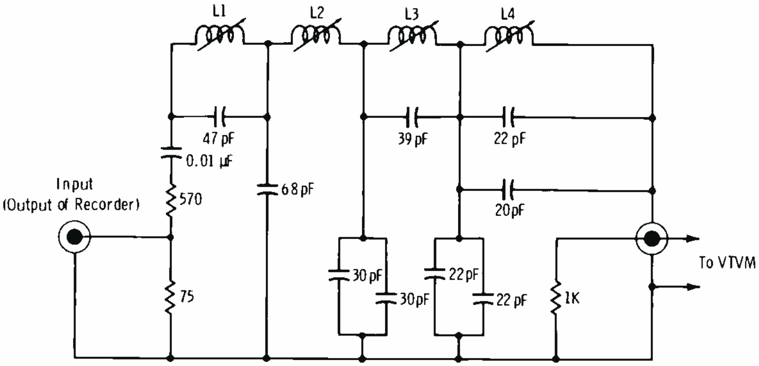
(J) Read the value of rms noise on the vtvm, and compare this figure to the 0.7-volt (p-p) level. Remember to take into account the measured insertion loss of the filter (approximately 5 dB for the filter shown in Fig. 12-13). Twenty times the log of this ratio is defined as the video signal-to-noise ratio of the television recorder.

NOTE: Later systems (high-band and low-band) employ built-in facilities as described following the discussion of the noise-meter method.

Video Noise Meter Type UPSF—A block diagram of the Rohde & Schwarz type UPSF video noise meter is shown in Fig. 12-14. This instrument serves to measure unweighted and weighted noise voltages in tv transmission systems. It is particularly suitable for measurements in the region between the black and white levels of the video signal range, even in the presence of line or field blanking intervals with or without sync pulses. For this reason, the noise meter features horizontal or horizontal plus vertical-interval blanking. Thus the test signal is cleared of the sync and blanking pulses and, during the blanking interval, brought to the mean value of the amplitude in the video signal range (Fig. 12-15). The loss of noise energy during the blanking period is taken into account when calibrating the indication.

This noise meter was designed to satisfy the relevant CCIR recommendations, Geneva, 1963 (Rec. 421.3.3), concerning noise-voltage measurements in tv transmission systems. A low-pass filter built to CCIR recommendations (Rec. 421 Annex II) prevents noise voltages exceeding the upper frequency limit of the transmission system from being measured. A continuous-random-noise weighting network built in conformity with CCIR specifications (Rec. 421 Annex III) simulates the sensitivity characteristic of the eye to noise voltages.

The video noise meter is suitable for measuring noise voltages of equipment such as tv cameras, film scanners, and video tape recorders, and for noise-voltage measurements on radio links, coaxial lines, tv transmitters, tv receivers, and tv translators. In the case of noise-voltage measurements



(*A*) *Circuit.*

Northill Coils			Crest (Microtran) Coils	
Coil	Part No.	Value in µH	Part No.	Value in µH
L1	1000-F	14.5-22	200-3	6.6-20
L2	1000-I	55-110	200-5	33-110
L3	1000-H	29-55	200-4	16-55
L4	1000-F	14.5-22	200-3	6.6-20

(*B*) *Coil values.*

Frequency	Relative Attenuation (dB)
< 100 Hz	45
< 10k Hz	6
10 kHz-4 MHz	0
4.2 MHz	6
4.5 MHz	40

(*C*) *Characteristics.*

Fig. 12-13. Bandpass filter (based on data originally supplied by Ampex).

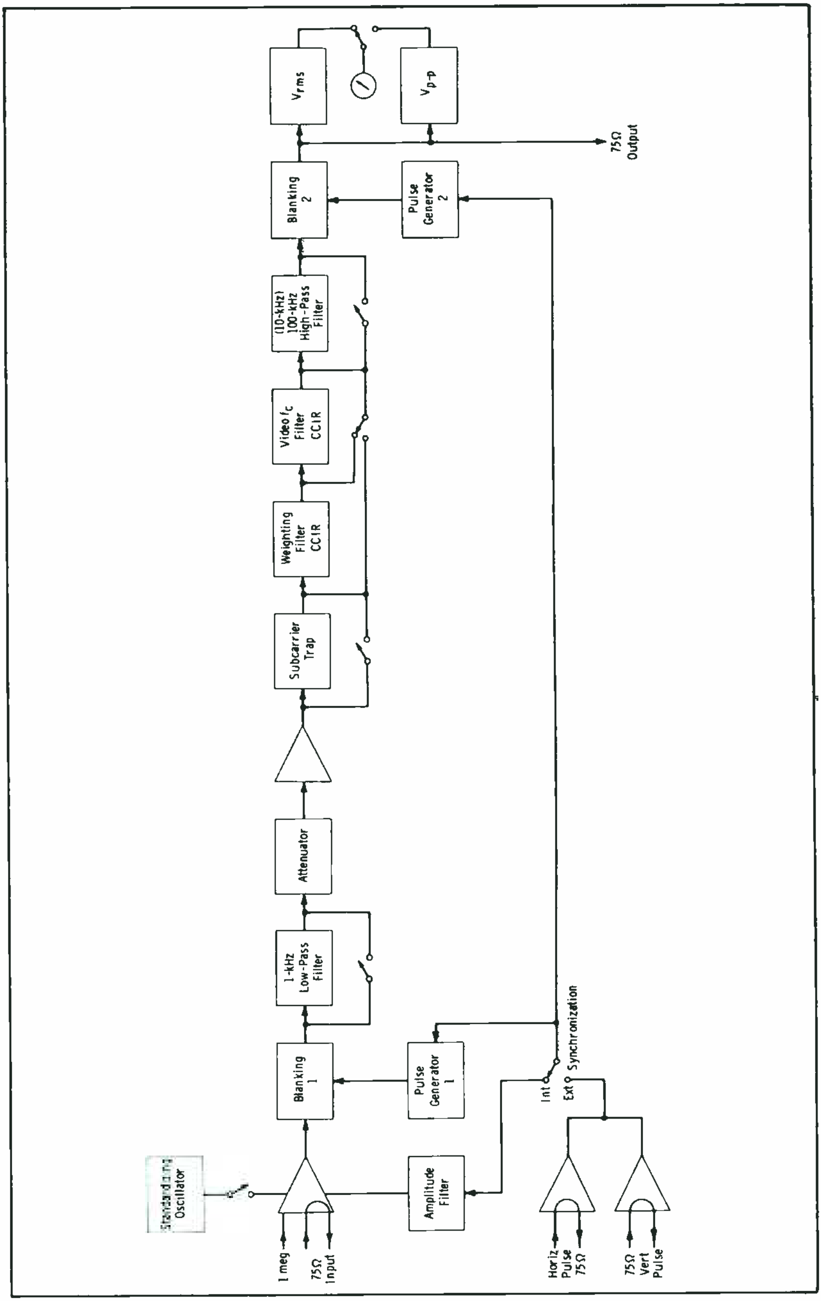


Fig. 12-14. Block diagram of video noise meter Type UPSF.

on color tv systems, a trap tuned to the frequency of the chrominance subcarrier prevents the measurement of any residual components of the subcarrier. Apart from the rms-value indication recommended by the CCIR, the video noise meter also gives peak-to-peak value indication capable of responding to noise peaks even of short duration.

The noise signal, cleared of sync pulses and blanking intervals, is available at a socket for the connection of an oscilloscope, so that a quasi-peak-to-peak amplitude display can be obtained.

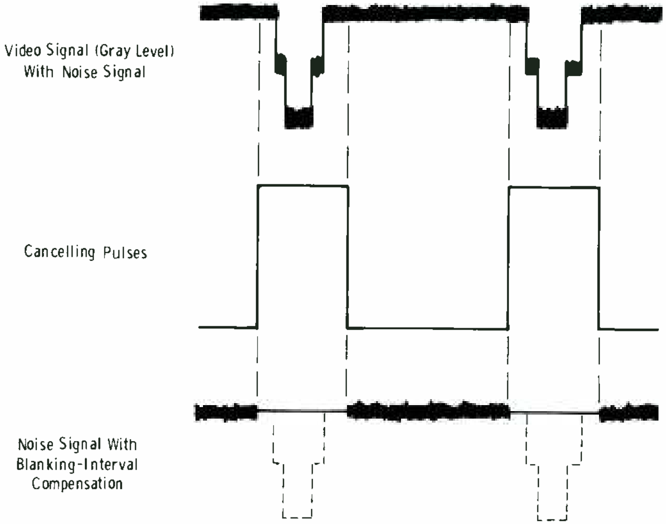


Fig. 12-15. Principle of noise-voltage measurement with horizontal or vertical-interval blanking.

The measurement and frequency ranges and the possibility of switching over to different inputs and outputs as well as to internal or external synchronization make the instrument suitable for a number of applications. Thus the cost of using the instrument for video-tape systems can be justified by its other uses and applications at the studio and transmitter.

As mentioned previously, the Ampex VR-2000B and RCA TR-70 systems employ built-in facilities for checking the S/N ratio. These specific applications follow.

Ampex VR-2000B S/N Ratio Measurement—Each VR-2000B system is factory adjusted to assure that it operates well within the performance specifications. These specifications include an E-E signal-to-noise ratio of 60 dB or better and a playback signal-to-noise ratio that is specified for each recording standard in Table 12-2. Because measurement of system signal-to-noise ratio is occasionally a matter of considerable interest, a facility for this measurement has been provided. The procedure which follows explains the use of this facility.

Table 12-2. Ampex VR-2000B Video Signal/Noise Specifications

Standard	Minimum Signal/Noise Ratio[1]
Low-Band Color	40 dB
High-Band Color	46 dB

[1] Ratio of p-p noncomposite video to rms noise; noise measured at midgray level using wide-band true-rms voltmeter through 5.8-MHz low-pass filter; standard tip engagement.

(A) Set the AFC/CLAMP switch at one of the gray-level positions (i.e., position 3 or 4). Turn the VIDEO INPUT LEVEL switch to the off position. Set the SERVO MODE selector to the Preset or the Line Lock position. Thread a blank tape on the tape transport.

(B) Initiate the record mode, and record the gray-level frequency for 2 or 3 minutes; then press the STOP push button.

(C) Turn the TRANS SUPP switch (on the setup control panel) to the CW setting. Connect the video-signal system output through a 5.8-MHz low-pass filter to an rms-indicating meter. The rms meter will indicate the E-E signal-to-noise ratio, which should be 60 dB or better. Reproduce the recording made in step B. The rms meter will now indicate the rms noise content of the reproduced signal. The meter indication may then be compared with the 0.7-volt (or 0.714-volt, depending on the recording standard) normal level of the video portion of the composite signal, to determine the S/N ratio.

NOTE: The CW setting of the TRANS SUPP switch causes the transient suppressor to produce transient-suppression pulses that overlap the interval during which the rf switch is transferring the pickup to successive video heads. Necessarily, these pulses occur at the horizontal rate as a function of the phase of the head drum. Thus, this facility eliminates head-switching transients which would otherwise greatly increase the rms noise indication and produce an erroneous measurement of signal-system noise.

There are inevitably many potential generators of noise in a complex electronic system. (Amplifiers and random thermal effects are examples of noise generators.) In the VR-2000B system, generated noise is excluded from the video-signal system because its input is not connected to the output of the video heads until they have engaged the tape. At all other times, the video-signal system receives incoming video from the output of the modulator. This exclusion of generated noise eliminates the time that would otherwise be required for the video electronics to first recover from a noise condition when the play mode is entered. Thus there is no normal condition in the VR-2000B system under which noise is passing through the video signal path.

(D) Press the STOP push button.

RCA TR-70 S/N Ratio Measurement—The video signal-to-noise ratio is defined as the peak-to-peak video voltage divided by the rms noise voltage. (Video here does not include sync. The noise is *random noise only* and is not meant to include other undesired components such as switching transients, cross talk, moiré, tape scratches, or similar items.)

The machine is first set up to record and play normally, with particular attention on fm deviation and output video level. The normal level of the video portion of the signal is 0.714 volt peak-to-peak for a one-volt composite output (100 IEEE units of video and 40 IEEE units of sync). This 0.714 volt is used as the video signal level for S/N calculations. The machine output is adjusted to give exactly this level as measured on an oscilloscope.

To read the noise level separate from the video, a test recording is made in the noise test mode, thus giving a recording of unmodulated fm carrier. The machine is then played back using the noise test mode, and the demodulated noise output of the machine is measured with a meter. The ratio of 0.714 to the noise reading gives the numerical signal-to-noise ratio. For example, a noise reading of 0.00714 volt would give an S/N ratio of 100 times (40 dB).

The test recording for the noise measurement is made with the fm carrier at a frequency corresponding to picture gray level. The noise measurement is made at a point in the system just ahead of the ATC and processing amplifier. This is done to avoid false readings due to regenerated sync and spurious signals due to random ATC operation.

In order to obtain a representative measurement of the video S/N ratio, the operating conditions must be carefully controlled. The tape must be a high-performance type and in good condition. The meter and oscilloscope must be carefully calibrated. The meter must be a true rms-reading meter such as the Hewlett-Packard 3400A. Capstan tracking must be carefully adjusted, and the guide position must be carefully set to minimize switching transients. Another factor to consider is the condition of the heads. The S/N ratio improves as the heads wear and the pole-tip protrusion decreases. Of course, when the heads wear out, the S/N ratio rapidly gets worse.

If a Hewlett-Packard 3400A meter is not available, an approximate measurement can be made with a Hewlett-Packard 400D meter if 2 dB is added to the *noise* reading (subtract 2 dB from the S/N ratio). If no meter is available, an approximate reading can be made by using the oscilloscope to measure the noise. In this case, peak-to-peak noise should be measured. It has been found experimentally that, under these conditions, a suitable conversion factor is 12 dB. Thus, divide 0.714 by the peak-to-peak noise as seen on the oscilloscope. Express this ratio in decibels and add 12. The noise reading should not include extreme noise peaks.

Proceed as follows to perform signal-to-noise measurements on the RCA TR-70 system:

1. Set up the machine normally, using a multiburst or color-bar signal, a good headwheel panel, and good, high-performance tape.
2. Be sure that the following procedures have been carefully followed:
   (a) Deviation adjustment
   (b) Record-current optimization
   (c) Guide adjustment on test tape
   (d) Playback equalization
   (e) Demodulator balance (performed on low-band monochrome standard, then switch back to desired standard)
3. Switch the RECORD REF control on the reference generator module to House Sync and the selector switch on the tape sync processor module to TW.
4. Switch the guide servo module to manual.
5. Remove the MATC video module, and insert the signal module.
6. Connect the meter to pin 17 of the signal module using 75-ohm cable with a termination at the meter.
7. In the E-E mode, measure the blanking-to-white video level at the meter termination using a carefully calibrated oscilloscope. This level should be 0.714 volt peak-to-peak. Adjust the VID GAIN control on the postemphasis module for exactly 0.714 volt peak-to-peak using the oscilloscope.
8. From this point on, do not change the adjustment of the VID GAIN control.
9. Make a one-minute recording of the multiburst or color-bar signal. After one minute, let the machine continue recording. Set the TEST SELECT switch on the fm test panel to Noise, and press the RECORD switch and then the TEST switch.
10. Continue with this noise-test (gray-level) recording for two minutes.
11. Rewind and play the multiburst or color-bar recording.
12. Adjust the guide position and tracking carefully.
13. Check the playback equalization, and adjust if needed.
14. When the noise-test recording (gray level) comes up, switch the meter to the −40-dB scale and read the noise.
15. Observe the demodulator on the monitor, and carefully adjust the guide for minimum switching transients. Raise the monitor contrast to make the transients plainly visible.
16. Observe the fm level on the cro, and adjust the tracking for maximum output.
17. Make further fine tracking and guide adjustments to minimize the noise.
18. Use the minimum noise reading, but do not count occasional dips which may be due to the meter time constant.

NOTE: For convenience in reading signal-to-noise ratio in decibels, note that on many Hewlett-Packard meters 0.0071 volt is nearly in line with −41 dB. On these meters, the S/N ratio can be read directly by subtracting *one*. Thus −41 = −40 dB.

19. If the specified S/N ratio (same as in Table 12-2) is not obtained, perform the following steps to effect an improvement:
    - (a) Use another tape.
    - (b) Degauss the heads.
    - (c) Reoptimize the head currents.
    - (d) Observe the noise with an oscilloscope, and check for the presence of hum, interference, oscillations, etc. The noise should be random.
    - (e) Look at the E-E noise with the meter. To do this, use the same procedure as for record-playback noise, but with the machine in the stop and E-E modes, set the TEST SELECT switch on Noise, and press the TEST switch. The E-E S/N ratio should be from −55 to −60 dB.
    - (f) Use another headwheel panel.
    - (g) Change the nuvistors in the head preamplifier (playback) and compare the S/N-ratio measurements.

Recording and Playback of Nonsynchronous Signals

Certain troubleshooting procedures require the use of nonsynchronous signals which are recorded and played back as necessary. These nonsynchronous signals may consist of sweep, cw sine waves, or square-wave signals not containing sync or blanking information.

Recording Procedure—To record nonsynchronous signals, proceed as follows:

1. Check the level indication on the cro, and set the input level at its source to provide an indication of 0.7 volt (100 IEEE units). This is the correct input level for recording.
2. Set the TEST SELECT switch on the fm test panel to the Input position.
3. Press the MASTER RECORD switch on the record panel; then press the TEST switch on the fm test panel.

Playback Procedure—To play back nonsynchronous signals, proceed as follows:

1. Set the TEST SELECT switch on the fm test panel to the Input position.
2. Press the PLAY switch on the play control panel; then press the TEST switch on the fm test panel. The machine will now play back a nonsynchronous recording.

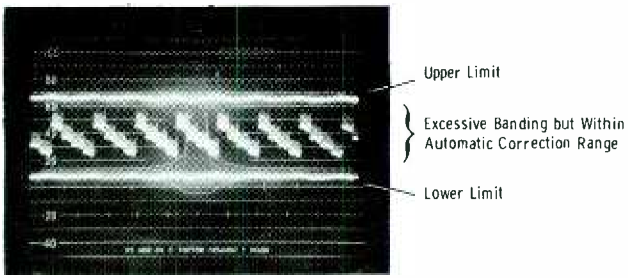
NOTE: The TEST switch on the fm test panel must be pressed after going into an operating mode, or the switching logic will inhibit the test function.

12-5. USE OF AUTOMATIC COLOR CIRCUITRY IN MAINTENANCE

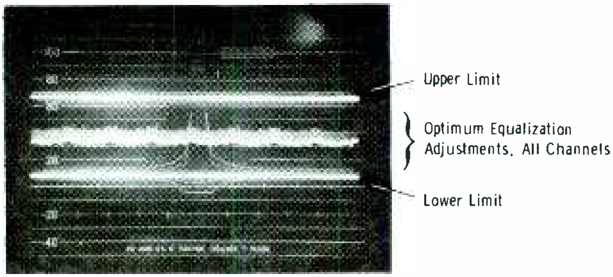
The experienced maintenance technician soon learns to employ information supplied by the Ampex Colortec and Velocity Error Corrector, or the RCA Cavec, in judging certain system functions. Velocity-error and chroma-error signals can be monitored for various defects in setup and alignment.

For example, see Fig. 12-16. On the RCA TR-70, when the cro CAC monitoring push button is depressed, the upper and lower limits of the automatic correction range are displayed as shown. Fig. 12-16A shows the pattern when the channel equalization controls are not matched (see Fig. 11-14A). Without automatic chroma correction, severe color banding would result. With CAC in the circuit, the amount of banding shown by Fig. 12-16A would still be within the automatic correction range, and no color banding would be apparent. Fig. 12-16B shows the display when the four channel playback amplifiers are properly equalized.

> NOTE: The display described above is also available on the Ampex AVR-1 when the CHROMA push button is pressed for the A-scope. Upper and lower limits are not displayed on the Ampex, but if the burst levels are correct, the burst-envelope display will be at the center line of the A-scope.



(*A*) *Equalization controls not matched.*



(*B*) *Playback amplifiers properly equalized.*

Fig. 12-16. CAC monitoring waveforms, TR-70 system.

Head-resonance compensation has been discussed previously. There is a further adjustment that is particularly important to color, especially if the Auto Chroma accessory is present in the Ampex VR-2000B system. This is an adjustment of the master equalizer and the individual channel playback equalizers to minimize color differential gain in all the channels, and to verify the settings of record levels and playback resonance compensators.

The front panel of the master equalizer (module 17 of the Ampex VR-2000) includes two controls. One is potentiometer R1, MASTER PB RESPONSE; the other is 5-position switch S1, TURNOVER FREQUENCY.

The procedure for the minimization of color differential gain makes use of a test signal that is standard in many color-equipped stations. It is a composite of a stairstep (or sawtooth) signal with subcarrier added. The stairstep (usually 10 steps) is the luminance portion of the signal, and it varies between the blanking and peak-white levels; the subcarrier frequency is nominally equal to the color-subcarrier frequency of the recording standard in use. For this test, the subcarrier should be adjusted to a peak-to-peak amplitude equal to the peak-to-peak burst level and to the peak-to-peak sync level (i.e., 40 IEEE units in the oscilloscope display).

Color-equipped Ampex VR-2000B systems include an etched board (mounted in the stability marker box) on which a subcarrier filter and subcarrier detector are built. The output of the detector is routed to the channel-B input of the waveform monitor. Thus, when channel B of the waveform monitor is in use, the display is the rectified subcarrier of the signal selected by the video monitor selectors (on the audio and video monitor selectors panel). If the Tektronix Model RM 529 waveform monitor is employed, the SYNC switch must be set at Ext in order to obtain a stable presentation. The procedure follows.

(A) To begin the procedure, record the standard test signal for several minutes, taking care to set the luminance deviation correctly.

(B) While reproducing the recording just made, examine the reproduced waveform. The output of the demodulator may be examined in the display of the waveform monitor by pressing the DEMOD output push button on the monitor switching panel. If all the compensators are correctly adjusted, and differential gain has been minimized, the display will be the normal rectified envelope of Fig. 12-17. (The normal noise shown is inherent in the record/reproduce process.) If the compensators are not set correctly, differential gain will be present, and the rectified envelope will slope in a direction and at an angle that is directly related to the accumulated adjustment error. The differential gain of the off-tape signal should be compared with that of the input signal by alternately pressing the DEMOD and INPUT push buttons (of the video monitor selectors).

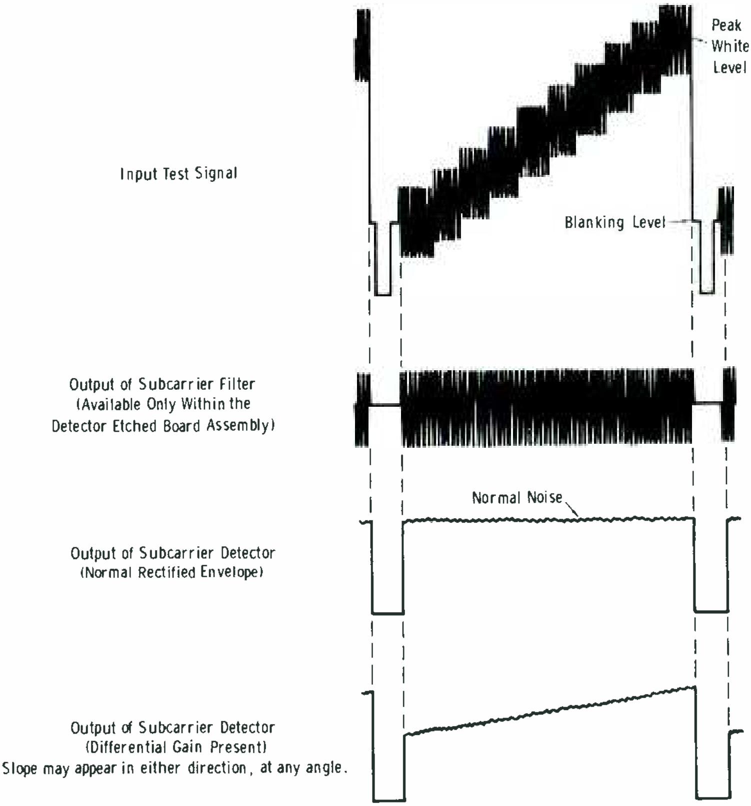


Fig. 12-17. Input test signal vs output of subcarrier filter and detector, Ampex VR-2000B system.

The controls that may require slight retuning to minimize differential gain include MASTER PB RESPONSE (on the master equalizer) and playback equalization controls CH1, CH2, CH3, and CH4 (on the operating control panel). The TURNOVER FREQUENCY switch (on the master equalizer) must be set at the optimum tap. Repeated tests on a series of VR-2000B systems have shown that for operation on 525-line high-band standards, typical settings are:

TURNOVER FREQUENCY: Position 3 or 4
MASTER PB RESPONSE: "9 O'clock"
CH1, CH2, CH3, and CH4: Between −3 and −4 on their scales.

Examination of the demodulator output may reveal that the outputs of the video heads exhibit significant differences between channels. For example, the output of one or more heads may exhibit a concave or convex differential gain curve, or a slope instead of a flat response. This is evidence that the FREQ COMP and Q COMP controls in these head channels require very slight retuning. The necessary retuning should not exceed a change of 0.2 on the FREQ COMP scale, or one numbered division on the Q COMP scale. If retuning within these narrow limits does not provide flat response in each channel, it is possible that the earlier adjustments using the sweep generator were not made correctly and must be repeated.

It is important to remember that differential gain must be at minimum at the time that the chroma level is correct. The operator will find that as the individual channel equalizers are turned clockwise or counterclockwise, the response line moves up or down and in so doing tends to tilt one way or the other. The correct adjustment will have been achieved when the rectified off-tape subcarrier waveform matches that of the E-E condition in both height and flatness. A good way to test for this is to momentarily depress and release the E-E push button (located under the system control panel), which will temporarily return the system to the E-E condition, permitting the comparison. To prove that the adjustments are correct, a multiburst signal should be recorded and then reproduced. If the reproduced signal exhibits flat frequency response and an absence of differential gain, the adjustments are correct.

If a difference in differential gain between head channels persists, the uniformity of the recording of individual channels should be checked as follows:

(A) Turn all but one of the channel equalizers fully clockwise; leave one at its normal setting.

(B) Set the TRACK SELECTOR at its Home position, and reproduce the differential-gain test signal recording. Note the degree of differential gain of the channel selected in step A.

(C) Repeat step B with the TRACK SELECTOR set successively at 2, 3, and 4. Determine whether or not a change of height or flatness occurs. If each of the heads has been properly optimized in recording, the differences observed will be negligible; if one of the recorded tracks appears to differ from the others, that recording channel should be reoptimized by the standard method previously described. Table 12-3 may be useful in determining which head made the recording of a specific track.

12-6. CHECKING SERVO STABILITY

The mark of a good servo system is immediate stabilization of the picture as the vacuum guide engages the tape with the rotating heads. Momentary instability immediately following this action is often caused by the velocity loop in the head servo because this loop must function rapidly to obtain control tight enough for the phase loop to take over. Aside from

Table 12-3. Identification of the Video Head That Recorded a Specific Track

Playback Channel Observed	Track Selector Setting			
	Home	2	3	4
1	1	4	2	3
2	2	3	1	4
3	3	1	4	2
4	4	2	3	1

"touchy" tubes (which usually can be located by light tapping with a pencil), the following points all have a bearing on general servo stability:

1. Check all tape-transport tension adjustments, cleanliness of the headwheel and capstan, and the control-track head.
2. Check the condition of the tape and the number of splices; the latter is particularly important if the video heads have been worn to 1 mil or less of tip projection.
3. Check the centering of adjustments; always be certain that frequency controls are placed in the center of the range at the limits of which frequency is lost. It is also good practice from a preventive-maintenance standpoint to ascertain the minimum and maximum pulse width obtainable from multivibrators. In this way, the time when proper pulse widths or a square wave cannot be obtained may be anticipated before trouble occurs (particularly in older tube-type equipment).

NOTE: In setting the free-running frequency of 240- or 60-Hz oscillators of the triggered type, use the power-line triggers on the scope, and adjust the oscillator for slight left-to-right drift on the scope trace. This sets the oscillator free-running frequency slightly lower than the trigger frequency (accounting for the slightly lower than 60-Hz field rate of color) so that trigger control is stable. If the free-running oscillator frequency is higher than the trigger frequency, unstable operation may result.

4. Become thoroughly familiar with the normal flow path of all control pulses so that the inputs and outputs of the various individual chassis or circuits can be quickly traced.
5. Check power supplies and power-supply regulation on a regular basis.
6. A closed-loop servo system has two major functions, loop gain (cannot exceed unity) and phase gain (cannot go to 180°). If operation does not remain within these limits, oscillation occurs. The load on

the headwheel or drum can be set on the heavy side by increasing tip penetration and then on the light side by decreasing tip penetration to the point of loss of tape contact, ignoring jogs in the picture. If a tip penetration is found where the worst possible stability occurs, set the servo loop gains and phase gains for optimum stability at this point. Return the tip penetration to standard. Stable operation should result throughout the life of this headwheel assembly, barring other troubles.

7. Other units may affect servo stability. Check demodulator (detector) balance, processing-amplifier stability (afc circuits), and stability of reference pulses relative to a source of known stability such as the local synchronizing generator.
8. Difficulty in servo lock-up upon initial start of the machine (in playback) can be caused by an automatic chroma corrector that greatly increases the chroma gain before lock-up is achieved. Logic circuitry is normally a part of such systems so that automatic correction locks out until stable playback is achieved. Always remove any automatic correction circuitry where possible to check for any effect on servo lock-up time.

12-7. UNDERSTANDING SERVO FUNCTIONS

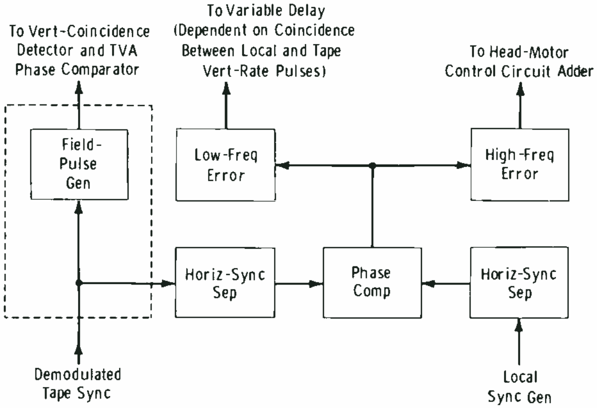
It is important to have a thorough understanding of basic servo functions. Let us review these requirements briefly as follows.

The low-band monochrome, nonsynchronous (head-tachometer pulse) mode of operation is a relatively "loose" head-motor servo. It is entirely satisfactory for monochrome operation when it is not necessary to mix other signals with the tape playback. But for color operation, even when it is not required to mix a local signal with the tape-playback output, time-base requirements include some form of "synchronous" operation.

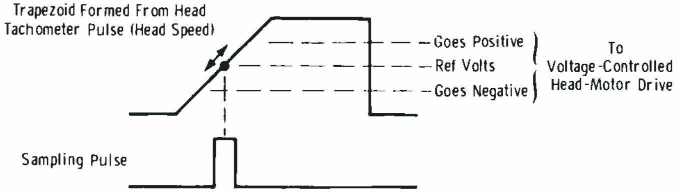
Essentially what we must do is "tighten up" the servos, as described in the following steps:

1. The field-rate playback signal must be made a standard color field rate of 59.94 Hz. Therefore, there must be a comparison between the field rate coming from the tape system and a standard field rate supplied by the local sync generator locked to a color standard. Any error between these two signals must be utilized to control the head (and capstan) servo.
2. The horizontal-rate playback signal must be made a standard color line rate of 15,734 Hz. Therefore, there must be a comparison between the horizontal rate coming from the tape system and a standard horizontal rate from the local sync generator locked to a color standard. Any error between these two signals must be utilized to control the head (and, in turn, the capstan) servo.

3. Now that the *servos* are being held to a basic color standard, the "dot interlace" of the color-subcarrier information must be maintained in spite of the tolerances of the mechanical head-to-tape contact. To do this, there must be a comparison between the color sync burst coming from the tape and the color subcarrier from the local color standard. This comparison occurs in the Color ATC section of the video control circuitry. This comparison enables circuitry which provides a "regenerated burst" which can then be phased for proper flesh-tone reproduction on the color monitor. If you keep the time-base concept, you realize this is the "tightest" servo and signal requirement for the tape system.



(*A*) *Added circuitry for full genlocked control.*



Sampling Pulse From:

RECORD MODE: Reference Vert From Stripped Sync of Video Signal Being Recorded

PLAYBACK MODE:

(1) NONSYNCHRONOUS: Reference Vert From Local Sync Gen or Power Line

(2) VERT ALIGN: Reference Vert From Comparison of Local Vert Rate to Demodulated-Signal Vert-Sync Rate
Note: This mode also involves control of capstan motor to "track" head playing vert sync to local vert sync.

(3) GENLOCKED: Same as (2) but Added "Time-Modulated" Vert Comparison to Horiz-Sync Errors
Note: This mode also involves additional error correction to head-motor control circuitry at horiz rate.

(*B*) *Pulses in record and playback modes.*

Fig. 12-18. Headwheel control.

Now go to Fig. 12-18A, which shows the basic added circuitry needed to obtain full genlocked operation of the tape system. The demodulated tape sync from the playback signal is phase-compared to local horizontal sync. The error signal is split into two components: a low-frequency (or phase) error which feeds the variable delay and a high-frequency (velocity) error which adds to the headwheel-motor control circuitry.

The system incorporates a number of lock-sense buses. For example, such a bus comes from the vertical-coincidence detector. When vertical lock is achieved, the fully synchronous mode can take over as shown by Fig. 12-18B. Such circuits normally energize relays which sequence the lock-up procedure.

Note that the primary signal for Fig. 12-18B is the head-tachometer pulse formed into a trapezoid. The sampling pulse changes through the required modes of operation as shown. Step 3 is the final step, and the tightest servo.

The simplest operation of the capstan servo occurs in the record mode. In this mode, the capstan motor is electronically synchronized to the frequency and phase of the head motor. In the playback mode, more recent tape systems have added circuitry for faster lock-up and tight control in synchronous operation.

Until the head motor is first locked up, the capstan must be driven aimlessly from either a free-running multivibrator or an integration of

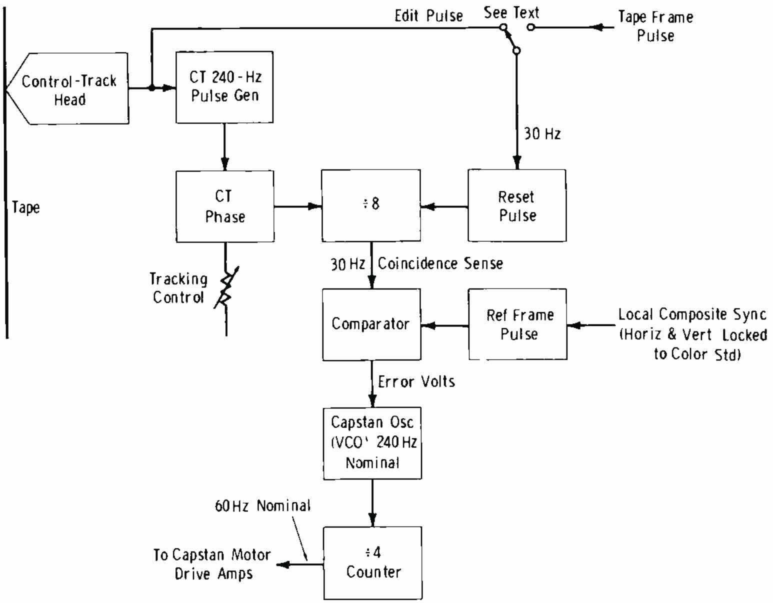


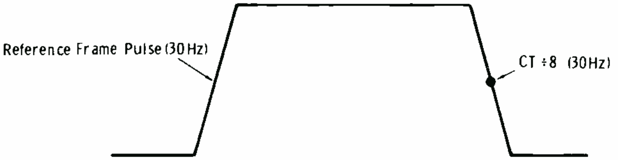
Fig. 12-19. Tightening capstan playback servo.

the speeding-up headwheel motor. But if the head-speed (tachometer) signal is removed from a requirement of initial capstan lock-up, this condition will not exist.

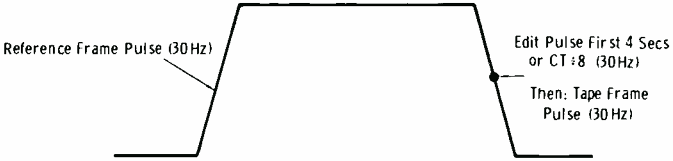
The vacuum tape guide does not engage the head with the tape until about 1½ to 2 seconds after machine start is initiated. But the tape *is* engaged with the control-track head (which is mounted on the vacuum guide) at all times. This signal is available immediately upon start of the machine.

Also available, even before start-up is initiated, is the reference frame pulse formed from local sync. This is always present at one side of a phase comparator, as illustrated basically in Fig. 12-19.

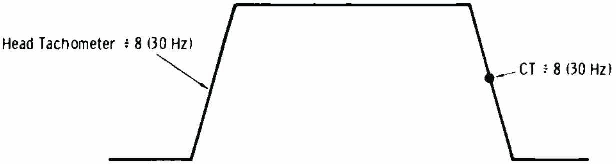
Consider the simplest mode of operation, the nonsynchronous playback (neither vertical nor horizontal lock-up with local sync). Now follow through slowly and carefully. You know that the tape frame pulse, since it is derived from the demodulated playback signal, cannot be immediately available. But the recorded edit pulse (if any) is available immediately. Again, if you are following carefully and using what you know about timing relationships, you know that the edit pulse has the same relationship (during initial recording) to the head vertical sync as the tape frame pulse would have. So if the edit pulses are available and usable, the system will lock up vertically as in Fig. 12-20B. But this is *not* a requirement for nonsynchronous operation.



(*A*) *Nonsynchronous mode of playback.*



(*B*) *Vertical-align playback and synchronous mode.*



(*C*) *Synchronous playback, vertical-align requirement dropped.*

Fig. 12-20. Capstan control for faster lock-up.

The point is that if no edit pulses are available or if they are degraded, the capstan can still lock up to the condition shown in Fig. 12-20A. In practice, the circuitry contains AND gates (coincidence gates), OR gates, and lock-sense buses to insert or remove reset-pulse gates.

The second step of lock-up is shown in Fig. 12-20B. The trapezoid is still derived from the ever-present reference frame pulse. The sampling pulse is that just described for nonsynchronous operation. (The system will already lock up vertically if edit pulses are present.)

After the head motor has been engaged by the vacuum guide, the *tape* frame pulse (demodulated from the video vertical interval) becomes available, and the synchronous mode of operation (as far as the capstan is concerned) exists. It is now the job of the capstan to keep the head playing back vertical sync coincident with local vertical sync. It will speed up or slow down according to the command of the error signals in order to maintain this tracking.

When framing (vertical alignment) is not required, the head servo drops the requirement for tva (tape vertical alignment), and the variable delay section is controlled only by the circuitry of Fig. 12-18A. Then the head motor, after a disturbance, locks immediately to the next horizontal line (although a noncorresponding sync pulse is used), and recovery is much faster than waiting for vertical framing.

At the same time, the capstan must now follow changes in head phasing (which occur after disturbances) to maintain the tracking set by the control-track phase-adjustment knob (tracking control). So now the capstan reference becomes that of Fig. 12-20C. The servos are being controlled by station sync, but you cannot count on being able to use special effects, etc., since proper phasing may not exist with other local sources. This is the Ampex horizontal mode, or the RCA Linelock mode.

12-8. CHECKING THE SAMPLE-AND-HOLD CIRCUITRY

It should be apparent at this point that the sampling servo is quite common in vtr systems, and the maintenance technician should become familiar with techniques for checking and servicing servos. Remember that even the Automatic Timing Correction (ATC) circuitry becomes a part of the overall servo system, and that this circuitry also involves the sample-and-hold technique.

Assume the picture is unstable, possibly tearing out, even in the nonsynchronous mode of operation. You might notice, by using the monitoring selector switch, that this is first occurring at the Amtec or the ATC output, while the demodulator output is satisfactory. Or, the condition might be such that the servos will not lock at all, and a stable picture is not available even at the demodulator output. Further assume that the system has selectable time-error correction in or out, and that you find that the picture stabilizes with ATC in the out (off) position. There are two possibilities: (1) the timing is incorrect, or (2) the trapezoid, sawtooth, or sampling pulse is missing or low in amplitude.

Fig. 12-21 is a representative circuit to illustrate the basic testing technique. This is applied specifically to ATC, but it will work with any of the sampling error circuits in the tape system. Use a dual-trace scope with one input at the Q1 collector (sample pulse) and the other input at the trapezoid connection to the center tap of T1. (A test point is normally provided at such connections.) Check first simply for the presence of both pulses. If one or the other is missing, check back through that particular path.

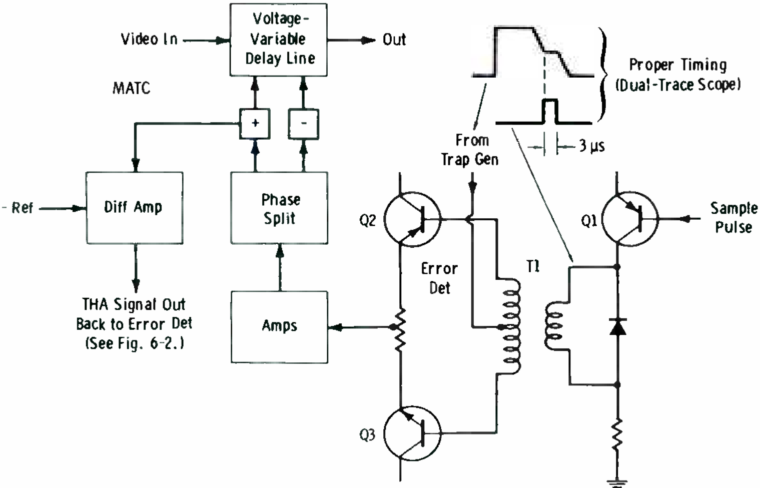


Fig. 12-21. How to distinguish between time error and amplitude error.

Proper timing is evident if the sample pulse occurs near the center of the trapezoidal slope. If proper timing is not obtained at this input to the error detector, the fault will be found in the horizontal-alignment differential amplifier. (This measures the phasing between sampling pulse and trapezoid to hold the variable delay line in the center of its range, using a dc reference voltage against which to measure.) If timing is correct up to the input of the error detector, you know the fault then lies in the error detector itself or in following amplifiers. You will be able to apply this type of troubleshooting technique to any pulse-sampling afc circuit, of which there are many in tape systems.

Some of the latest systems do not have ATC on or ATC off available on a switch. However, if it becomes evident that the ATC is malfunctioning, you can do without it in an emergency. For example, on the RCA TR-70, simply pulling the Cavec module out from its back connector will open the ATC error-correction circuitry. If Cavec is not used, the jumper on pins 28 and 29 of the back connector of the Cavec position may be removed to delete the ATC function. (Check your particular system for a similar way of removing ATC.) *Everything* (headwheel, guide servo, playback equalizers, etc.) must be adjusted perfectly for color operation, but a program can sometimes be saved by this emergency procedure.

Keep in mind the three fundamental headwheel (drum) servo functions and the basic ways to recognize their performance:

1. There is some form of voltage-controlled oscillator (vco) which works from the comparison (frequency discrimination) of the head tachometer with a fixed reference. This can be termed a time-constant control.

   If you place the picture monitor on external sync and play a tape in a nonsynchronous mode, you would adjust any time-constant control for minimum horizontal roll on the monitor. This is strictly a frequency control at the horizontal rate.
2. Velocity loop gain contains high-frequency positional errors. The gain should just be sufficient to get as fast a lock-up as possible, but not so "stiff" that there is instability on start-up, splice, etc. If the gain is too low, the response is "rubbery" after a transient.
3. Phase loop gain contains low-frequency errors for proper damping of the velocity loop. The headwheel (drum) has a natural tendency to "hunt" at between 10 and 30 Hz. At too low a gain, there will tend to be a low-frequency "oscillation" in the drum error servo outputs.

Servo adjustments are generally made with a condition of maximum load. This simply means that the guide is placed in about a 1-mil "heavy" penetration while such adjustments are made. Then normal penetration should result in tight control.

12-9. BASIC APPLICATIONS AND SERVICING OF LOGIC CIRCUITRY

Integrated circuitry and solid-state logic in general are fast replacing discrete components and more cumbersome (older) circuit philosophy. For example, the Ampex AVR-1 servo systems are 100-percent logic, the same as or similar to those described in Chapter 13. The latest cassette and cartridge video-tape systems (Chapter 13) contain many such advancements in video, fm, control, and servo functions. The principles of operation are identical to older ideas, but the results are obtained on a much faster and more stable time base. We will now illustrate an application of logic circuitry to a fast servo lock-up auxiliary development for the RCA TR-70 known as Fablock. Chapter 13 will explore further the applications to cassette and cartridge video-tape systems.

NOTE: It is imperative that the reader have a background in logic circuitry at least equivalent to that of Chapter 3 of *Television Broadcasting: Systems Maintenance* by Harold E. Ennes (Indianapolis: Howard W. Sams & Co., Inc., 1972).

The RCA Fablock

Fablock operates on two main areas of the machine, the take-up reel motor boost control circuit and the circuits that limit the capstan servo bandwidth (see Fig. 12-22). One of the main causes of slow lock-up is application of boost torque to the take-up reel for an unnecessarily long period. Fablock overcomes this by monitoring the frequency of the control-track playback signal and removing the boost as soon as the tape being played back reaches a speed corresponding to some predetermined control-track frequency (typically 210 Hz). To allow the tape to reach this speed as quickly as possible, Fablock causes the capstan motor to be driven at a constant rate, until the control-track signal exceeds the predetermined frequency, and then switches control of the capstan speed to the capstan-servo error circuits.

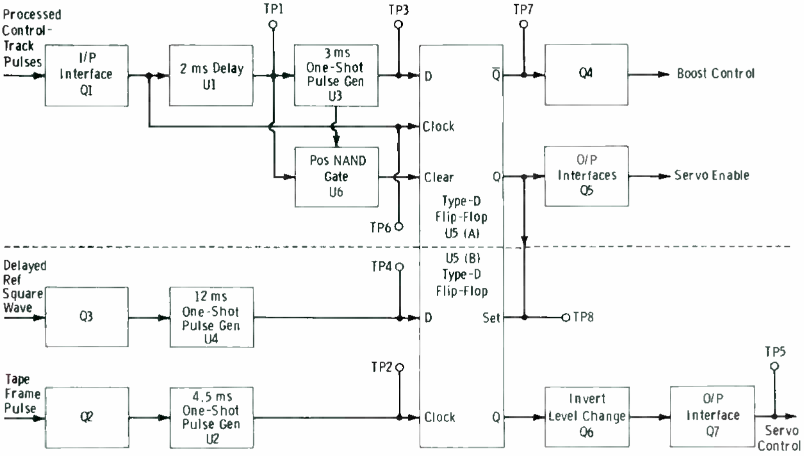


Fig. 12-22. Block diagram, Fablock main circuit board.

An additional cause of slow lock-up is the relatively narrow bandwidth normally used in the capstan servo. Because of the necessarily low sample rate of the capstan servo, this bandwidth must be kept narrow during normal operation to prevent hunting. Fablock, therefore, improves the speed of lock-up by introducing a new mode of capstan-servo operation referred to as the wideband pull-in mode. In this mode, the Fablock temporarily disconnects certain bandwidth-restricting components from the capstan-servo error amplifier circuits. As a result, if the capstan servo measures a large phase error during this period, the rephasing is carried out at a rapid rate.

Entrance into the wideband mode is controlled automatically by a circuit called the near-lock detector, which is enabled as soon as the control-track monitoring portion of the Fablock determines that the tape has come up to speed. This circuit compares each successive tape frame pulse with the corresponding delayed reference square wave and decides whether or not the timed edges of these signals are within a predetermined range (approximatly ±6 milliseconds) of coincidence. Approximate coincidence occurs only when the capstan servo is nearly locked, since the capstan-servo sample pulse is derived from the tape frame pulse and the capstan trapezoid is derived from the reference square wave (Fig. 12-20B.)

If the circuit determines that near-lock does not exist, it provides a control signal which places the capstan servo in the wideband mode until the next comparison is made. As soon as near-lock is detected, however, the circuit reinserts the bandwidth-restricting components, thereby allowing the capstan servo to function normally.

Action of the Fablock is not restricted to the initial lock-up period after entering the play mode. If an asynchronous switch occurs at any time during playback, the machine temporarily reverts to the wideband mode. During this period, the large capacitors in the bandwidth-determining circuits, which have been temporarily disconnected, retain a memory of the previously determined capstan error voltage. Therefore, when near-lock is achieved and these components are reinserted, the long-term memory voltage is added to the short-term error voltage already present in the servo error amplifiers. As a result, the capstan motor quickly reverts to normal speed without overshooting excessively.

The main Fablock board includes two circuits, the control-track presence and speed detector (portion shown above the dash line in Fig. 12-22) and the capstan servo near-lock detector.

Control-Track Detector In Fablock

The control-track detector (Figs. 12-22 and 12-23) includes inverter/interface amplifier Q1, monostable circuits U1 and U3, positive-logic NAND gate U6, Type-D flip-flop U5A, and control transistors Q4 and Q5. The input to the circuit consists of 10-volt negative-going control-track playback pulses (240/250 Hz) from the control-track record/play module of the machine. These pulses are differentiated and applied to interface inverter Q1. The output of Q1 is a positive-going pulse train going from the low logic level of −5 volts to the high logic level of 0 volts. These pulses are applied to the high-level actuated input (pin 5) of monostable U1.

The period of U1, which is determined by R7 and C3 (Fig. 12-23) is approximately 2 milliseconds. Whenever the input goes high, therefore, the Q output goes high and the $\overline{Q}$ output goes low for approximately 2

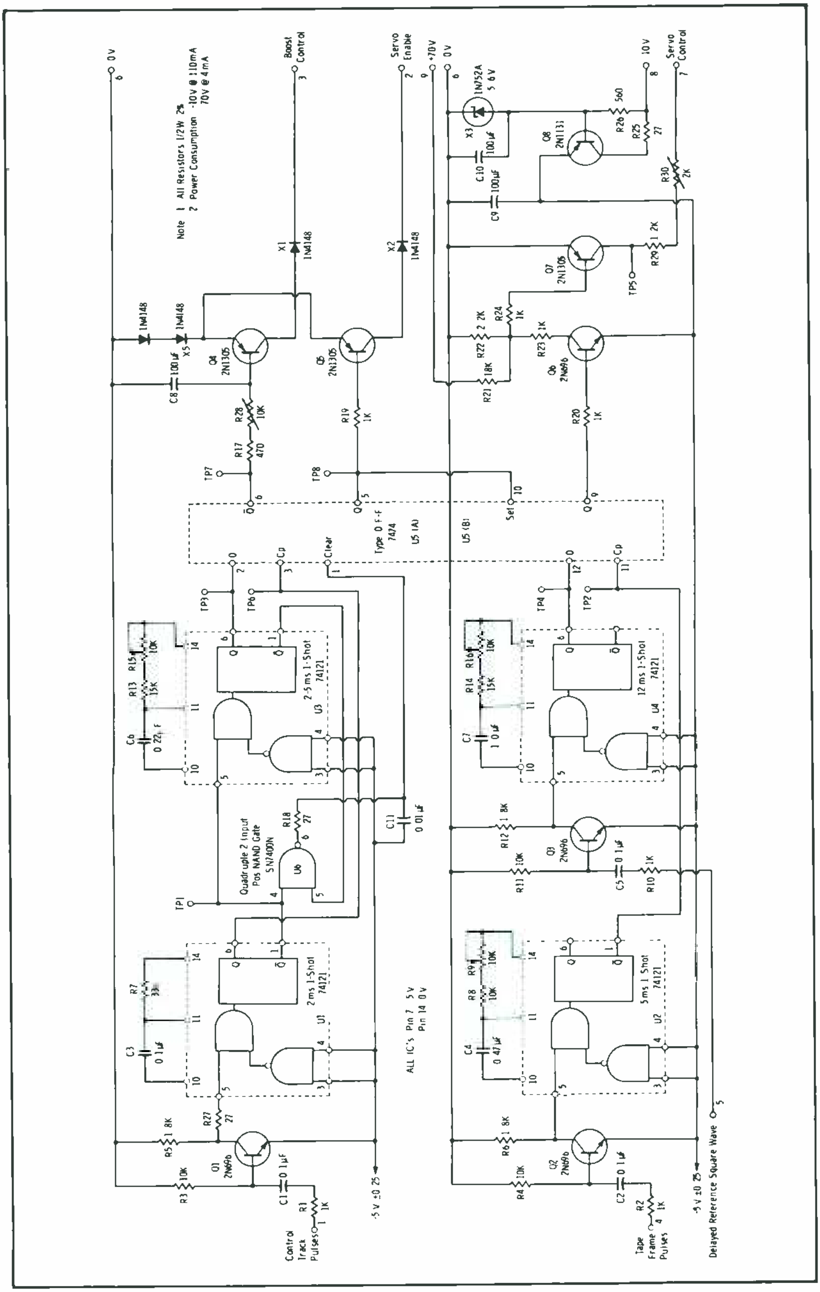


Fig. 12-23. Schematic diagram, Fablock main circuit board.

milliseconds. The $\overline{Q}$ output of U1 is connected to the high-level actuated input of monostable U3. As a result, U3 is triggered at the end of the period of U1.

Monostable U3 has an unstable period of approximately 3 milliseconds, which is adjustable by R15. The Q output of U3, therefore, which is connected to the D input of flip-flop U5, goes high approximately 2 milliseconds after each control-track pulse and returns to low 5 milliseconds (sum of periods of U1 and U3) after each control-track pulse.

The Q output of U1 is connected to the clock input of flip-flop U5. The clock input, therefore, goes high whenever U1 is triggered. If the period between control-track pulses is greater than 5 milliseconds (indicating that the frequency of the control-track signal is less than approximately 210 Hz), the D input of U5A will already have returned to the low level when each clock pulse occurs. As a result, U5A will be triggered into (or remain in) the reset state (Q output low and $\overline{Q}$ output high). If, however, the period of the control-track signal is less than 5 milliseconds (indicating that the frequency is greater than approximately 210 Hz), the D input of U5A will still be high when the clock pulse occurs. As a result, U5A will assume the set state. The exact control-track frequency at which the changeover occurs may be adjusted with R15.

In addition to the D and clock inputs, U5A is controlled by the level applied to the clear input from the junction of R18 and C11 in the output circuit of NAND gate U6. The input to this gate consists of the $\overline{Q}$ outputs of U1 and U3. When a control-track signal is present, these two outputs are high simultaneously only for a period of approximately 30 nanoseconds, which occurs while U1 is triggering U3. Since, however, R18 and C11 provide a delay of approximately 100 nanoseconds, the clear input of U5A never goes low, and the operation of the flip-flop is unaffected by the clear input.

If, however, a satisfactory control track is not present, the $\overline{Q}$ outputs remain high for longer than 100 nanoseconds. As a result, the clear input goes low, thereby placing U5A in the reset state.

The $\overline{Q}$ output of U5A is fed through a time-delay circuit consisting of fixed resistor R17, rheostat R28, and capacitor C8 to interface/inverter amplifier Q4. The Q output is fed to interface/inverter Q5 and to the set input of flip-flop U5B in the near-lock detector circuit. The output of Q4 (boost control) is fed to the take-up reel motor boost control circuit on the control (or driver control) module of the machine. The output of Q5 (servo enable) is fed to the splice control relay in the capstan error or capstan phase module.

When the machine is switched into the play mode, the Q output of U5A remains low and the $\overline{Q}$ output remains high until a control-track signal of the required frequency is present. Under these conditions, Q5 becomes saturated, thereby effectively grounding the servo enable bus. As a result, the capstan servo will be disabled in a manner similar to that in the record mode. The capstan motor will, therefore, rotate at the nominally correct speed at this time and will not be affected by the capstan-servo error. In addition, Q4 will remain cut off, thereby open-circuiting the boost control bus and allowing normal application of boost to the take-up reel motor.

The low level from the Q output of U5A is also applied to the set input of U5B in the near-lock detector (described later). As a result, U5B is held in the set state at this time, thereby disabling the near-lock detector.

As soon as the control track reaches the required speed, U5A becomes set, as previously described. The Q output therefore goes high and enables the near-lock detector. In addition, Q5 becomes cut off, thereby enabling the capstan servo.

The $\overline{Q}$ output of U5A also goes low at the same time, but Q4 still remains cut off for a delay period which is adjustable by R28. At the end of this delay, Q4 becomes saturated and disables the boost control circuit. The delay period is required because the slack tape, which is shared equally by the two tension arms on the transport at the instant of starting, is all collected at the arm nearer the take-up reel by the time the control-track detector registers the up-to-speed condition. Therefore, to prevent this arm from bottoming and actuating the tape-break switch, boost must still be applied for a short additional period.

Capstan Servo Near-Lock Detector In Fablock

The near-lock detector (Figs. 12-22 and 12-23) consists of inverter/interface amplifiers Q2 and Q3, one-shots U2 and U4, type-D flip-flop U5B, inverter/level-change amplifier Q6, and transistor switch Q7. The inputs to the circuit consist of the delayed reference square wave and the tape frame pulse from the capstan servo. In the capstan servo, the delayed reference square wave is used to generate the capstan trapezoid, and the tape frame pulse is used to generate the sample pulse, which becomes locked to the trapezoid waveform when the servo has stabilized. Thus, when the reference square wave and tape frame pulse are almost coincident, the capstan servo will be nearly locked.

The reference square wave, which has a frequency of 30 or 25 Hz (15 or 12.5 Hz during fast lock-up capstan interval), is differentiated and inverted by Q3 to form positive-going trigger pulses between −5 and 0 volts. These pulses are fed to the high-level actuated input of U4. The unstable period of U4, which is adjustable by bracket-pulse potentiometer R16, is approximately 12 milliseconds. The Q output of U4 is fed to the D input of flip-flop U5B. Thus the D input goes high for approximately 12 milliseconds each time that U4 is triggered.

The tape frame pulses are differentiated and inverted by Q2, to form positive-going 5-volt trigger pulses which are fed to U2. The unstable period of U2, which is adjustable by the sample-pulse delay potentiometer, R9, is approximately 4.5 milliseconds. The $\overline{Q}$ output of U2 thus goes low when U2 is triggered, and it returns to the high state 4.5 milliseconds later. This output signal is fed to the clock input (terminal 11) of flip-flop U5B.

As previously mentioned, before the control track has come up to speed, a low level is fed from the Q output of U5A in the control-track detector to the set input of U5B, thereby holding U5B in the set state (Q output high). As soon as this low is removed, however, control of U5B is transferred to its D and clock inputs. The clock pulse occurs 4.5 milliseconds after U2 is triggered by the tape frame pulse, and the D input is high for 12 milliseconds after U4 is triggered by the reference square wave. Thus, if the timed edges of the tape frame pulse and reference square wave are more than approximately ±6 milliseconds apart, the D input will be low when the clock pulse occurs, and U5B will, therefore, be triggered into the reset state. When, however, the timed edges are within ±6 milliseconds of each other (defined as the near-lock condition), the D input will be high when the clock pulse occurs. As a result, U5B will be triggered into the set state and will remain in that state as long as near-lock exists. As previously mentioned, the timing between the outputs of U2 and U4 depends on adjustment of the sample-pulse delay potentiometer, R9, and the bracket-pulse potentiometer, R16. These potentiometers are normally adjusted so that when the capstan servo is locked, the trailing (positive-going) edge of the pulse from the $\overline{Q}$ output of U2 occurs in the center of the pulse period of U4.

The Q output of U5B is fed to inverting and level-shifting amplifier Q6, which controls transistor switch Q7. When U5B is in the set state, the Q output is high (at 0 volts), and Q6 is saturated. As a result, Q7 conducts and grounds resistor R29. Since this resistor, in series with potentiometer R30 (servo time-constant control), is connected to the damping components of the capstan-servo error amplifier, these components are inserted in the circuit, thereby allowing the capstan error circuits to function normally. When, however, U5B is in the reset state, the Q output is low. As a result, both Q6 and Q7 are cut off, thereby disconnecting the damping components.

From the preceding, it can be seen that when U5B is initially held in the set state before the control track has reached the desired frequency, the damping components are in the circuit, thereby allowing a memory voltage to build up on the damping capacitors. After the control track has reached the desired frequency, U5B is triggered into the reset state by the next clock pulse, thereby removing the damping components and speeding up the capstan servo. Then, when near-lock is detected and the damping components are reinserted, the previously developed memory voltage is reapplied, thereby preventing the servo from overshooting excessively. The servo time-constant control, R30, permits adjusting the damping characteristics. This control is normally adjusted for critical damping as described under setup adjustments.

Fablock −5 Volt Regulator

A power-supply circuit consisting of transistor Q8, zener diode X3, resistors R25 and R26, and capacitors C9 and C10 is provided on the Fablock board. This circuit reduces the −10-volt input from the machine to a regulated −5 volts as required by the Fablock logic circuits.

Fablock Subboards A and B

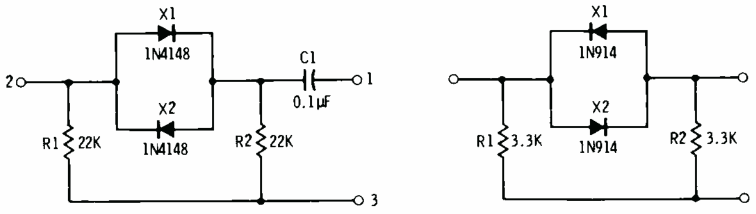
The circuits of Fablock subboards A and B are shown in Fig. 12-24. Only one of these boards is actually used in a particular installation, depending on the type of machine. Subboard A is installed in the control-track record/play module of the TR-50, TR-60, TR-70, TR-70A, TR-70B, TR-22D, TR-3, TR-3A, TR-3B, TR-4A, TR-4B, and TR-4C machines. Subboard B is installed in the corresponding module of the TR-22A, TR-22B, TR-22C, and TR-4 machines. The boards perform identical functions but differ slightly to suit the requirements of each control-track circuit.

These boards are required because the control-track playback amplifier in its original form is a 240- or 250-Hz tuned amplifier with so much gain that it provides an appreciable 240- or 250-Hz output due to amplification of cross talk and noise, even when no control track is present. Although this spurious signal does not affect normal non-Fablock operation, it is undesirable since it could cause the Fablock circuit to register the presence of a satisfactory control track when none is present.

Subboard A or B is inserted at a point in the amplifier where the amplitude of the cross talk and noise is considerably lower than the level of a normal control-track signal. The circuit on the board provides a coring action which causes the amplifiers following it to ignore all signals below a level greater than that of the cross talk and noise. Thus, when no control track is present, the control-track playback amplifier output is zero.

Fablock Setup Procedure

We will describe the rather simple setup procedures for this circuitry so that a brief outline of maintenance and servicing techniques can be included.



(*A*) *Subboard A.* (*B*) *Subboard B.*

Fig. 12-24. Schematic diagrams, Fablock subboards.

Control-Track Sensor Adjustments—

1. Make a stable recording of 5 minutes duration.
2. Select the CAP ERROR display on the cro.
3. Enter the standby mode and, while depressing the CAP SET button on the capstan oscillator module, adjust the capstan free-running speed to give minimum drift between the sine-wave and spike displays.
4. Select the tonewheel playback mode, and switch the picture monitor to external sync.
5. Maintaining pressure on the CAP SET button, enter the play mode, and observe the picture monitor for overspeed characteristics. If R15 in the Fablock circuit is correctly adjusted, the tape should not overspeed. Repeat this step after adjustment of R15, if necessary.
6. Wind to the end of a 90-minute tape, and make a stable recording of 5 minutes duration. Make adjustments to R28, as required, so that on starting, boost is maintained for a sufficient time to avoid build-up of a loop at the take-up damping arm. If the range of R28 is insufficient, the boost voltage should be moved to the next higher transformer tap.
7. Remove the control-track record/play module, and enter the play mode. Make a final adjustment of the CAP FREQ control to obtain minimum run-through as observed on the fm position of the cro.

Near-Lock Detector Adjustments—

1. Turn R9 (sample-pulse delay) and R16 (bracket-pulse width) on the Fablock unit to the maximum clockwise position.
2. Enter the play mode, and wait for the machine to lock. With a dual-trace oscilloscope, observe TP2 and TP4 on the Fablock unit.
3. Adjust R16 to give a positive pulse width of 12 milliseconds at TP4.
4. Adjust R9 to bring the trailing edge of the narrow, negative-going pulse on TP2 to midway through the positive period of the waveform on TP4.
5. Stop the machine, enter standby, and re-enter the play mode. The machine should then lock within the specified time of two seconds. If performance is unsatisfactory, adjustment of R30 is required. Potentiometer R30 in the Fablock unit is associated with the damping capacitor in the basic servo error amplifier. It should be adjusted to give minimum overshoot as seen on the capstan trapezoid display.

NOTE: On either side of the correct setting of R30, excessive hunting will be experienced. Owing to individual variations between machines, fine adjustments to R16 and, consequently, R9 may be found to offer an improvement in lock-up time. In general, however, R16 should not be adjusted to give more than one half-cycle of overshoot before lock, to avoid a permanent hunting condition. (This condition will occur if the near-lock range is made too narrow.)

Maintenance Procedure for Fablock

An outline of the maintenance procedure for this circuitry will serve to give the reader a basic technique for troubleshooting of logic circuitry in general.

The precautions normally taken when working with semiconductors and printed circuits should be observed when working on the Fablock board. No more heat than necessary should be applied when removing suspected parts, to avoid damage to both components and the bond between the board and the printed wiring. In general, restrict the application of heat to a maximum of 5 seconds at a time. Use of a pneumatic or other form of desoldering aid is recommended. After a replacement of any transistor, ensure that the plastic spacer is retained in position. This will afford increased thermal protection when resoldering.

To aid servicing and replacement, all integrated circuits are plugged into sockets. They should be removed from the sockets before any soldering is attempted on these sockets. Since semiconductors, in general, are sensitive to any voltage overload, it is advisable to remove power before any maintenance is attempted.

The following equipment will be required for troubleshooting the Fablock.

1. Tektronix Type 545 oscilloscope with dual-trace plug-in, or equivalent.
2. Test meter with 20,000 ohms/volt sensitivity and ranges suitable for checking 5, 10, and 70 volts dc.
3. Normal service tools, including:
   (a) Soldering iron (25-watt)
   (b) Desoldering tool
   (c) Long-nosed pliers
   (d) Side-cutters
   (e) Screwdrivers

This section should be used in conjunction with the preceding discussion of the theory of operation. Before starting any fault-finding routine, check that the derived power-supply voltage of −5 volts is present and within its tolerance of ±0.25 volt.

The signal path through the Fablock unit, including test points, is shown in the simplified block diagram of Fig. 12-22. If a fault should develop in operation, this diagram should be consulted to determine which inputs are required by the nonfunctioning area, and a logical progression of checks should be carried out from input and output. The following indicates a suggested troubleshooting procedure.

1. Capstan servo remains in record mode, evidenced by sine-wave and spike display on monitoring cro during playback.

   (a) Switching transistor Q5 (servo enable) could be short-circuited. Check Q5.
   (b) Fault in U1, U3, U5, or U6 (associated with control-track speed detection). Check U1, U3, U5, and U6.
   (c) No feed of processed control-track pulses to Fablock. Check for presence of control-track pulses at pin 1.
   (d) Control-track control R15 misadjusted. Check adjustment of R15 as directed under Setup Procedure.
2. Monitoring cro display switches rapidly between trapezoid and sine wave during servo lock-up.
   (a) Control-track detector set at too high a frequency. Turn control-track potentiometer (R15) clockwise.
3. Trapezoid display continuous in playback, but servo hunts rapidly and locks up only after a considerable time, if at all.
   (a) Sampling delay off center, or bracket-pulse setting too narrow.
   (b) Capstan damping incorrect. Increase settings of bracket-pulse control (R16) and sample-pulse delay control (R9) to maximum clockwise, and recheck operation. If the operation is now satisfactory (hunting eliminated), carry out final setup in accordance with Setup Procedure section. If it is still unsatisfactory, set R16 to give a 12-millisecond pulse at TP4, set R9 to place the positive edge of the TP2 waveform at the midpoint of the TP4 positive pulse, and adjust R30 for minimum hunting. With R30 too far counterclockwise, a slow hunting condition will occur; if it is too far clockwise, the hunting will be more rapid. A critically damped condition can be reached between these two extremes; this condition results in a much reduced hunting period.

If the operation is still unsatisfactory, proceed as follows:

1. Withdraw the capstan error module (TR-22 and TR-70 series) or capstan oscillator module (TR-3, TR-4, TR-50, TR-60 series).
2. Locate the C11 positive terminal (TR-22, TR-22A, TR-22B, TR-22C) or the C17 positive terminal (TR-22D, TR-70, TR-70A, TR-70B) or the C39 positive terminal (TR-3, TR-4, TR-50, TR-60 series). Remove the Fablock lead from this terminal and connect an 1800-ohm resistor to ground.
3. Reconnect the module to the machine either by reinserting it directly or, preferably, in a module extender, and initiate the play mode. The machine should now lock up in identical fashion to a machine not equipped with the Fablock accessory. If it does not, a more basic servo fault is indicated, and the servo maintenance manual should be consulted. If the machine does lock, with the machine in playback carry out the checks in the following steps.

4. Pin 5, TP8, should be at a level between −2 volts and 0 volts (as opposed to −3 to −5 volts). (This will be true only if the tape being played has a satisfactory control track.)
5. Pin 12, TP4, should have a positive-going pulse of approximately 12 milliseconds duration and greater than 2.5 volts amplitude, sitting on a base line between −5 and −4.5 volts, and occurring at the frame rate (once every two frames during fast lock-up capstan interval on either 525/15-Hz edit pulses or 625-line high-band operation). Absence of these pulses indicates a malfunction in the area of U4, or absence of delayed reference square-wave input.
6. Pin 11, TP2, should have negative-going pulses of approximately 5 milliseconds duration and greater than 2.5 volts amplitude with negative peaks between −5.0 and −4.5 volts, and occurring at the frame rate (once every two frames during fast lock-up capstan interval on either 525/15-Hz edit pulse or 625-line high-band operation). Absence of these pulses indicates a malfunction in the area of U2, or absence of input tape frame pulses.
7. Confirm that the positive-going edge of the pulse at TP2 occurs during the positive excursion of the pulse at TP4. (This requires the use of either a dual-trace oscilloscope or a single-trace oscilloscope with facilities for external, delayed triggering from reference vertical). Ideally, the positive-going edge of the pulse at TP2 should occur halfway through the duration of the pulse at TP4, and it should be so adjusted with the sample-pulse delay control (R9 in Fig. 12-23).
8. A satisfactory checkout of all conditions in steps 5, 6, and 7 should give rise to a logic high condition at pin 9 of U5 (0 to −2 volts, as opposed to −3 to −5 volts). Failure to obtain a logic high at pin 9 with all inputs correct points to a fault condition in U5. In the event of a satisfactory logic high and continuing faulty operation, proceed to the next step.
9. Check the operation of Q6 and Q7. With a logic high at pin 9 of U5, Q6 should saturate, and the Q6 collector should be at approximately −4.5 volts. This causes Q7 to saturate, which in turn grounds R29 in Fablock, resulting in normal, reduced servo bandwidth.
10. Check for continuity between Fablock Pin 7 and the C11 positive terminal in the capstan error module (TR-22, TR-22A, TR-22B, TR-22C), the C17 positive terminal in the capstan error module (TR-22D, TR-70, TR-70A, TR-70B), or the C39 positive terminal in the capstan oscillator module (TR-3, TR-4, TR-50, TR-60).

12-10. AUDIO SYSTEM MAINTENANCE

The following major pieces of test equipment are required for audio system checks and adjustments:

1. Audio signal generator (Hewlett-Packard Model 206A or equivalent)
2. AC voltmeter (Hewlett-Packard Model 400 or equivalent)
3. Vacuum-tube voltmeter or sensitive volt-ohmmeter
4. Oscilloscope (Tektronix Type 547 or equivalent)
5. Distortion meter (Hewlett-Packard Model 330C or 331A, General Radio Type 1932A, or equivalent)
6. Degausser (supplied with machine)
7. Test module (supplied with machine)

The audio heads may eventually become slightly magnetized. If the magnetism is not removed, it could cause distortion, loss of high-frequency response, and in particular, increased tape noise in the output. However, the heads may easily be demagnetized with the degausser provided in the accessory kit included with the machine.

For best signal-to-noise ratio, each audio head should be degaussed before every critical recording session as follows:

1. Place the EQUIPMENT POWER circuit breaker in the off position, but leave the UTILITY POWER circuit breaker on so that power is supplied to the convenience outlet.
2. Connect the degausser power cord to the convenience outlet on the front of the recorder.
3. Place the tip of the degausser gently against the pole pieces of the head, and slowly move the degausser from side to side two or three times with the degausser *just barely* in contact with the head poles.
4. With the degausser poles directly over the head poles, lift the degausser off the head, and withdraw it very slowly and evenly. Then unplug the degausser power cord.

CAUTION: To avoid scratching the heads, never allow metal objects to contact the head posts or the pole pieces of the heads. If the plastic coating on the tip of the degausser wears off, place masking tape on the degausser before using it.

Audio-system tests and adjustments are facilitated by the fact that the audio simulplay head makes it possible to adjust the audio recording system while simultaneously checking the results through the playback and monitoring systems. The purpose of these adjustments (all of which occur in the recording system) is to permit making recordings that produce the specified signal-to-noise ratio and to provide a flat overall record/playback frequency response through the audio range.

To illustrate general audio-system maintenance techniques for the video tape recorder, we will present the procedures recommended by RCA for the TR-70. Since the adjustments depend on each other, they should be performed in the sequence presented. After the adjustments are completed, the signal-to-noise ratio and the overall record/playback frequency response should be checked.

Test Setup

The audio-system tests are performed with a tape speed of 15 inches per second except where noted otherwise. All audio covers and shields should be in their proper places. The audio monitor amplifier is connected for monitoring. Fig. 12-25 shows the test-setup connections. These connections are changed as directed in the procedures, in order to accomplish the specific test and adjustment in progress.

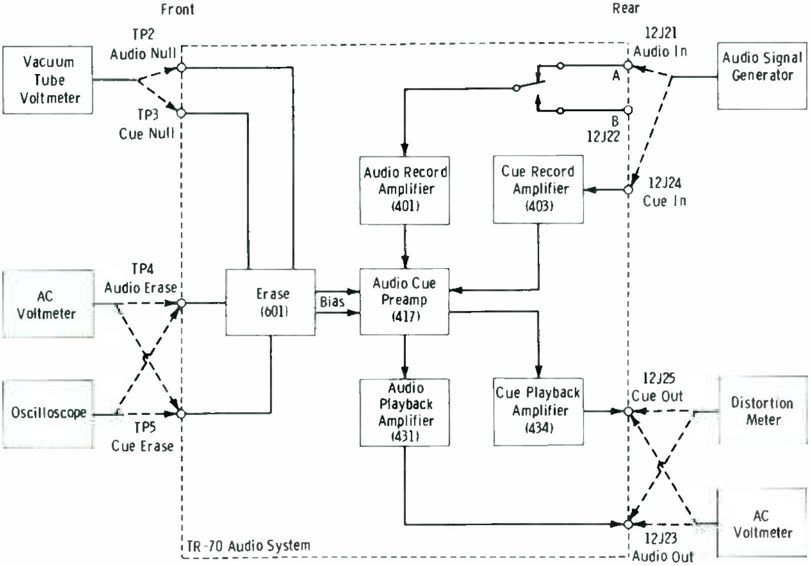


Fig. 12-25. Test setup for RCA TR-70 audio-system checks and adjustments.

Audio Test

The audio test requires that the machine be in normal operating condition, with tape in the machine. Proceed as follows:

1. Connect the audio signal generator to the AUDIO LINE A IN jack (12J21). The generator is connected across pins 2 and 3 of the jack. Pin 1 is ground. Then switch to Video A.
2. Set the audio signal generator for a balanced output of 600 ohms. Terminate the generator in 600 ohms.
3. Connect the distortion meter with a 600-ohm load resistor to the AUDIO LINE OUT jack (12J23). Pins 2 and 3 are across the output. Pin 1 is ground.
4. Set the LEVEL control on the record amplifier module for maximum gain (fully clockwise).

5. Adjust the audio signal generator for a 1000-Hz output. Adjust the output level to −10 dBm.
6. Turn the E-E switch (on modulator afc module 509) on. The input signal should now be present at the output and at all audio monitor positions.

Erase-Head Tuning and Noise-Null Adjustments

In the audio-system tests and adjustments, the head-tuning and noise-null adjustments are accomplished as follows:

1. If the AUDIO BIAS control (R33), on the audio/cue preamplifier module (module 417), has been disturbed or replaced, preset it to a two-thirds position in the clockwise direction.

NOTE: The adjustment shaft of control R33 is located on the upper side of module 417 and slightly right from center. The module is located on the tape transport, just above the heads.

2. If the audio record high-frequency equalization trimmer capacitor (C16) has been disturbed or replaced, preset it to one-quarter turn from fully tightened (counterclockwise).

NOTE: Trimmer capacitor C16 is located slightly right from center.

3. Connect a dc voltmeter between the AUDIO NULL test point and ground on erase oscillator module 601.
4. Adjust the AUDIO DC NULL control, on the erase oscillator module, for a zero indication on the voltmeter.
5. Place the EQUIPMENT POWER circuit breaker in the off position, and carefully degauss all heads.
6. Place the EQUIPMENT POWER circuit breaker in the on position.
7. Terminate the AUDIO IN (12J21) line with 600 ohms (or switch in full attenuation on the audio signal generator).
8. Place the machine in the setup mode.
9. Connect the oscilloscope to the AUDIO ERASE test point (TP4) on the erase oscillator module and look for 140 volts peak to peak. If the voltage level is not at 140 volts, place the erase oscillator module on an extender frame and adjust the audio erase level control (R96) for the required indication of 140 volts peak to peak.
10. Remove the preamplifier shield cover, and connect the oscilloscope to the audio record input point on audio/cue preamplifier 417. This is at capacitor C17, which is located on the lower side of the board, to the extreme right.
11. Adjust bias trap coil L1 for a minimum signal indication, which should be below four volts peak-to-peak. The adjustment screw of coil L1 is located adjacent to control R33.
12. Remove the oscilloscope leads.

13. Press the AUDIO ON push button on the record panel, and make a recording with no input signal.
14. Press the AUDIO PB push button on the audio switcher. Rotate both the LEVEL control on audio playback module 431 and the audio monitor SPEAKER VOLUME control to fully on (clockwise) while listening to the simultaneous playback of the recording.
15. Adjust the AUDIO TUNE control (C31) on erase oscillator module 601 for minimum noise level as heard on the loudspeaker.

NOTE: Noise indications may be observed on the ac voltmeter (from 12J23) as sharp fluctuations over a steady indication of approximately 0.08 volt, which is caused by the bias signal. Also, the meter input terminals may be shunted with a 0.1-μF capacitor to permit noise indications to be observed directly on the ac voltmeter.

16. Adjust the AUDIO DC NULL control (R88) on the erase oscillator module for further noise reduction. This adjustment should be performed carefully to obtain the lowest tape noise. Rotate the control no further than necessary in either direction of minimum level indication to find the null point. The noise level is usually 0.04 volt with the machine stopped, or 0.05 volt with the machine operating in the play mode over this recording. Indications are obtained with the ac voltmeter.

Bias and High-Frequency Control Adjustment

Proceed as follows to adjust the bias and high-frequency controls:

1. Record a 1000-Hz signal with a zero-level indication on the VU meter while the AUDIO REC push button on the audio switcher is depressed.
2. Press the AUDIO PB push button on the audio switcher, and adjust the LEVEL control on audio playback module 431 to obtain an indication of approximately −3 on the VU meter.
3. Adjust the AUDIO BIAS control (R33) on the audio/cue preamplifier module (module 417) for maximum signal-output indication on the VU meter. If the VU-meter indication exceeds zero level, reduce the LEVEL-control setting on the audio playback module (module 431) so as to obtain a true peak setting for the AUDIO BIAS control.
4. Measure the bias voltage on the audio record/play head (2PU3), from pin 3 of the head to ground. Record this value.
5. While recording a 1-kHz signal, adjust the playback LEVEL control for a 0 indication on the VU meter.
6. Set the signal-generator frequency to 15 kHz, and hold the generator output level the same as at 1 kHz in step 5 above.
7. Adjust the audio record high-frequency equalization control (C16) for the same output level as noted in step 5.

8. Set the AUDIO BIAS control (R33) on module 417 to maintain a constant bias voltage as determined in step 4.
9. Repeat steps 5, 6, and 7 if necessary.

Distortion Test

The distortion test and associated adjustments are accomplished as follows:

1. Connect the distortion meter in parallel with the voltmeter that is across the output of the machine.
2. Adjust the audio signal generator for a 400-Hz output, and set the level to 10 dBm (2.45 volts). Set the attenuator to 10 dB.
3. Rotate the LEVEL control on audio record module 401 to its maximum clockwise position.
4. Record a one-minute section of tape at this input level; then decrease the attenuation in 1-dB steps to +7 dBm while recording each level for approximately one minute. While recording, position the MIC switch to Audio, and announce the input level into the microphone; then return the MIC switch to the off position.
5. Rewind this section of the tape and play it back. Set the LEVEL control on module 431 for approximately 2.0 volts, as indicated on the output ac voltmeter.
6. Place the distortion meter in the calibrate mode, and adjust the distortion-meter input control for a full-scale meter indication; then read the overall distortion.
7. Reset the input control on the distortion meter as the level changes, according to the level announced in step 4, and read the overall distortion.
8. Determine what input level is required for the distortion to reach 3 percent (if distortion is excessive, begin recording at a lower level).
9. Reset the attenuator to the level determined in step 8, and place 10 dB of additional attenuation in the audio generator.
10. Place the machine in the setup mode.
11. Press the AUDIO REC push button on the audio switcher.
12. Mount the audio record module (module 401) on an extender frame, and adjust the record-level meter calibration control (R47), located near the rear half of the module, to obtain a zero indication on the VU meter at this input level (10 dB below the input for 3-percent distortion).
13. Place the machine in the stop mode.
14. Turn on the E-E switch on the 509 module panel.
15. Press the AUDIO PB button on the audio switcher.
16. Adjust the playback-loop level control (R45) for zero indication on the VU meter, with the same input as in step 12.

17. Remove the module extender frame, and replace the module in its proper place in the machine.
18. Record a section of tape at this 0-VU recording level, and play it back. The distortion should not exceed 1.5 percent.
19. Press the AUDIO REC button on the audio switcher. Reduce the attenuation of the signal generator 10 dB; then press the VU −10 DB button on the audio switcher, and note that the meter indication decreases to 0 (±1) VU.

Signal-to-Noise Ratio Measurement

The signal-to-noise ratio is measured as follows:

1. Replace all audio shields, and record a 400-Hz tone on a section of tape at a 3-percent distortion level; then play it back.
2. Set the LEVEL control on the audio playback module (module 431) for an indication of 3.2 volts (10 dBm) on the ac voltmeter.
3. Adjust the input sensitivity control on the distortion meter for 0-dB reference at the present level setting.
4. Rewind the tape to the starting point of the 3-percent distortion recording, and terminate the audio input terminals (or apply full attenuation to the audio signal generator).
5. Operate the machine in the audio record mode over the section of tape having the distortion recording to erase the tape with the audio erase head only.
6. Rewind the tape to the beginning of this recording, and play the tape back. Observe that the noise voltage level is at least 55 dB below the output voltage at the 3-percent distortion level. The equivalent voltages are a 0.005-volt noise level with the 3.2-volt setting.
7. Rewind the tape to a section where the audio is erased; then place the machine in the play mode.
8. Operate the machine into and out of the audio record mode, and note at what points on the counter the changes are made.
9. Play the tape back, and observe that the switching transients recorded are at least 40 dB below the 3-percent level, as indicated on the distortion meter.

E-E Frequency Response

The playback loop is checked for frequency response as follows (this circuit may also be referred to as the back-to-back function or electrical-to-electrical circuits):

1. Set the tape speed to 15 inches per second.
2. Adjust the audio signal generator to supply 1000 Hz at 10 dBm, and add an attenuation of 10 dB.

NOTE: Keep the output level of the audio signal generator constant.

3. Press the AUDIO PB button on the audio switcher.
4. Place the machine in the stop mode, and set the E-E switch on the 509 module to On.
5. Adjust the distortion-meter level control for a 0-dB indication.
6. Measure the frequency response from 50 Hz to 15 kHz. The limits should be plus zero or minus 1.5 dB.
7. Set the tape speed to 7.5 inches per second, and repeat the entire procedure at this tape speed.

Record/Playback Frequency Response

The frequency response for tape speeds of 15 and 7.5 inches per second in record and playback is tested as follows:

15 Inches per Second—

1. Set the tape speed to 15 inches per second.
2. Adjust the signal generator to supply 1000 Hz at 10 dBm, and add an attenuator of 10 dB (0 dBm output level).

NOTE: Readjust the level of the audio signal generator as required to maintain a constant output level.

3. Press the AUDIO REC button on the audio switcher.
4. Place the machine in the setup mode.
5. Adjust the LEVEL control on the audio record module (module 401) for an indication of zero on the VU meter.
6. Noting that the output meter of the audio signal generator is held constant at 10 dBm, record the frequencies in Table 12-4, starting at 1000 Hz and disregarding changes of the audio record level as indicated on the VU meter.
7. Switch the MIC AUDIO/CUE selector switch to the Audio position, and announce each frequency in the microphone; then return the switch to off while recording the frequency.
8. Terminate the output line with a 600-ohm resistor.
9. Rewind and play back this recording, and adjust the LEVEL control on the audio playback module (module 431) for 1.23 volts rms (4 dBm), as indicated on the ac voltmeter, while playing back the 1000-Hz reference tone.
10. Press the AUDIO PB button, and note that the VU meter indicates 0 (±1) VU.
11. Adjust the input sensitivity control on the distortion meter for zero dB, while the meter function is positioned for set level, and the meter range is set for 100-percent indication.
12. Measure the frequency response as indicated by the distortion meter. For high-frequency response adjustments, if required, refer

Table 12-4. Frequency-Response Chart

Frequency (Hz)	Audio Output (dB)		Cue Output (dB)	
	15 in/s	7.5 in/s	15 in/s	7.5 in/s
1000	0 (Ref)	0 (Ref)	0 (Ref)	0 (Ref)
50	±2	—	±2	±3
60	—	±2	—	—
100	±2	±2	—	—
190	—	—	±2	±3
200	±2	±2	—	—
310	—	—	±2	±3
400	±2	±2	—	—
1000	±0.5	±0.5	±0.5	±0.5
3000	±2	±2	—	—
5000	±2	±2	—	—
7000	±2	±2	±2	±3
10,000	±2	±2	±2	±3
12,000	±2	—	—	—
15,000	±2	—	—	—

to procedures given previously under Bias and High-Frequency Control Adjustment.

7.5 Inches per Second—

1. Switch the tape operating speed to 7.5 inches per second, and repeat the entire procedure at the reduced tape speed. The record LEVEL control on module 401 is set at 1000 Hz for an indication of −10 VU for the 7.5-in/s procedure.
2. Mount the audio record module (module 401) on an extender frame.
3. Operate the machine at 7.5 inches per second while operating in the audio record mode.
4. Make a 1000-Hz recording at the −10 VU record level, and adjust the audio-output LEVEL control on module 431 for 0 VU output.
5. Set the audio signal generator to supply a 10-kHz output at the same oscillator output level. Disregard an increase in record VU-meter indication.
6. If necessary, adjust the 7.5-in/s high-frequency equalization control (R32), on the audio record module (module 401), to obtain the same playback output level at 10 kHz as at 1000 Hz. Use the distortion meter for an output indicator.

NOTE: Control R32 is located just forward of the center of the board and on the upper half.

7. Rewind the tape to the starting point of this recording.
8. Play back the recording, and note that the response is the same for 1000 Hz as for 10 kHz (if not, readjust control R43 in audio record module 401).

EXERCISES

Q12-1. Name two head faults not under your control, and describe how to check for these faults.

Q12-2. If you notice on a color monitor that 3 or 4 bands of 16 lines each (indicating one of the four video heads) have excessive color beats (moiré) resembling herringbone interference, what is the most probable cause?

Q12-3. What is the quickest way to check amplitude-vs-frequency response of the E-E, playback, and record functions?

Q12-4. Give the proper time base to use on the Tektronix Type 529 waveform monitor to evaluate correctly (A) the T-pulse and (B) the 2T-pulse on the cro graticule.

Q12-5. What test signal most conveniently evaluates luminance-to-chrominance delay inequality?

Q12-6. What color-picture impairment results from luminance-to-chrominance delay inequality?

Q12-7. What factors other than electronic circuit problems can cause poor servo stability and slow lock-up?

Q12-8. What factors other than electronic circuit problems or misadjustments can cause poor audio performance?

CHAPTER 13

Quadruplex-Tape Cassette/Cartridge Systems

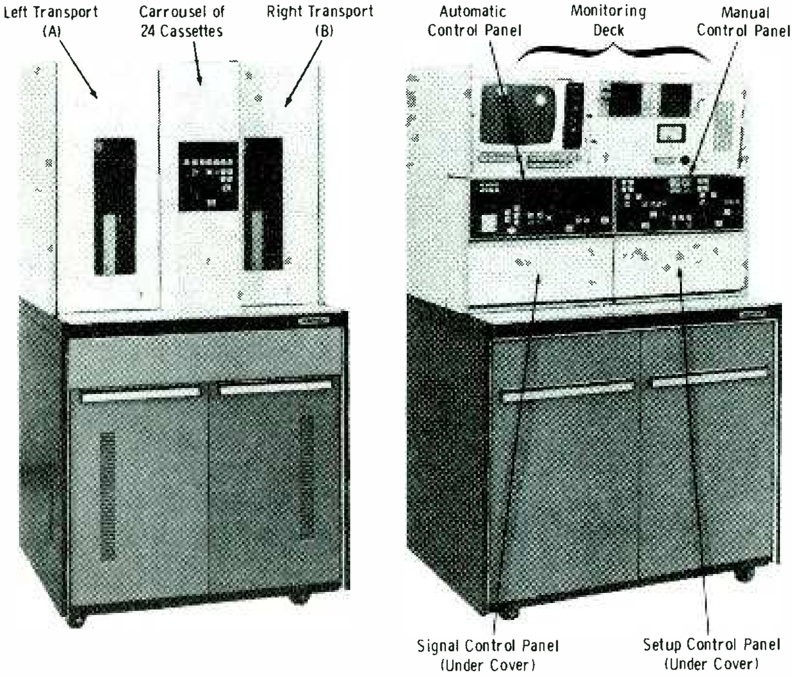
A system for the production of programming and station breaks from a number of short prerecorded video tapes, generally through the use of dual tape decks, is termed a *cassette* system by Ampex and a *cartridge* system by RCA. The same quadruplex rotating headwheel is used in the cassette/cartridge machine as is used in the larger systems previously described.

The Ampex ACR-25 automatic video cassette recorder/reproducer system may be purchased as a completely independent system or as a unit which shares certain electronics with the Ampex AVR-1. Similarly, the RCA TCR-100 can be obtained as a completely independent system, or as one that shares electronics with an RCA TR-70.

13-1. THE AMPEX ACR-25

The ACR-25 is a dual-transport, cassette-loaded, vacuum-threaded, two-inch quadruplex video tape recorder/reproducer. It consists of two units, the transport console (Fig. 13-1A) and the control console (Fig. 13-1B). The operator has random access to 24 cassettes which are contained in a carrousel located between the two tape transports. Each cassette has a capacity of 6 minutes, plus leader and trailer, at 15 in/s (12 minutes at 7½ in/s). The machine records in high band only, but it will play back high band, low band, monochrome, or color. Recordings made on a conventional reel-to-reel machine can be spooled into cassettes and played back on the ACR-25. Conversely, tapes recorded in the ACR-25 can be put on a reel and played on a conventional vtr.

Performance specifications of the cassette machine are the same as those of the Ampex AVR-1, due to the use of the AVR-1 signal and time-base-correction systems. Ten-second spots can be played back-to-back, and lock-up time is 0.2 second (0.35 second for 625-line standards). By utilizing the rewind lock-out feature on longer program segments, programs up to six minutes in length can be played back-to-back with ten-second spots. In this mode, the cassette does not rewind after play is complete, but is returned immediately to the carrousel. It can then be rewound manually at a later time when the ACR-25 is off line.



(*A*) *Transport console.* (*B*) *Control console.*

Courtesy Ampex Corp.

Fig. 13-1. Ampex ACR-25 cassette tape system.

As stated earlier, the ACR-25 records in high band only. The various record modes are: (1) onto either the A or B transport, (2) onto both the A and B transports simultaneously from the same program source, and (3) B-to-A or A-to-B dubs within the machine. A mechanical record lock-out switch is available on each cassette as protection against accidental erasure of a master tape.

In addition to the standard equipment configuration, the ACR-25 can also be used in conjunction with an AVR-1 to time-share the time-base-correction electronics.

Since all of the AVR-1 design features are incorporated in the ACR-25, accessories such as auto-chroma, velocity compensator, auto-tracking, drop-out compensator, etc., are also available on the ACR-25. Two additional accessories which contribute to the back-to-back playback capability are: (1) control-track rewrite, which allows the operator to record a new control track on the tape if the original one is unusable, and (2) automatic playback adjust, which allows the operator to record on the cue track, in digital form, information that will correct chroma phase, video gain, audio gain, and black level on a tape that was not recorded correctly. This information is recorded only once, and every time the tape is played thereafter, it will be correct.

Many of the controls on the ACR-25 can be located at a remote point, and the machine can be interfaced with a station computer.

Transport Console

The transport console contains two identical vacuum-threaded tape transports; a carrousel; an internal air system; head, capstan, and carrousel motor drive amplifiers; transport power supply; main power transformer; cassette carriage; and transport electronics bay. The cassettes are moved from the carrousel to the transport loading area by the cassette carriage. The tape is then withdrawn from the cassette and threaded into the transport by the vacuum threading process. Fig. 13-2A illustrates the transport with front cover open. Fig. 13-2B presents a detailed cutaway view of the transport with a cassette in place and the tape threaded.

In order to perform the threading operation rapidly and accurately, the capstan, audio shield, and female guide retract in unison when the tape threading operation begins, and move into the normal operating position, again in unison, when the tape is threaded. When the rewind and unthread operation occurs, the same events take place with the additional step of high-speed rewind. Rewinding is done without head-to-tape contact. The design of the vacuum tape transport allows for gentle, rapid, and precision tape handling in an enclosed, controlled environment, eliminating dust and contamination from tape surfaces.

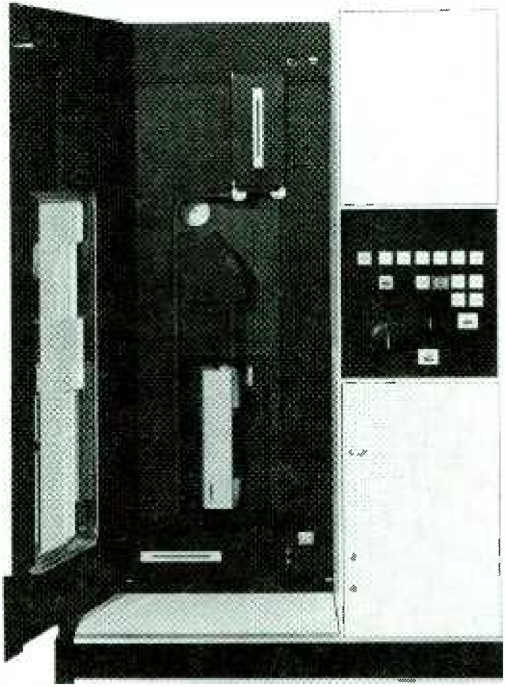
The vacuum columns, video and audio heads, and capstan are accessible from the front for cleaning and maintenance. The carrousel load controls are located on a panel between the two transports. The operator has access to any group of four cassette bins in less than one second by pushing the appropriate button on the load control panel. Cassettes are loaded from the right-hand side of the carrousel through a double interlocked door (Fig. 13-3).

Control Console

The control console contains video, audio, signal, and waveform monitors and four control panels: (1) automatic, (2) manual, (3) secondary, and (4) maintenance. The control console also contains servo-card bays, logic-card bays, the signal system, time-base-corrector electronics, and power supplies. Many of the printed circuit boards used in the ACR-25, such as signal-system and time-base-correction boards, are directly interchangeable with boards used in the AVR-1. In addition, the Mark XX video head is used on both machines.

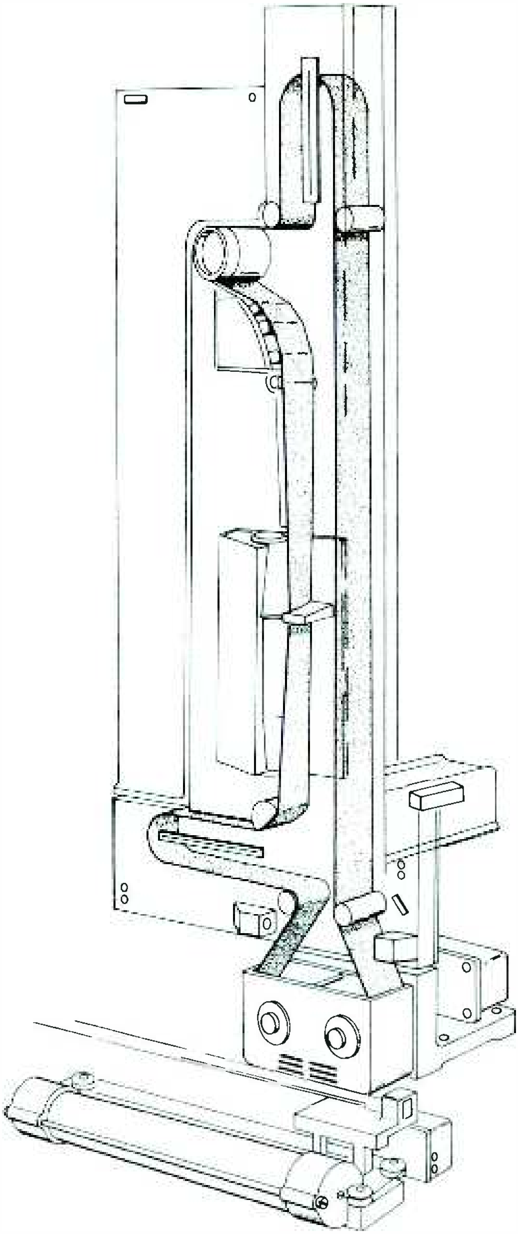
Automatic Control Panel

The automatic control panel consists of a left-hand and a right-hand portion. The left-hand portion (Fig. 13-4A) contains a 40-event random-access memory which can program the 24 cassettes in any number of sequences and events required up to 40. This portion also contains the sequence display, sequence buttons, event buttons. keyboard, and keyboard display. The right-hand portion (Fig. 13-4B) contains the warning panel (similar to the AVR-1) and the status display, which tells the operator the status of both tape transports and the carrousel. This portion also contains a number of push buttons, as follows. The AUTO button establishes that the machine will play cassettes in the sequence as determined by the programming of the memory. The SEMI-AUTO button establishes that the machine will play two previously threaded and cued cassettes in sequence and will continue to play cassettes as they are manually selected by moving



(*A*) *Front cover open.*

Fig. 13-2. ACR-25

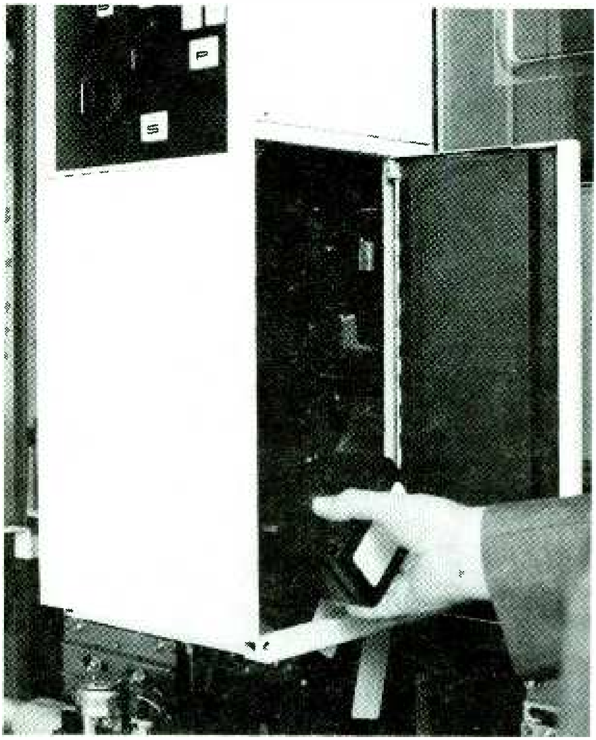


(*B*) *Cutaway view.*

Courtesy Ampex Corp.

cassette tape transport.

the bin selector switch to another number. The LOAD CONTROL button allows access to the carrousel for the loading of cassettes. The READY button threads and cues the first two cassettes to be played in an automatic sequence. The CANCEL button returns any cassettes in the tape transports to the carrousel. The AUTO PLAY button starts the playback of an automatic sequence. The NEXT button immediately starts the tape next in line and ends the tape that is playing. The REMOTE button delegates selected functions to a remote point.

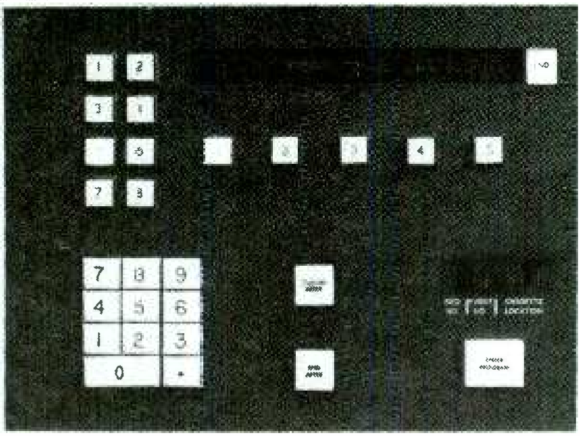


Courtesy Ampex Corp.

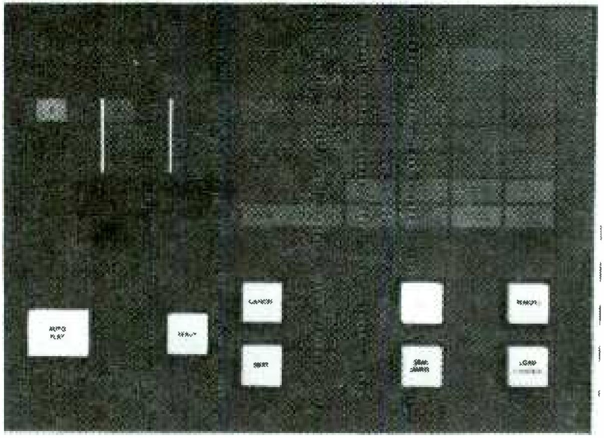
Fig. 13-3. Loading of cassettes into carrousel.

Manual Control Panel

The manual control panel contains all controls required to load, thread, cue, record, playback-shuttle, unthread, and unload cassettes from either transport manually. This panel also contains an electronic tape timer and push buttons for the various record modes, such as rewrite control track, dub record, cue-sequence record, audio and video record (transport A or B or both), etc.



(A) Left-hand section.



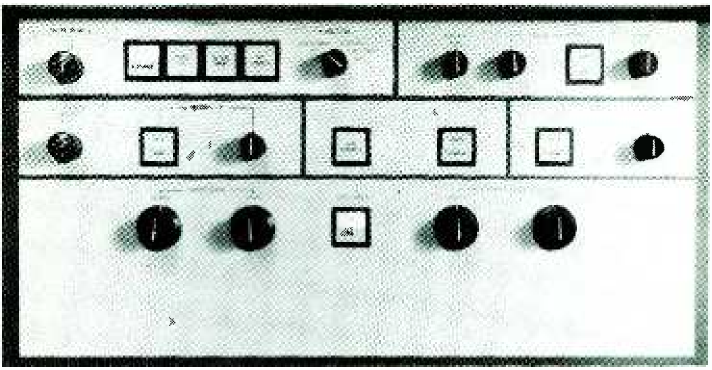
(B) Right-hand section.

Courtesy Ampex Corp.

Fig. 13-4. Automatic control panel of ACR-25.

Secondary (Signal) Control Panel

The secondary control panel (Fig. 13-5) is located below the automatic control panel and contains the Mark IV Electronic Editor (optional accessory); audio and video input and output level controls; standards selection controls; tracking, chroma-level, and black-level controls; control-track rewrite (optional); and automatic playback adjust (optional). Except for control-track rewrite and automatic playback adjust, all controls on this panel exist on the AVR-1 and serve the same purpose.



Courtesy Ampex Corp.

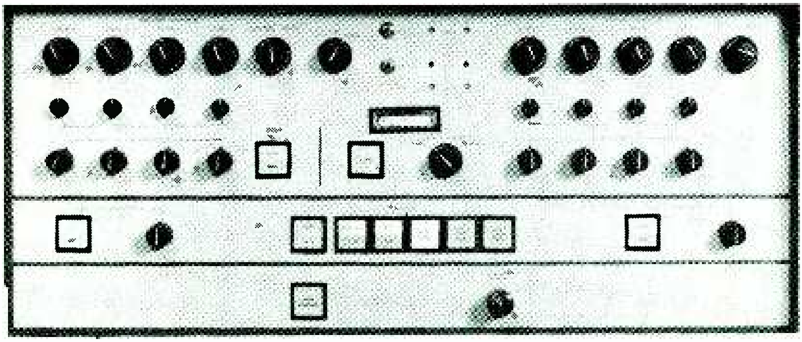
Fig. 13-5. Secondary (signal) control panel.

Maintenance (Setup) Panel

The controls on the maintenance panel (Fig. 13-6) are those that are required to set up the machine initially for proper playback. They are identical to those controls found on the AVR-1, with the exception that there are two of everything that requires adjustment (two transports, two heads, etc.).

Spot Leader

The spot leader consists of a mechanical start-of-tape (sot) marker, 10 seconds of blank tape, one second of leader, up to 6 minutes of program (at 15 in/s), one second of trailer, 10 seconds of blank tape, and the mechanical end-of-tape (eot) marker (Fig. 13-7). The sot and eot markers are merely precision holes punched in the video tape.



Courtesy Ampex Corp.

Fig. 13-6. Maintenance (setup) control panel.

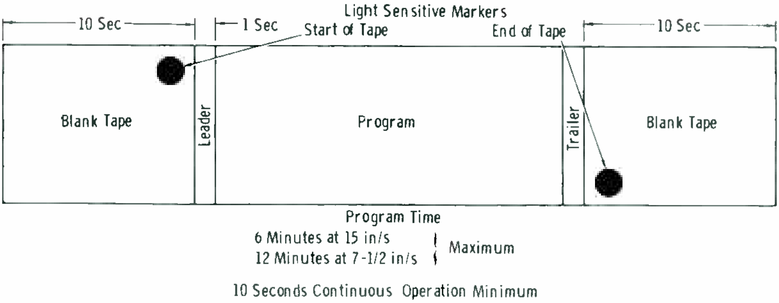


Fig. 13-7. Spot leader.

Fig. 13-8 shows utilization of the cue track. The proposed SMPTE time and address code (Chapter 10) has been incorporated in the ACR-25 and is recorded on the cue track. The spare bits can be used to (A) verify program content, (B) record automatic playback data (chroma phase, video gain, audio gain, black level), (C) provide a cue-up point for start of program, (D) provide an auto-roll cue for a film projector or vtr, (E) provide an auto-roll cue for start of next cassette, or (F) provide a program stop cue (Fig. 13-9).

Cassette

The cassette (Fig. 13-10) contains a maximum of 6 minutes of program material (at 15 in/s), plus leader and trailer. Programs may be recorded onto a fully loaded cassette, or prerecorded tapes may be physically transferred from a reel to a cassette, thereby allowing complete interchangeability and avoiding further recording generations. The cassette spools may be removed from the cassette and shipped or stored in a shipping container.

The cassette is hinged and is easily opened for removal of the spools. Captive record and rewind lock-out buttons are located on the cassette.

13-2. AMPEX SYSTEM DESIGN CONSIDERATIONS

Development of the ACR-25, a broadcast-quality cassette video tape recorder, required the design of many new electronic and mechanical

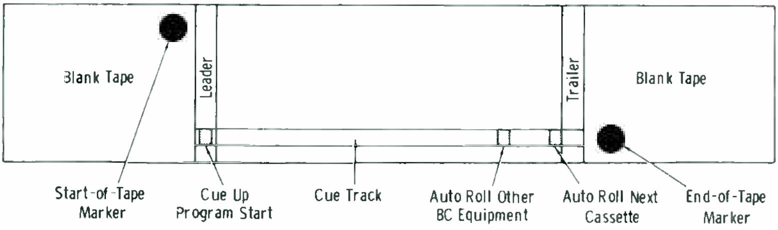


Fig. 13-8. Utilization of cue track.

systems. This section describes requirements and design solutions for the signal-processing, headwheel-servo, and capstan-servo systems, including their relation to conventional video tape recorders, as described by the Ampex Corporation. In order to emphasize the reasons for particular system parameters, a brief overview of the complete system is presented.

Overview

Most important in overall system design objectives were fully automatic operation, convenient and reliable tape handling, and a cycle time that would allow 10-second spots to be played back-to-back. To accomplish these goals, the ACR-25 has two vacuum-threaded tape transports that are supplied with video-tape cassettes from a shared, random-access carrousel storage area. Transports, carrousel, high-power drive components, and preamplifiers are contained in the transport console unit. Control logic, audio and video processing, servos, and monitoring are contained in the control console unit. A sequence of events determined by the control logic delivers cassettes to the transports and threads the tapes in a reliable, high-speed manner. Once threaded, the cassette recorder is much the same as any reel-to-reel machine, so the burden then falls upon the standard vtr components to provide high-quality, fully synchronous video. When each tape is no longer needed, it is rewound, unthreaded, and finally returned to the carrousel.

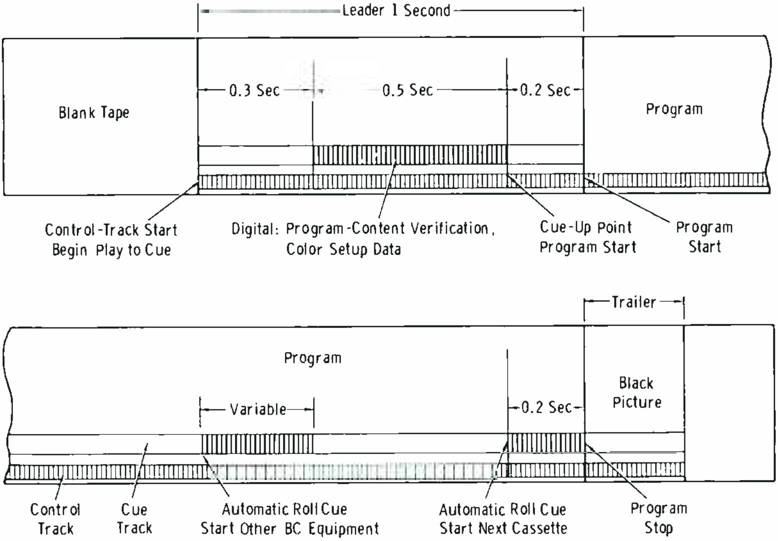
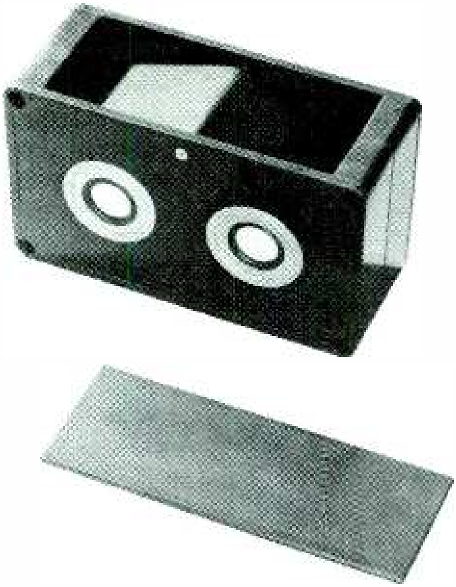
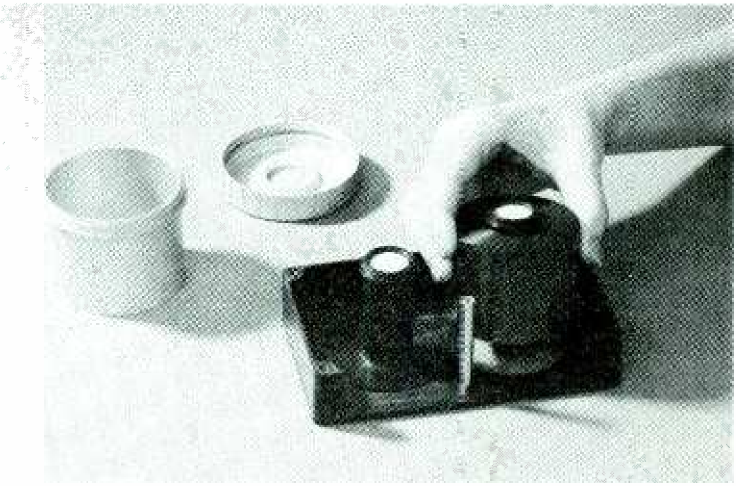


Fig. 13-9. Control functions.

A much-simplified block diagram of the ACR-25 electronics is shown in Fig. 13-11. The basic approach to design of the dual-transport system



(*A*) *Loaded cassette.*



(*B*) *Loading of tape.*

Courtesy Ampex Corp.

Fig. 13-10. Video-tape cassette.

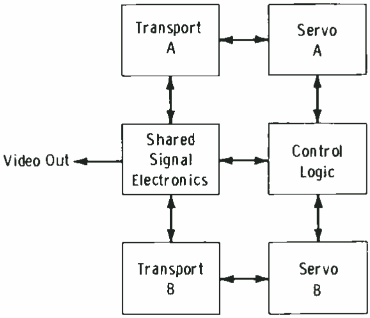


Fig. 13-11. Simplified block diagram of ACR-25.

was to share as much of the signal electronics as possible, but also to provide two complete sets of servo electronics, so that tape handling could be accomplished as easily and rapidly as possible.

Signal System

Design considerations for the signal system included minimizing the amount of circuitry required, self-contained operation with some optional external circuit sharing, flexible record capabilities, and fast cycle-time-

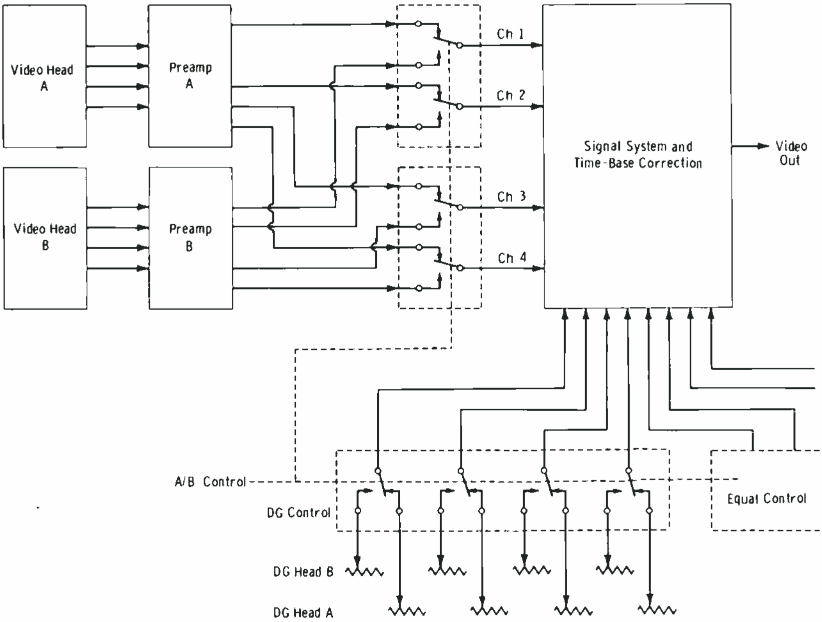


Fig. 13-12. Video reproduce mode of ACR-25.

related responses combined with automatic correction features. These goals were accomplished by adding a few simple switching circuits to a signal system and time-base corrector that are electrically identical to those used in the AVR-1.

In the reproduce mode, A/B switches are required for preamplifier rf, differential-gain control, and equalization control, as shown in Fig. 13-12. Switching between transports is done in the uncombined head rf output during a vertical interval. Since there are two video quadruplex heads, there are eight video preamplifiers followed by a four-pole, double-throw electronic switch feeding the standard signal system. Switching is initiated at a time determined by the control logic.

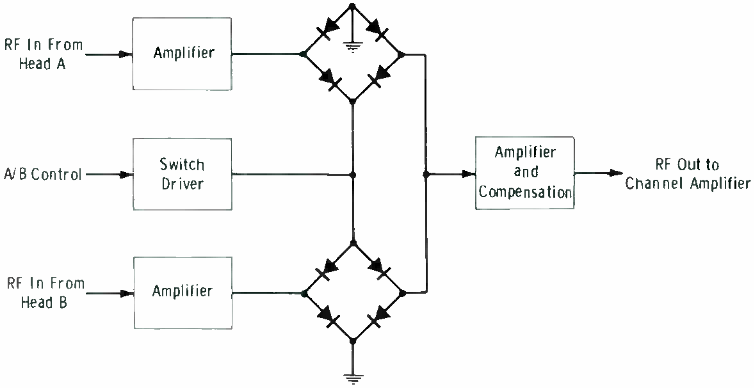


Fig. 13-13. Playback rf switch in ACR-25.

The four playback rf switches are constructed on two shielded printed-wiring assemblies containing two switches each. A block diagram of one switch is shown in Fig. 13-13. Most critical of the specifications for this switch is isolation, since it is possible for the video head in one transport to be used for recording while the other is used for playback. During this mode of operation, the signal present at the unwanted input is about 20 dB higher than the nominal playback value. Rejection of the unwanted signal is 80 dB, while the frequency response of the desired channel is ±0.1 dB from 100 kHz to 16 MHz at unity gain. Second-harmonic distortion is less than −60 dB.

Channel-by-channel equalization and differential-gain control are set to particular values by dc voltages applied to the standard signal-system circuits. Since the two video heads have different characteristics, it is necessary to switch these voltages obtained from two independent sets of front-panel controls. Automatic control of equalization is an optional accessory as in other vtr's.

Since there is only one demodulator, video signals off-tape are not available to one servo system during roll time if the other transport is being

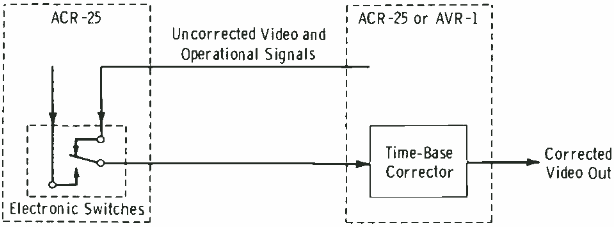


Fig. 13-14. Sharing of time-base corrector.

used for playback. Therefore, the servos lock to the control track, and when the A/B switch occurs, the new horizontal-sync time may differ by as much as ±½ line. In order to produce a fully synchronous output, the time-base corrector must have a 64-microsecond range. This wide time-base-correction range is an extremely important factor in simplification of the signal-system electronics for a dual-transport vtr. A further simplification is possible since the time-base corrector is easily shared by two vtr's as shown in Fig. 13-14.

Flexible record capabilities are provided by two switches in the record rf path and one switch in the input video path, as shown in Fig. 13-15. In record-only modes, the dub switch selects input video, while the two record

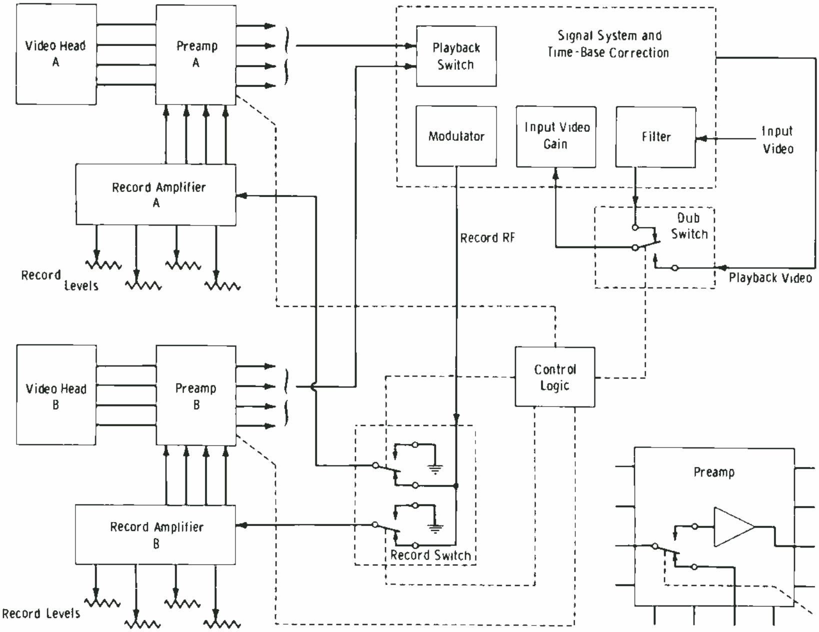


Fig. 13-15. Record mode of ACR-25.

switches direct the modulator output. It is possible to record on transport A, transport B, or both. A block diagram of the dub switch is shown in Fig. 13-16. This switch isolates the two possible video sources without degrading system specifications. Rejection of the unwanted signal is at least 70 dB, while the frequency response of the desired signal is ±0.1 dB from dc to 10 MHz. Differential phase is within 0.5°, and differential gain is less than 0.5 percent. Isolation specifications for the record switch are determined by operation during the dub mode. Record rf leaking into the active preamplifier must be avoided. This turns out to be relatively easy, since the record amplifier is turned off and there is relay switching in the preamplifier. With a gated limiter amplifier, the output from the undesired channel is at least 70 dB below the incoming signal. Frequency response through the desired channel is ±0.1 dB from 100 kHz to 16 MHz.

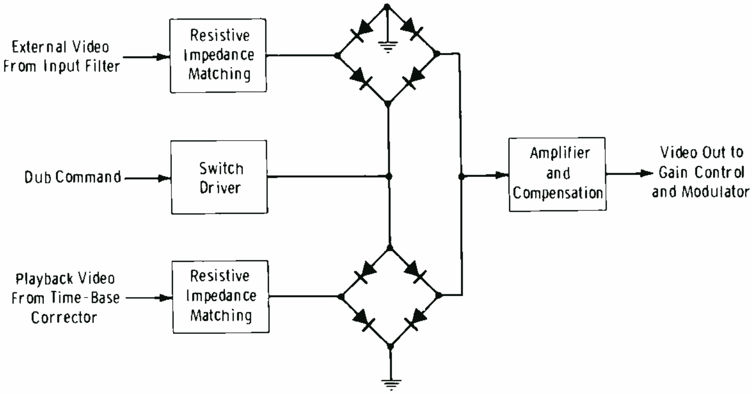


Fig. 13-16. Dub switch in ACR-25.

It is quite likely that spots to be played back-to-back will have been made on different vtr's at different locations and with different variations from standard practice. To handle these variations during automatic operation, chroma phase, video output level, and black level are controlled by dc voltages which may be changed corresponding to digital information recorded on the cue track.

Head and Capstan Servos

Each tape transport has associated with it a complete third-generation head and capstan servo system. These two independent systems are tied together by control logic as required for back-to-back operation. Cycle time (defined as the amount of time required after the completion of one spot until the next spot is available) is almost entirely determined by the various servos. Basic elements of cycle time are shown in Chart 13-1. Although the signal system needs only simple switches to handle back-to-back operation, it is necessary for the head and capstan servos to respond to normal opera-

Chart 13-1. Elements of ACR-25 Cycle Time

Thread Into Rewind Mode
- Stop Head and Tape
- Move Capstan and Guide
- Pull Tape Into One Column

Rewind

Unthread From One Column

Change Cassette
- Eject
- Move Carrousel
- Inject

Thread
- Tape Into Top Columns
- Move Capstan and Guide

Cue
- Search
- Park

Roll

tions more quickly and to perform some new functions. Other major components of cycle time are determined by reel servos, the carrousel servo, and various electromechanical components.

An important segment of cycle time is cuing. Each time a spot is to be played, it is first threaded at a point ahead of the cue point. At the earliest possible time, the tape is pulled forward at 150 in/s until digital information from the cue track starts the park cycle. Fig. 13-17 is a block diagram of the cue servo. The basic functions of this servo are to generate a velocity profile for parking and to determine when the tape is properly parked.

When the cue command is received, the up/down counter is preset to 488, which represents the number of capstan tachometer pulses between

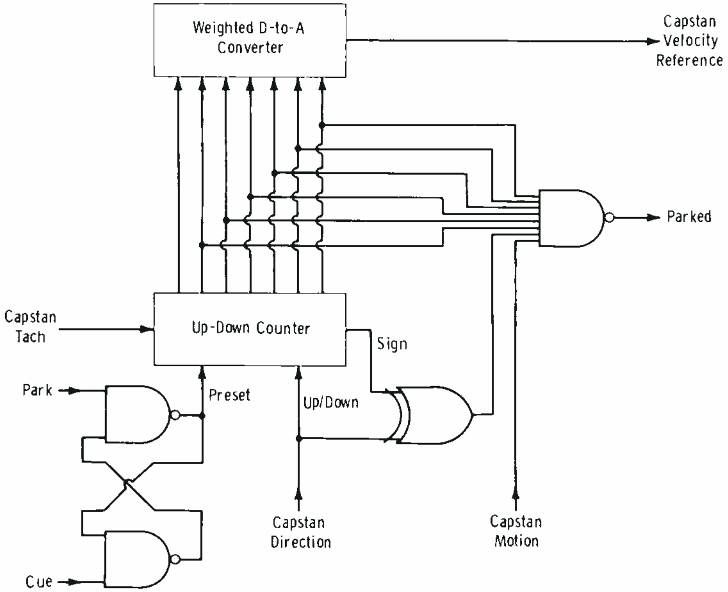


Fig. 13-17. Cue servo in ACR-25.

where the park command will be given and the desired parking point. Contained on the cue track is a continuous playback-speed countdown of time before the start of message (som). In both 525- and 625-line operation, the park command is given at two seconds, seven frames before the som. Due to the difference in tape speed, a 525-line tape will park at 0.2 second before som, whereas a 625-line tape will park at 0.35 second before som. These distances correspond to the respective roll times for 525- and 625-line operation. Receipt of the park command releases the preset input and allows the counter to function. Digital information from the counter drives a weighted digital-to-analog converter which produces a reference velocity profile for the capstan servo. Three conditions must be met before the capstan is considered to be parked and the capstan servo is put into the stop mode. These conditions are: the tape is within ± 1 frame of the desired parking point, capstan motion is less than 3.75 in/s, and the capstan direction is such that the last increment of motion will move it closer to the desired parking point. The total time required for the cuing process is less than one second when the tape is threaded at a point approximately 80 inches before som.

The time required for the headwheel to come up to speed and the time required to stop are also important segments of cycle time. Start-up time is mainly a function of motor-drive amplifier power and may be accomplished during the cuing cycle. Stopping is more important. Since the tape is rewound under reel-servo control without any head-to-tape contact, it is necessary to stop the headwheel prior to retracting the vacuum-guide block. Circuitry was added to the headwheel servo to provide velocity control for deceleration down to zero speed. With the brushless dc motor of the Mark XX head, this was accomplished simply at a low level by merely reversing the phase of the drive commands to the six-phase motor and detecting a stopped condition in a manner similar to capstan parking.

Automatic features common to the AVR-1 are autotracking and guide servo, which are helpful in back-to-back operation of tapes that vary from standard practice. Even though the servos are capable of locking up on a badly misplaced control track, this does not occur in the 0.2 second allowed in cycle time. For this reason, one of the servo systems is equipped with the capability of replacing any control track with one recorded to standard specifications. This is done once when the tape is first previewed, and thereafter fast lock-up will always be obtained.

Fig. 13-18 is a block diagram of the control-track rewrite method. Basically, the capstan position loop is locked by using an advanced control-track read head so the control track can be erased and rewritten using the normal heads.

Module B1 generates a positional-error signal by comparing the phase of the advanced read-head signal to the headwheel-tachometer signal. Since an incorrect control track may be of any phase, the head-tachometer pulses may be shifted by 0 to 360° as determined by the control-track preset, a front-panel adjustment. Both the advanced control-track head and the erase head are located in the video-erase stack; hence a 5-kHz low-pass filter is required to eliminate erase-bias frequencies from the advanced control-track signal. The control-track filter and squarer are standard circuits as used in the normal playback mode. Position information from module B1 is added to the normal velocity information obtained by comparing the headwheel tachometer and the capstan tachometer.

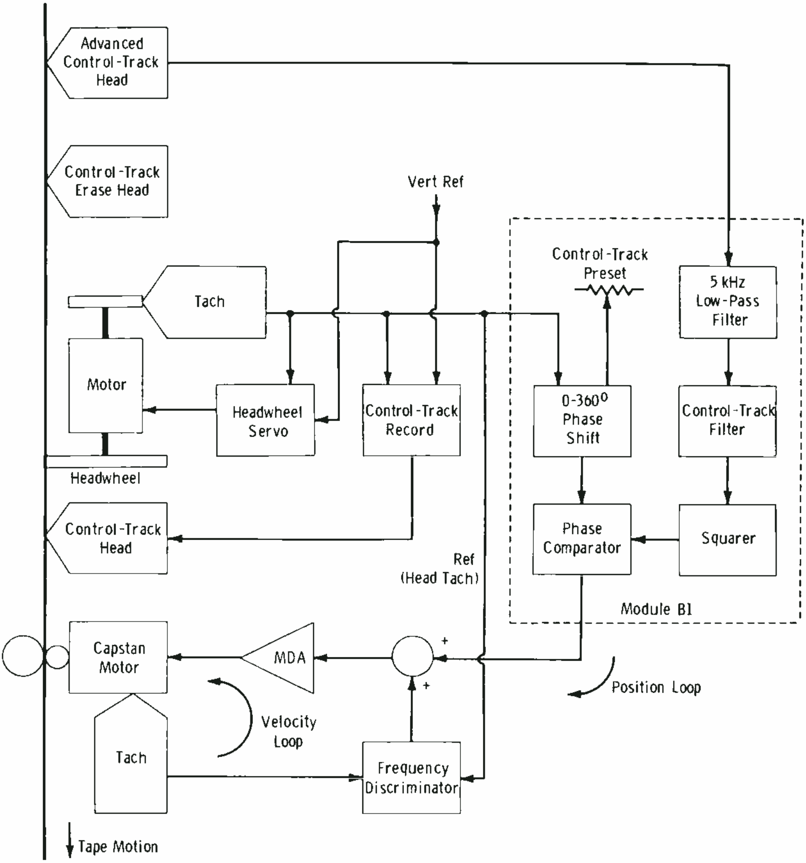
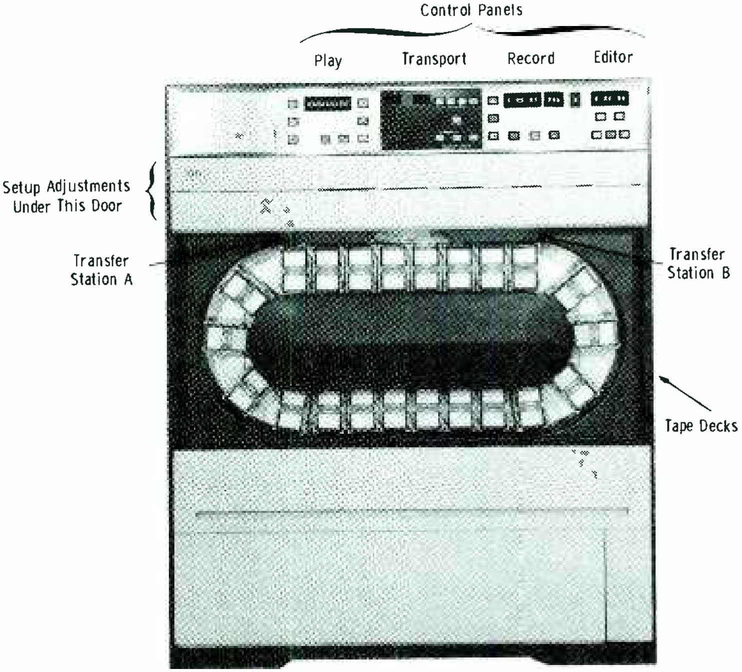


Fig. 13-18. Control-track rewrite mode in ACR-25.

13-3. THE RCA TCR-100

The RCA TCR-100 makes and/or plays tv program material contained in cartridges which hold from 2 seconds to 3 minutes of tape. The machine holds 22 cartridges (Fig. 13-19). The system is most useful in handling



Courtesy RCA

Fig. 13-19. Front view of RCA TCR-100 cartridge system.

short program segments such as those that occur during a station break. Commercials and program events in cartridge form can be aired automatically in sequence, with all details, including threading and video switching between cartridges in a sequence, handled by the system.

The cartridge system utilizes a video-tape cartridge as the carrier, or package, for each recorded segment. It has the capability of playing back the cartridges one after another, assembling signals from each into a complete, continuous program. This is accomplished by including two playback stations (tape decks) within the equipment. Also included are appropriate switching and control electronics and a cartridge-changer mechanism with a capacity of 22 cartridges. The equipment is programmed to play a sequence simply by placing the appropriate cartridges in the changer mechanism in the order in which they are to be played. It is made ready by activating a cue-up mode, and at the appropriate time, the sequence is initiated by supplying a single start command.

The cartridge is a molded plastic container measuring approximately 2½ × 3⅓ × 5 inches. It holds two small spools of two-inch quadruplex video tape. It provides proper tape handling in the equipment, as well as adequate tape protection outside of the equipment. To achieve protection, doors on three sides of the cartridge are normally closed. They open automatically once the cartridge has reached the playing station of the equipment. For convenience in handling and storing, there are no protrusions on the cartridge; all requirements are met within the rectangular outline.

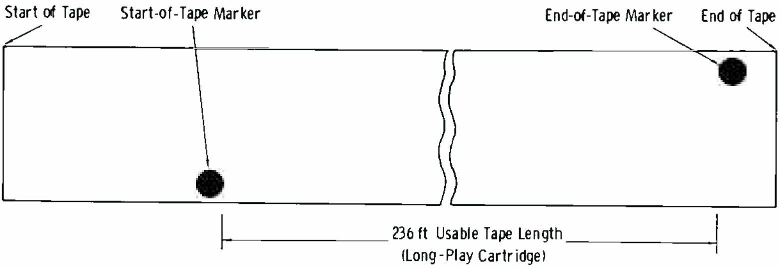


Fig. 13-20. Locations of mechanical cue markers.

Maximum tape capacity is 236 feet of usable tape length plus leader and trailer. This gives a program playing time of a little more than 3 minutes at 15 in/s for 525-line television systems. The recorded format on the tape is the same as for high-band quadruplex reel-to-reel tapes. There is only one recording standard and one tape speed (15 in/s). The recorded format also includes several cue marks, which are necessary for proper operation of the system. These are placed on the tape automatically when a cartridge is recorded.

Every cartridge has two permanent mechanical (reflective) cue marks located near the ends of the tape (Fig. 13-20). These are used to prevent the tape from being completely unwound under any condition while in the equipment. Also, the start-of-tape marker is used as the bench mark for recording. To make ready for recording, the equipment automatically locates the start-of-tape marker in order to determine where on the tape a recording should begin.

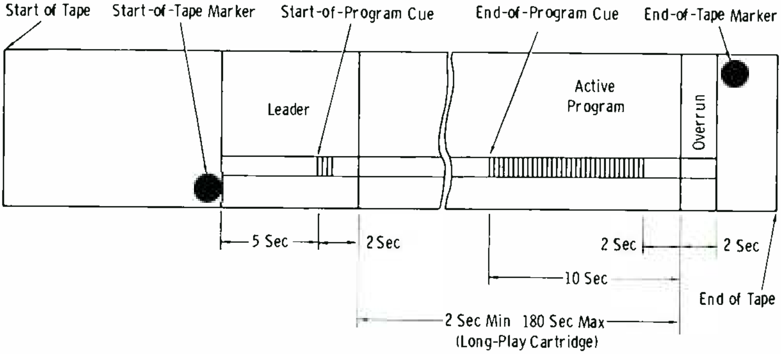


Fig. 13-21. Cartridge-tape format.

The recorded tape format (Fig. 13-21) requires two additional magnetic tone marks on the cue track of the tape to determine the exact location and duration of the actual program segment. A start-of-program tone mark is placed exactly two seconds before the start of the active program material. This mark is used to determine the exact point from which the equipment will start when it is commanded to play back. Therefore, a two-second preroll command must be given. The cartridge recorder will start up and provide a fully synchronized color picture in less than two seconds so that the signal may be reliably put on the air two seconds after start-up.

An eight-second end-of-program tone mark is placed ten seconds before the end of the program. This mark is positioned during recording by telling the system the duration of the program, from which the system computes the correct location for the mark. There is also a mode available to reposition this mark to correct an improperly recorded tape. The trailing edge of the eight-second tone mark is used for the start pulse to the next cartridge in a sequence, so that the two-second preroll is automatically provided. This gives the concept known as *sequential automation.*

The magazine is the cartridge-storage device and the physical interface between the operator and the machine. The magazine contains 22 individual bins for storing cartridges. The bins are mounted on a continuous belt which can be indexed on command, clockwise or counterclockwise, to get the desired cartridge to line up with the entry portals. Indexing is accomplished by a photoelectric sensor, which controls the actuation of a clutch and gear-head motor.

To transfer the cartridge into the recorder, each entrance portal is equipped with a transfer station containing pneumatically actuated claws and a carriage. The claws engage the cartridge, and as the carriage travels, the cartridge is pushed through the entry portal. To retract the cartridge, the reverse procedure is followed, and the cartridge is pulled back into the bin.

All of the bins are continuously accessible to the operator for loading or unloading. However, the operator needs to know which bins are being used. For this, small V-shaped, numbered flags are used. The position of a flag indicates the status of the bin. If the flag is tipped to the right, it physically blocks the entrance to the bin, indicating that its cartridge has been transferred into the recorder.

In addition to the mechanical portion, the magazine contains the logic required to perform the basic functions of indexing clockwise or counterclockwise and transferring in or out. A photoelectric reader provides continuous information about the belt location to the recorder control system.

The two transports contain automatic threading mechanisms (Fig. 13-22) in addition to the normal transport elements. To provide long tape life, the tape path and the threader have been designed to minimize contact with the oxide side of the tape. In the tape path, the erase heads and guiding elements contact only the back of the tape. A urethane-coated capstan is used to provide the necessary tape drive force without the use of a pinch roller; the capstan contacts only the back of the tape. Therefore, the only elements that contact the tape on the oxide side are the video, control-track, audio, and cue record/play heads.

Besides the usual signal electronics mounted close to the magnetic transducers, the transport contains the control logic required to thread and unthread the tape. Photoelectric sensors have also been included to detect fail-safe reflective foil markers placed on the back of the tape near the start and end.

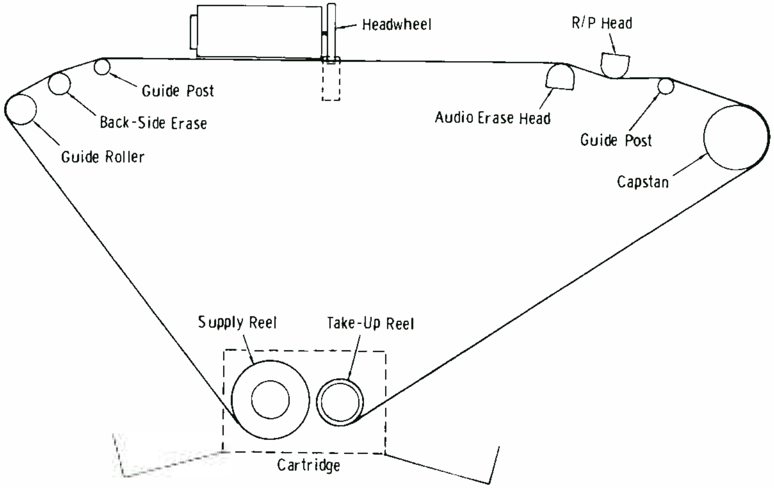


Fig. 13-22. Tape threading path.

The video playback uses a standard quadruplex rotating head assembly. In order to thread the tape through the vacuum guide and around the rest of the tape path, a special mechanism extracts a loop of tape from the cartridge and places the tape in the operating path. The threading mechanism then retracts so that it does not interfere with playback, record, or rewinding of the tape in the normal tape path. At the end of a play or record cycle, the tape is automatically rewound past the start-of-program mark; then the threading mechanism extends and removes the tape from the tape path, and the tape loop is drawn back into the cartridge. The cartridge is then available to be removed from the playing station.

The cartridges are handled in the equipment by a changer mechanism which can carry 22 cartridges (Fig. 13-23). This mechanism consists of a belt with 22 bins, and two transfer stations located above the entrance to each playing station.

The transfer from the bin to the playing station is accomplished by a pair of arms which rotate downward to engage the cartridge on its recessed

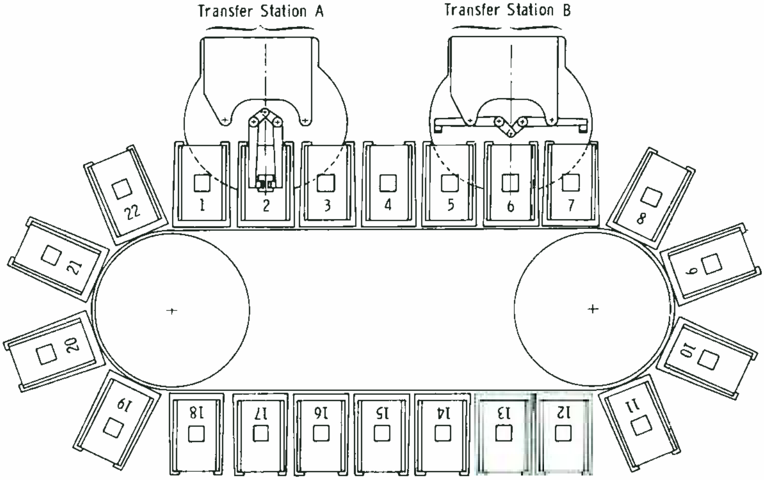


Fig. 13-23. TCR-100 belt changer mechanism.

plate at the rear. The arms then move horizontally back into the equipment to place the cartridge into playing position. Upon completion of a play (or record) cycle, the transfer arms again engage the cartridge and move it back into the bin.

The control system in the equipment provides all the facilities for playing cartridges in a continuous sequence. This sequence is determined by the order in which the cartridges are loaded into the belt. Fig. 13-23 shows the numbering of the sequential locations (bins) in the belt. It is normal to load the belt starting with bin 1. The belt is then positioned for starting by

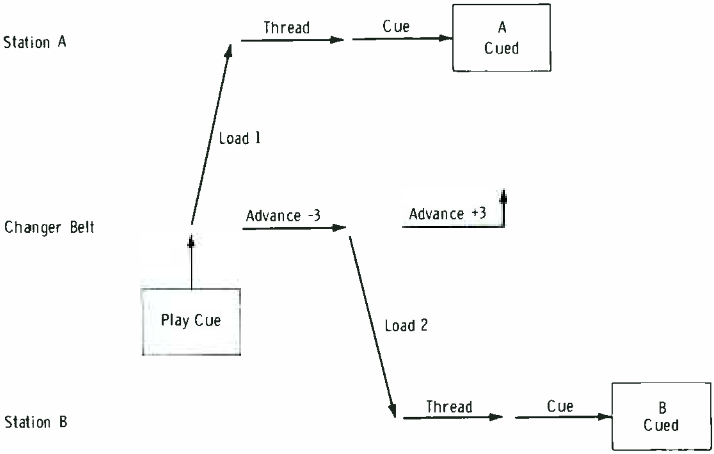


Fig. 13-24. Operations sequence, play cue mode.

activating the home mode, which causes the belt to move so that bin 1 is indexed at playing station A (left).

The machine is made ready for playing a sequence by activating the play cue mode. This initiates the sequence of operations shown in Fig. 13-24, which causes both the A and B playing stations to be loaded, threaded, and cued. At the completion of the cycle, indicators tell the operator that the play cue function is completed and the machine is ready to accept a play command.

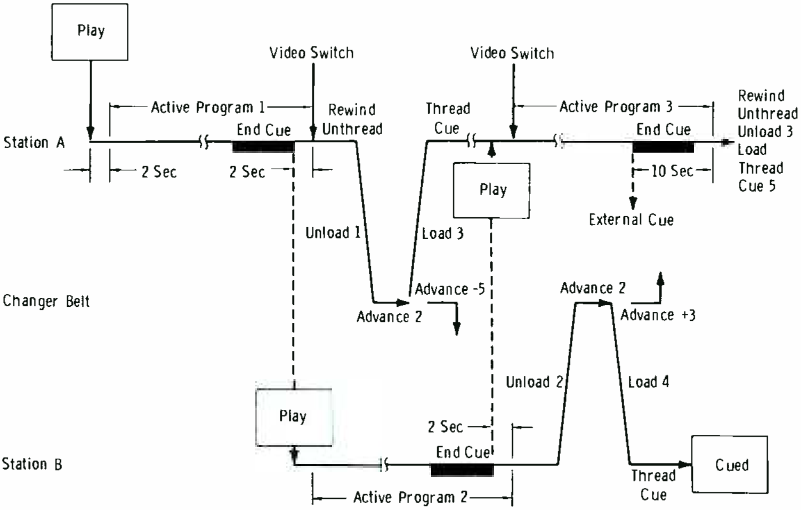


Fig. 13-25. Operations sequence for three cartridges.

A more detailed description of the process is as follows. The play cue command causes cartridge 1 to be loaded in station A (the belt was already positioned for this by the home mode). As soon as cartridge 1 is loaded, the belt moves three spaces to the right, which positions bin 2 at station B. The cartridge from bin 2 is then transferred into station B, and the belt immediately shifts three spaces back to the left. This puts it in position to receive cartridge 1 back in the bin after the cartridge has played and the tape has been rewound and unthreaded.

As soon as each cartridge is in the playing station, the station automatically threads the tape into the tape path and advances the tape in a forward run direction until the start-of-program cue is located. The tape stops accurately at this point, and the playing station is ready to accept a play command.

Upon receipt of a play command, the A station is started in the play mode (Fig. 13-25). The servo system provides a fully synchronized color picture in less than two seconds, and the active program material commences two seconds after start. The machine then plays through cartridge

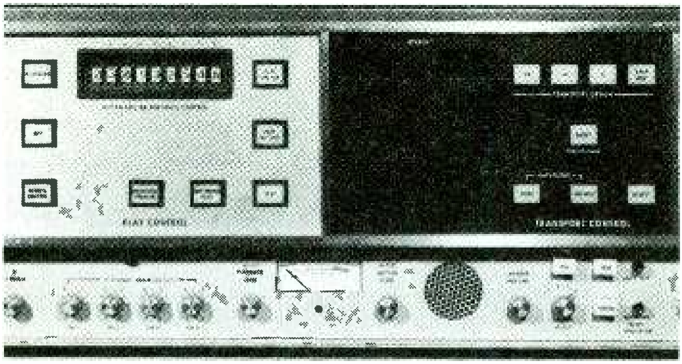
1 until the end cue is detected (starting ten seconds before the end of the program). The trailing edge of the cartridge-1 end cue is directed to start the B playing station. (This occurs two seconds before the end of the program on cartridge 1.) Two seconds after the start of the B station, this station will be fully synchronized, and the program is automatically switched from the A station to the B station. The program switch takes place during the vertical-blanking interval and gives a transition equivalent to an excellent electronic splice.

As soon as the program switch to the B station has taken place, the A station automatically rewinds cartridge 1 until the start cue is passed. Cartridge 1 is then stopped, unthreaded from the tape path, and unloaded back into bin 1 in the belt, which has been waiting in the proper position. The belt then moves two spaces to the left, which brings bin 3 into position at the A station. The cartridge from this bin is then transferred into the A station, and the thread and cue cycle is again activated. When threading and cuing of cartridge 3 are completed, station A is ready to accept a start trigger. Meanwhile, as soon as cartridge 3 has been transferred, the belt moves five spaces to the right, which places bin 2 at the B station, ready to receive cartridge 2 when its cycle has been completed.

The B station meanwhile is continuing to play cartridge 2. When the trailing edge of the end cue from cartridge 2 is passed, a start trigger is directed back to the A station. This station, containing cartridge 3, begins running, and after two seconds the program switches back to A. At this point, the B station goes through the cycle of rewind, unthread, unload, advance belt, load, thread, and cue to ready cartridge 4. The cycle of removing one cartridge and readying the next one in the same playing station takes a little less than twenty seconds. This means that the shortest program segment which can be sequenced continuously is twenty seconds. However, either the first or last segment in a sequence can be shorter, since it is not necessary to complete the cartridge change cycle at the other playing station during either the first or last segment of a sequence. In such cases, the cuing system is capable of handling program segment lengths down to two seconds.

Play Control

The play control panel is shown at the upper left in Fig. 13-26. Preparing the TCR machine for on-the-air operation is a 3-step procedure: programming, previewing, and playing. (1) To program the machine, the number of sequences and the number of cartridges in each sequence are put into the automatic AB sequence control, and the AUTOMATIC button is pressed. The PLAY CUE-UP button readies the first two cartridges for play. (2) To preview, the SEQUENCE PREVIEW button is pushed; then all events in the upcoming sequence are seen. (3) To put the machine on the air, the PLAY button is used. (If control is from another source, the REMOTE CONTROL button is used.)

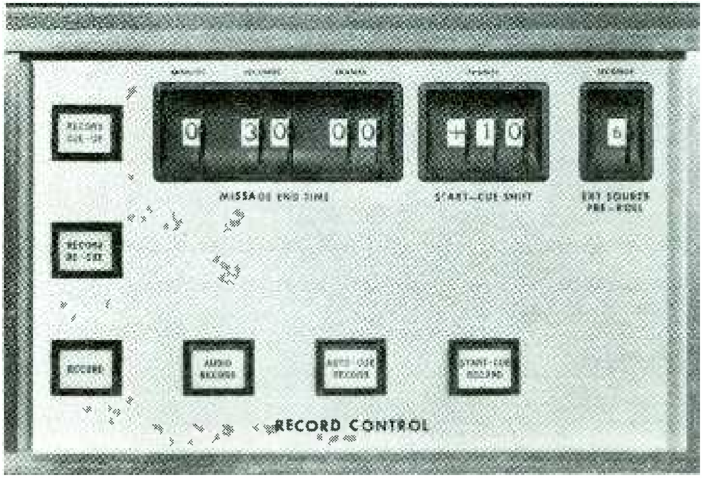


Courtesy RCA

Fig. 13-26. Play and transport control panels.

Transport Control

The transport control panel is shown at the upper right in Fig. 13-26. These controls select the transport option in which the machine is to operate and position the cartridge magazine. Provision is also made for cartridge reject and resetting of logic functions. The left-hand portion of the transport control panel is a 40-item illuminated status indicator. Color-keyed displays of red, orange, and green indicate relative importance. As a result, the operator is always aware of what is happening inside the machine.



Courtesy RCA

Fig. 13-27. Record control panel.

Record Control

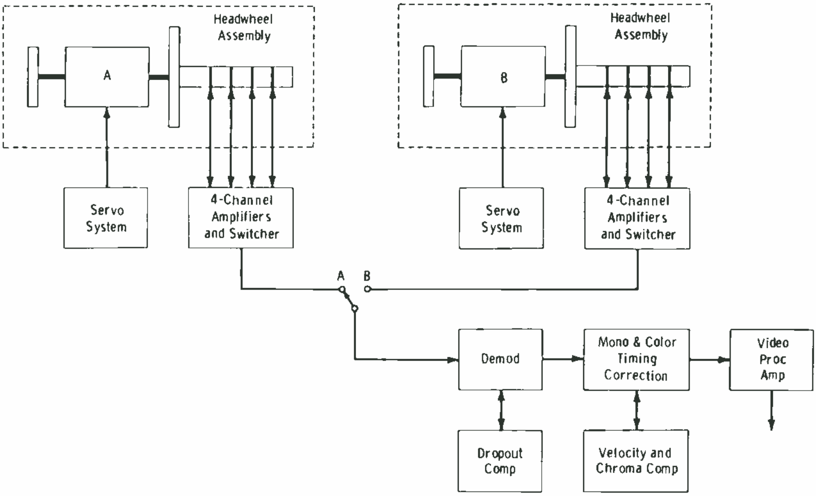
The record control panel is shown in Fig. 13-27. Cartridge recording on the TCR-100 is a three-step procedure: preset, cue-up, and recording. To preset the machine, the message length is set on the MESSAGE END TIME thumbwheels, and the external-source preroll time is set on the EXT SOURCE PRE-ROLL register. Next, the RECORD CUE-UP button readies the cartridge to be recorded. Then, a touch of the RECORD button starts the recording process. Following completion of the recording, the machine automatically rewinds and recues the cartridge for immediate replay. A touch of the PLAY button rolls the tape for review.

System Electronics

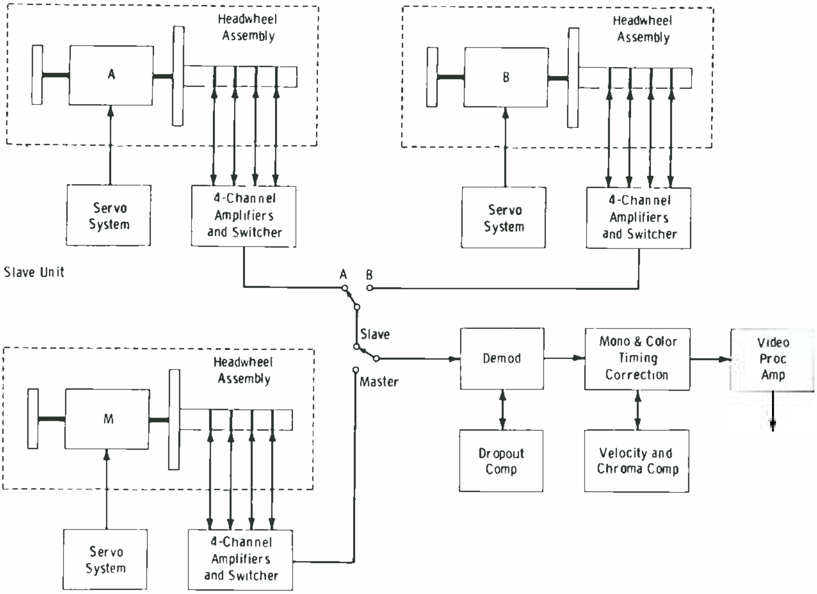
The system outlined in the preceding description could basically consist of two independent automated vtr systems coupled together with a common control system and a common cartridge changer belt. However, in such a system, it is not necessary to provide two complete electronic systems for the two vtr's because they are never used simultaneously. More specifically, it is completely possible to time-share the video-signal electronics. This is the most expensive portion of the tape-recorder electronics, so a major economy can be realized.

The sharing of video-signal electronics in playback is accomplished by performing the switching between the two playback stations while the signal is still in the fm format as recorded on the tape (Fig. 13-28A). Therefore, only one set of electronics—including demodulator, monochrome and color time-base corrector, velocity and chroma error compensator, dropout compensator, and signal-processing amplifier—is necessary for the two playback stations. However, to allow for one playback station to start while the other station is still on the air, it is necessary to provide two complete servo systems. It is also necessary to have an fm playback preamplifier, an equalizer amplifier, and an fm switcher for each of the two headwheel assemblies. With this equipment arrangement, the system will provide instantaneous signal switching between the two tape playback stations with excellent timing stability of both signals.

Since the video-playback signal electronics is identical to that in presently available high-band video recorders, the ultimate economy is achieved when the cartridge system "borrows" the signal electronics from an existing reel-to-reel vtr (Fig. 13-28B). In this case, the cartridge system is a "slave" to the reel-to-reel vtr, which becomes the "master." The master/slave arrangement is accomplished by modifying the master machine to provide an fm switch which selects between the normal fm output of the reel-to-reel electronics and the output of the cartridge slave unit. This switch is also arranged to operate during the vertical-blanking interval, and the servo system of the master machine is modified so that an excellent video switch transition is possible between the master machine and a cartridge. This



(A) Cartridge playback.

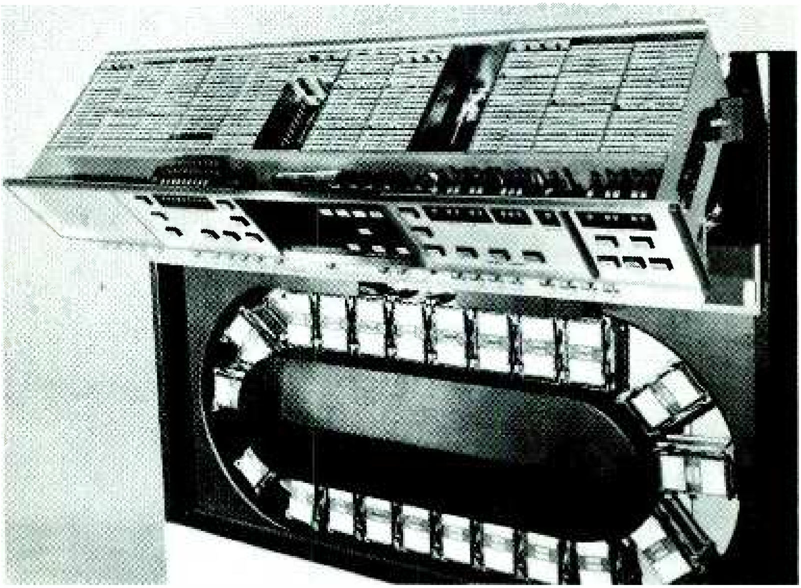


(B) Slave/master machine electronics.

Fig. 13-28. System arrangements for TCR-100.

means that it is possible to insert a sequence of cartridges in a program played on the master reel-to-reel machine with good video switch transitions at all points. It is also possible to go from the master machine to the cartridge playback, change or recue the tape on the master machine while cartridges are playing, and then go back to the master machine at the end of the cartridge sequence, all within the one master/slave equipment complex.

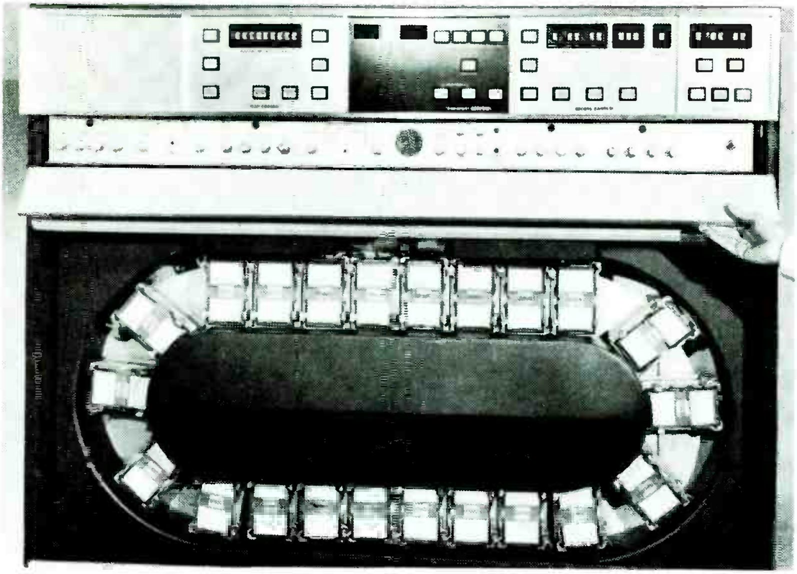
The TCR-100 electronics systems occupy enclosed spaces above and below the cartridge magazine and transport section. All of the control electronics is in a roll-out drawer behind the control panels above the magazine. Fig. 13-29 illustrates the roll-out and swing-down electronics arrangement for servicing accessibility. The electronics is made up of printed-circuit cards which plug into nests in each electronics drawer. Signal-handling and transport servo-system electronics is in a drawer below the magazine.



Courtesy RCA

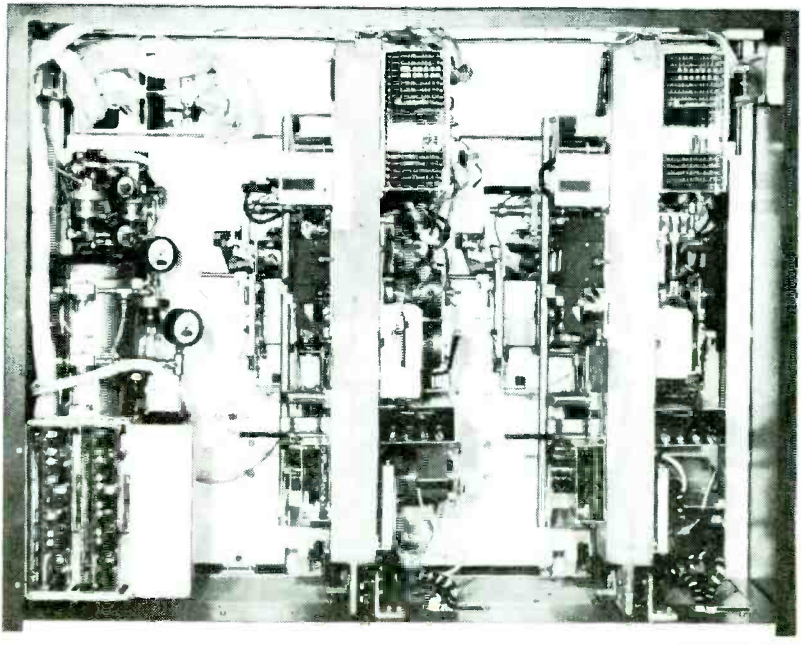
Fig. 13-29. Control electronics in servicing position.

Normal operation of the system requires that a setup routine be performed periodically, probably daily in most installations. In this routine procedure, the playback system of the cartridge recorder is equalized for optimum playback of a standard test cartridge. With the playback system thus adjusted, the recording function of the machine is then checked and adjusted, if necessary, to insure that the playback system and its automatic



Courtesy RCA

Fig. 13-30. Setup adjustment panel with door open.



Courtesy RCA

Fig. 13-31. Rear view of TCR-100.

correction devices are still in center range. Fig. 13-30 illustrates the setup control panel (the narrow panel above the cartridge magazine).

Both tape decks roll out on slides to allow routine maintenance procedures. Access to the transport decks is also available from the rear. Fig. 13-31 is a rear view of the TCR-100.

EXERCISES

Q13-1. Can tape recorded on a cassette/cartridge system be played back on a conventional vtr?

Q13-2. Can tapes recorded on a conventional vtr be played on the cassette/cartridge machine?

Q13-3. Does the Ampex ACR-25 cassette machine work alone, or in conjunction with another machine?

Q13-4. Does the RCA TCR-100 cartridge machine work alone, or in conjunction with another machine?

Q13-5. What is the meaning of (A) sot and (B) eot?

Q13-6. What means is used to mark sot and eot on (A) Ampex cassette tape and (B) RCA cartridge tape?

Q13-7. If the cassette/cartridge machine is self-contained, give the number of (A) video head panels, (B) transports, (C) demodulators, and (D) servo systems necessary.

Q13-8. What must be the maximum allowable lock-up time for a cassette/cartridge tape system?

CHAPTER 14

Video Disc Recording Systems

The video disc recorder, which essentially uses the same basic recording and playback techniques as the magnetic tape system, is rapidly becoming standard equipment in the television broadcast industry. The initial application of this system was in the slow-motion, stop-action type of "instant replay," and this is still one of the major functions performed by video disc recorders. However, its use has expanded in recent years into the field of providing automatic and practically unlimited varieties of special effects, editing, and animation techniques for creative television. Its possibilities in special teleproduction applications are rapidly expanding and are limited only by the imagination of directors, producers, and artists.

We will first examine the basics of the single-disc, two-head system. Then we will progress to the Ampex two-disc, four-head system, which is the most commonly used video disc recorder at the time of this writing. If the reader will study the contents of this chapter thoroughly, he should be able to keep abreast of future developments in this field, since certain fundamentals serve as the foundation for all such systems.

14-1. THE SINGLE-DISC, TWO-HEAD VIDEO SYSTEM

Examples of the single-disc, two-head system are the Visual Electronics Corp. VM-90 and the VDR-1000 by Data Memory, Inc., and TeleMation, Inc. Fig. 14-1 illustrates the basic function of a two-head disc recording system. The highlights of this technique can be outlined as follows:

1. The disc consists of aluminum substrates lapped to optical flatness, then electroplated with a thin layer of magnetic nickel-cobalt. This surface is then plated, or *flashed,* with a few microinches of rhodium to provide a mirror-like running surface for the heads and to prevent surface corrosion. The DMI video disc has a ¼-inch aluminum base coated with polished copper and an overlay of nickel-cobalt alloy

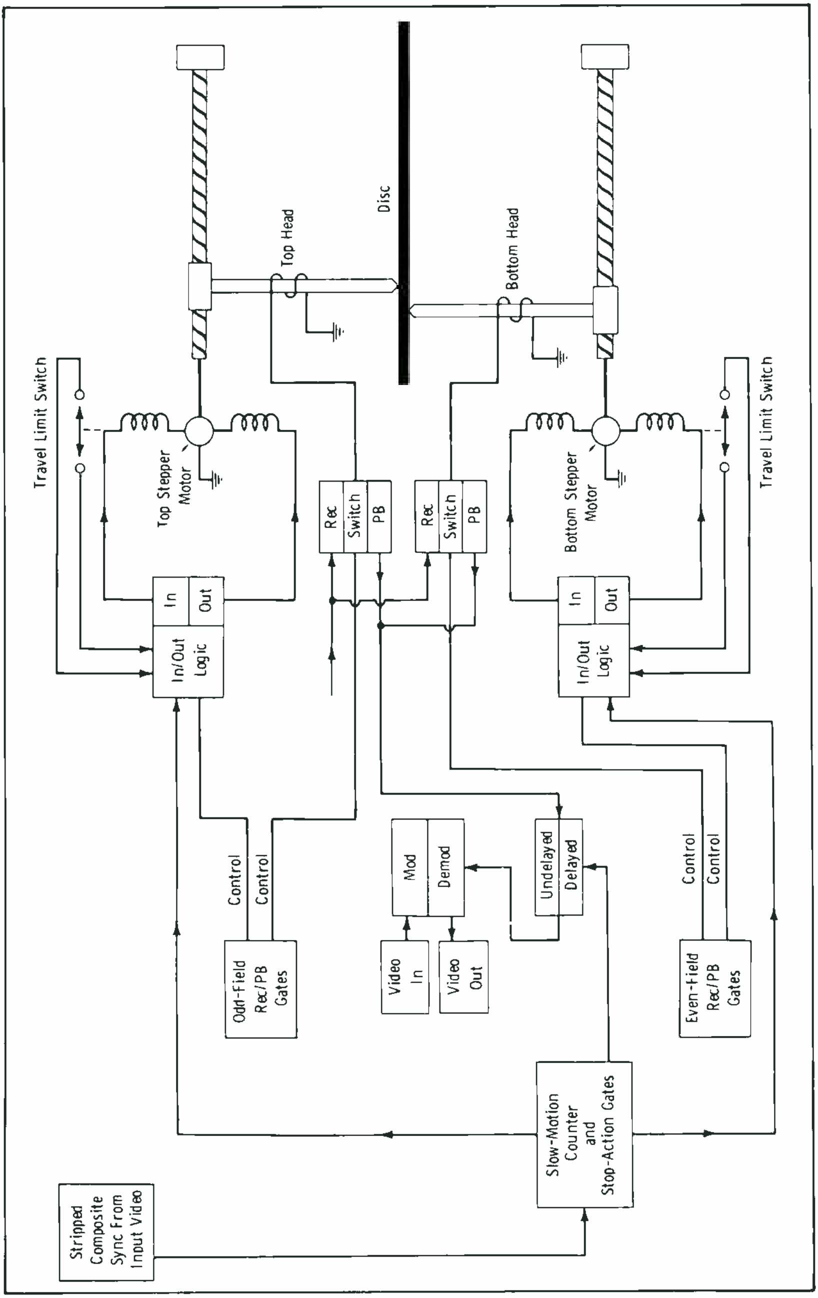


Fig. 14-1. Block diagram of two-head video disc recorder.

which accepts the magnetic signals. A coating of Chromecote provides an extremely smooth riding surface for the heads.

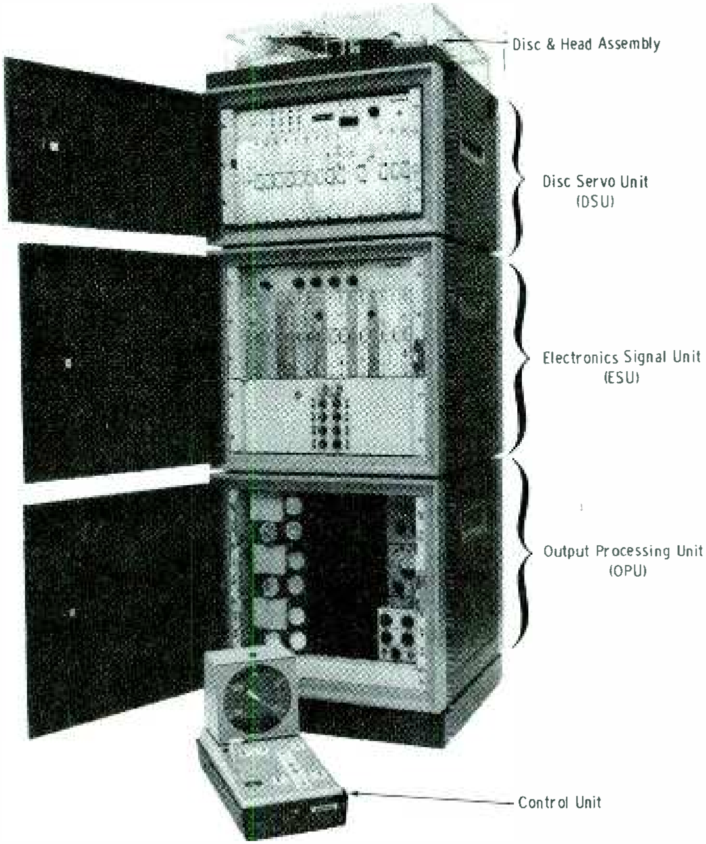
2. The rotating disc is contacted by two record-playback heads, one on top and one on the underside.
3. Individual fields are recorded as separate, circular tracks on the disc surface. In Fig. 14-1, the odd-numbered fields are recorded on the top, and the even-numbered fields are recorded on the bottom
4. The recording sequence is as follows: Starting at the inside edge of the disc, field 1 is recorded by the top head. Field 2 is recorded by the bottom head. During the time of field 2, the top stepper motor advances the top head two tracks. The top head then records field 3. During the time of field 3, the bottom motor advances the bottom head two tracks. The entire process is then repeated.
5. At the end of travel in the first direction (inside-out), the last two fields are recorded, and each head moves back one step, again recording the odd field on top and the even field on the bottom. The steppers then revert to movement to every other track, and information is recorded on the tracks left vacant on the first pass. With this two-head system, all tracks are filled in 30 seconds.
6. For slow-motion or stop-action playback, a field must be used over and over. To produce interlaced frames, the video information in a single field is first delayed by a half line and then (by means of an electronic switch) is undelayed for the next field duration. The information in the two fields is identical, but displaced vertically one-half line on the raster to provide a full interlaced frame. The question usually asked here is why a full *frame* is not repeated rather than one field. The answer is that in scanning the two fields making up a frame, a time differential of 1/60 second exists at any one point on the raster. A rapidly moving object (such as a football, for example) will produce a very noticeable double-exposure effect in the interlaced frame.

14-2. THE AMPEX HS-100 VIDEO RECORDER/REPRODUCER

The Ampex HS-100 is a two-disc, four-head recorder/reproducer system; it is quite popular for a large number of special applications at the time of this writing. We will first explore the general features of the equipment, and then progress into more detailed analysis of circuit functions. Much of the electronics is the same as that described for the conventional quadruplex recorder. We will, therefore, emphasize the circuits that differ from those already covered.

General

The Ampex HS-100 slow-motion video recorder and reproducer (Fig. 14-2) is a transportable instant-replay television recorder/reproducer man-



Courtesy Ampex Corp.

Fig. 14-2. Ampex HS-100 video disc recorder/reproducer system.

ufactured for use in studios, mobile vans, or indoor remote broadcast sites. It is capable of recording standard NTSC color or monochrome video signals and then immediately replaying the recorded material, either forward or in reverse, at normal speed, twice normal speed, one-half normal speed, one-fifth normal speed, or at manually controlled, continuously variable speeds ranging from stop-action (freeze) to normal. The HS-100 also permits operator-controlled, single-frame video advance, either forward or in reverse, whenever playback is in the freeze mode. The video output fully complies with NTSC and FCC standards regardless of speed or direction changes. Storage capacity is 1800 television fields, corresponding to 30 seconds of video material in the normal record mode, or 60 seconds of material in the alternate-field record mode (i.e., recording only every other television field).

The HS-100 is packaged in four units: the disc servo unit (dsu), the electronics signal unit (esu), the output processing unit (opu), and the control unit. Each unit is enclosed in a weather-resistant metal cabinet. Carrying handles on the cabinets facilitate movement of the equipment during transit and installation. For operation, the three larger units (dsu, esu, and opu) can be stacked vertically with the dsu on top, the esu in the center, and the opu on the bottom; or they can be placed side by side with the esu in the center. All controls required to operate the HS-100 are on the control unit. The control unit connects to the esu through a single 30-foot multiconductor cable (200-foot cable extensions are available on special order) and can be placed in any convenient location. Features of the individual units are described in the following paragraphs.

Disc Servo Unit (DSU)

The disc servo unit contains the electromechanical components of the HS-100 and their associated electronics. Electromechanical components include a disc drive assembly, with its associated circuitry, and four stepper assemblies. The disc drive assembly controls the rotation of two magnetic recording discs, each of which provides two recording surfaces (top and bottom side of each disc). Each of the four stepper assemblies controls the movement of one carriage assembly, with its record/reproduce head, across one of the four disc surfaces. The disc drive assembly and the four stepper assemblies are mounted on a machined aluminum top plate, which is in turn shock-mounted to the frame of the dsu cabinet. The top plate and the electromechanical and electronic parts mounted on it are called, collectively, the top-plate assembly. Protection for the top-plate assembly is provided by a clear acrylic dust cover. During handling and shipping, additional protection is provided by a removable steel cover that fits over the acrylic dust cover and latches to the dsu cabinet.

The electronics for the dsu is on plug-in printed circuit modules (cards) which plug into a card rack extending across the front of the unit chassis below the top-plate assembly. These components are protected by a door on the front of the unit. A connector panel and an air exhaust opening are located at the rear of the unit.

Electronics Signal Unit (ESU)

The electronics signal unit contains most of the signal-system electronics, the control logic, and the major parts of the power-supply system. Printed circuit modules on plug-in card assemblies are housed in a card rack extending across the front of the unit. A panel above the card rack contains secondary operating controls. A power supply, containing front-mounted fuses and test points, is mounted on a second panel directly below the card rack. The front of the esu is protected by a hinged metal door. A connector panel at the rear of the unit contains connectors for the main power cable, video inputs and outputs, sync inputs, and cables that interconnect with the disc servo unit, the output processing unit, and the control unit. Cooling for the esu circuits is provided by an internal blower.

Output Processing Unit (OPU)

The output processing unit contains a standard Ampex Amtec, a standard Ampex Colortec, and an Ampex processing amplifier. These assemblies are mounted on slide rails in the opu cabinet for easy maintenance access. All normally used operating controls (used for initial equipment setup) are on the front of the individual assemblies. The cabinet is equipped with hinged front and rear doors, a connector panel, and a blower. Electrical connections to the opu are made at the connector panel at the bottom rear of the unit.

Amtec Time-Element Compensator—The Amtec time-element (time-error) compensator is a self-contained electronic assembly. Most of the Amtec circuits are contained on plug-in printed wiring board assemblies which can be easily removed when the Amtec assembly is pulled forward on its slide-rail mountings. All operating controls for the Amtec are mounted on the right side of the assembly front panel.

Colortec Direct Color Recovery System—The Colortec direct color recovery system is, like the Amtec, a functionally self-contained electronic assembly, utilizing plug-in printed wiring boards. All operating controls for the Colortec are mounted on the right side of its front panel.

Processing Amplifier—The processing amplifier is physically similar to the Amtec and the Colortec in that it employs solid-state circuitry on printed wiring board assemblies. Operating controls and test points are located on the right side of the front panel.

Control Unit

The control unit contains all the primary controls used to operate the HS-100. It connects to the electronics signal unit by means of a multiconductor cable. All controls are illuminated push buttons except for a lever used for variable slow-motion speed control. All internal circuitry is mounted on one printed wiring board assembly. Mounted above the control panel is an illuminated clock-type dial, calibrated from 0 to 30. A white pointer on this dial indicates the head location relative to the 30-second storage capacity of the system. A red pointer tracks with the white pointer. This pointer can be stopped and then reset to its tracking position at the option of the operator to provide a cue marking. A red on-air lamp is provided at the top of the control unit. This lamp can be wired into the studio master control panel if desired.

14-3. BASIC FUNCTIONAL DESCRIPTION OF HS-100

Video recording in the HS-100 is accomplished by using high-band standards. The incoming composite video signal is converted to a frequency-modulated signal before it is recorded. During playback, the signal is demodulated to produce a standard video output signal. The record and reproduce processes are described separately in the following paragraphs.

Record Process

In the HS-100, video signals are recorded on the four surfaces of two metal discs rotating about a common vertical shaft. Recording is continuous until the operator overrides the record mode by selecting a reproduce or fast search mode. As long as recording continues, the latest 30 seconds (60 seconds for alternate-field recording) of recorded video is maintained in storage, ready for instant playback. Material recorded prior to the 30-second storage limit is progressively erased to permit recording of new material.

Disc Rotation—The rotation speed of the two recording discs is 60 revolutions per second (3600 rpm). This speed is precisely controlled by a disc-drive servo system which instantly detects and corrects drive-motor speed variations (Fig. 14-3). The primary purpose of the disc-drive servo is to lock the rotation of the discs in phase with the external reference vertical sync. This phase lock ensures that each complete revolution of the discs corresponds exactly to one television field, beginning and ending during the vertical blanking period. The disc-drive servo comprises an optical tachometer, driven by encoders on the disc drive shaft, the electronic circuits associated with the tachometer, a velocity discriminator, a phase comparator, the motor drive amplifiers, and the disc drive motor.

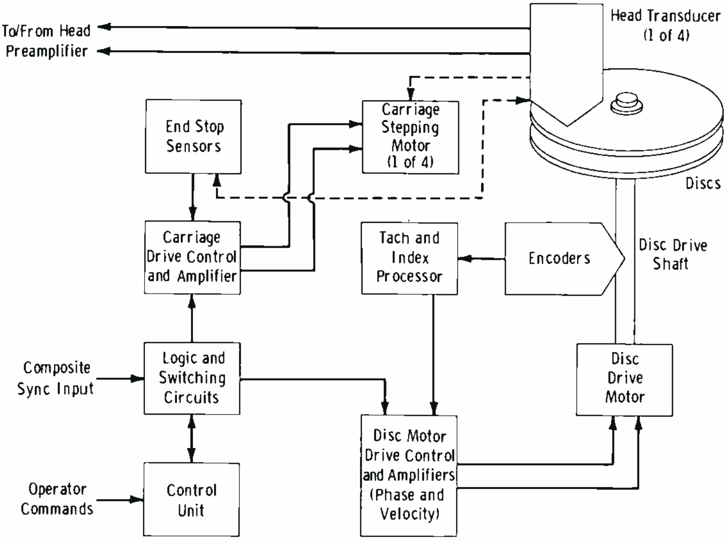


Fig. 14-3. Simplified diagram of disc-drive and carriage-stepping systems.

Head Movement—Each of the four head assemblies used in the HS-100 is moved by an independent stepper assembly that steps the head radially across the surface of the disc. For purposes of identification, the heads and their associated signal paths are referred to as head (or channel) A, head (or channel) B, head (or channel) C, and head (or channel) D. In addition to recording, each head also functions as a playback and erase head. During operation, head A steps radially across the top of the top disc, head B steps across the bottom of the top disc, head C steps across the top of the bottom disc, and head D steps across the bottom of the bottom disc.

Each head assembly consists of a ferrite head transducer and two ferrite pads mounted so that the head and the two pads extend perpendicularly from the corners of a triangular platform. The head and the two pads provide a stable three-point contact with the disc surface, and they are held against the disc by a cantilever spring which bears against the rear of the platform. The head carriage assembly, which moves the head assembly, is mounted on guide rails extending radially across the disc surface. As the head carriage is moved a given distance along the rails, the head transducer is carried across the disc in the same direction and for the same distance.

Driving power for the carriage assembly is provided by a stepping motor controlled by logic circuits and by end-stop sensors (which provide reversing commands). The carriage assembly is coupled to the shaft of the stepping motor through a pinned stainless-steel belt. The manner in which the stepping motors move (or step) their associated carriage assemblies is determined by the track format for the mode of operation being used.

Track Format, Normal Record Mode—Each field is recorded on the disc as a circular track; the head is held stationary while the disc makes one complete revolution. When head A completes recording a single field, head B starts recording the next field. While head B is recording, head A is being stepped to a new position. When head B has recorded its field, head C records the next field. While head C is recording, heads A and B are both being stepped to new positions. When head C has completed recording one field, head D starts recording, head A erases the track in which it is now positioned, and heads B and C are stepped to new positions. When head D completes recording one field, head A starts recording in the track it just erased, head B erases, and heads C and D step to new track locations. In this manner each head records every fourth field, and successive fields are recorded by heads A, B, C, and D in rotational sequence. Heads A and C record odd-numbered fields; heads B and D record even-numbered fields.

Recording, moving, and erasing follow a definite sequence for each head. For example, during field 1, head A records. During field 2, the stepper assembly moves head A 0.010 inch radially across the disc (tracks are 0.007 inch wide, 0.010 inch center-to-center). During field 3, head A is moved an additional 0.010 inch radially, placing it a distance of two tracks away from where it recorded (during field 1). During field 4, head A erases, with a dc current, any signal previously recorded on the track in

Table 14-1. Head Sequencing in Normal Record Mode

Head (or Channel)	Field 1, 5, 9, 13, etc.	Field 2, 6, 10, 14, etc.	Field 3, 7, 11, 15, etc.	Field 4, 8, 12, 16, etc.
A	Record	Step	Step	Erase
B	Erase	Record	Step	Step
C	Step	Erase	Record	Step
D	Step	Step	Erase	Record

which it is now positioned. At the start of field 5, the erase current to head A is switched off, and head A is fed the fm signal output of the record amplifier (part of record signal electronics). The sequence for each head is shown in Table 14-1.

Carriage Reversing—During any given field, one head is recording, one head is erasing, and the remaining two heads are being stepped to new track positions. The heads move in this manner toward the center of the discs until head A eventually reaches its innermost track. This position of head A is sensed by a lamp and photocell arrangement positioned so that the photocell detects head A as it makes its first step from its last record track position. The photocell output, acting through the carriage-control logic circuits, prevents head A from making the second stepping movement. During the two subsequent fields, heads B and C also reach their innermost point of travel and are similarly prevented from making their second stepping motion. On the next field, head A records on the track where it was stopped, and head D steps one track. On the following field, the direction of rotation of all four stepping motors is reversed. The heads then begin stepping toward the outer edge of the disc, following the normal sequence shown in Table 14-1 (Table 14-2 for the alternate-field mode) and recording between the tracks used when the head movement was toward the center of the discs.

At the outer edge of the discs, head travel is again inhibited and reversed by a second lamp and photocell arrangement. Thus, the heads travel continuously until stopped by an operator command. If a stepping error occurs,

Table 14-2. Head Sequencing in Alternate-Field Record Mode

Head (or Channel)	Field 1, 9, 17, 25, etc.	Field 2, 10, 18, 26 etc.	Field 3, 11, 19, 27, etc.	Field 4, 12, 20, 28, etc.	Field 5, 13, 21, 29, etc.	Field 6, 14, 22, 30, etc.	Field 7, 15, 23, 31, etc.	Field 8, 16, 24, 32, etc.
A	Record		Step		Step		Erase	Erase
B	Erase	Erase	Record		Step		Step	
C	Step		Erase	Erase	Record		Step	
D	Step		Step		Erase	Erase	Record	

Blanks indicate periods of inactivity.

the head-carriage logic circuits detect it and correct it at the end stops before allowing the carriages to reverse direction.

Alternate-Field Recording—In the alternate-field recording mode of operation, head sequencing is the same as for the normal recording mode, except that it is triggered at half the rate. The rotation speed of the discs, the track width, and the track spacing are unchanged. The sequence is shown in Table 14-2. Note that only the odd-numbered fields are recorded. During even-numbered fields, no steps are triggered, and the record amplifier is turned off. Erase current, however, is permitted to flow during the even-numbered field intervals.

Record Signal Path—The record signal path, shown in Fig. 14-4, contains a modulator (located in the electronics unit) and a record amplifier and four preamplifiers (located in the disc servo unit). The modulator module contains a preamplifier circuit which amplifies the composite video input, a pre-emphasis network, and a modulator which converts the composite video to a wideband fm signal (rf).

In the record amplifier module, the wideband fm is amplified and divided into four sequentially gated outputs, each of which is applied to a different one of the four preamplifiers. Each preamplifier contains a relay which is energized during the record mode and de-energized during playback. During recording, signals gated out of the record amplifier are applied directly to the head transducer by way of a record-current level-adjustment potentiometer (in the preamplifier) and the preamplifier relay contacts. An erase circuit in each preamplifier supplies a dc erase signal to its associated head transducer when commanded to do so by a gating pulse. The same pulses that gate the fm signals out of the record amplifier supply the erase commands for the preamplifiers. The lines carrying the gating pulses are connected in such a way that the pulse that gates the channel-A signal out of the record amplifier turns on the erase function in the channel-B preamplifier. Similarly, the pulse that gates the channel-B signal out of the record amplifier simultaneously turns on the erase function in the channel-C preamplifier. This sequence, applied to all four channels, ensures that when one head is recording, the head that will record next is erasing previously recorded material.

Reproduce Process

Among the factors involved in the playback of the recorded material are speed, direction, line interlace, chroma phase, and alternate-field playback. These factors are discussed in the following paragraphs.

Normal Speed—In the normal-speed, forward-direction playback mode, the sequence of carriage movement is identical to that used in record. The head connections are transferred, by means of relays, from the record and erase amplifiers to the reproduce preamplifiers. The outputs of the reproduce preamplifiers are sequentially gated through the rest of the reproduce electronics in the same manner that the record current was gated to the

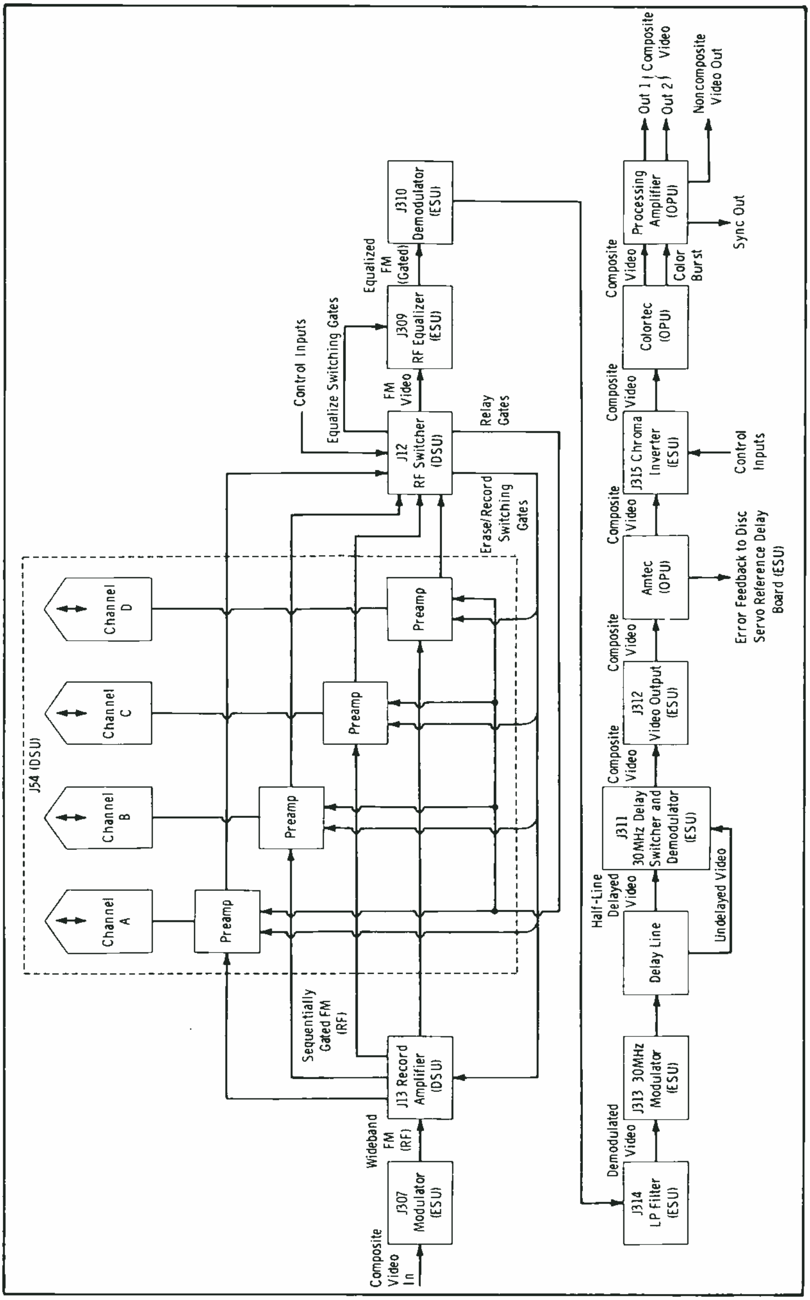


Fig. 14-4. Simplified block diagram of record/reproduce signal path.

heads in the record mode. The sequence of operations is shown in Table 14-3. Each field is reproduced in the exact sequence in which it was recorded so that the demodulated video output is in standard NTSC form.

Still-Frame—In the still-frame, or freeze, mode, the playback sequence of Table 14-3 is stopped on a particular field, and the system video output is derived from the continuously repeated playback of a single track. In this mode, line interlace and chroma phase are restored by special techniques to produce a standard television signal.

Line Interlace—The normal television video signal is a succession of odd and even fields characterized by a half-line shift of horizontal sync (with respect to vertical) in each field (Fig. 14-5). This half-line shift produces line interlace of the two fields that constitute a frame. When, as in the case of still framing, each successive field is derived from the same recorded track, and is therefore identical to the one preceding it, interlace must be restored artificially.

The phasing of the record switcher in the HS-100 is such that each recorded field begins and ends just after the last equalizing pulse of the vertical interval (point A′ or B′ of Fig. 14-5). Odd fields, as recorded on the disc by heads A and C, begin at A′ and end at B′; even fields, as recorded by heads B and D, begin at B′ and end at A′. To produce line interlace artificially, odd fields are changed to even fields, or even fields are changed to odd fields, by insertion of a half-line delay in the video signal during the horizontal-scanning interval of each field (i.e., from A′ to B, or from B′ to A). The half-line delay insertion is controlled by the system logic. By knowing what type of field is required (by examining reference sync) and knowing what type of field is being reproduced by each head, the logic controls the insertion of the half-line delay as required, always removing the half-line delay during the vertical interval, A to A′ and B to B′. Accordingly, during still-framing, the half-line delay is inserted during the horizontal-scanning interval of alternate fields.

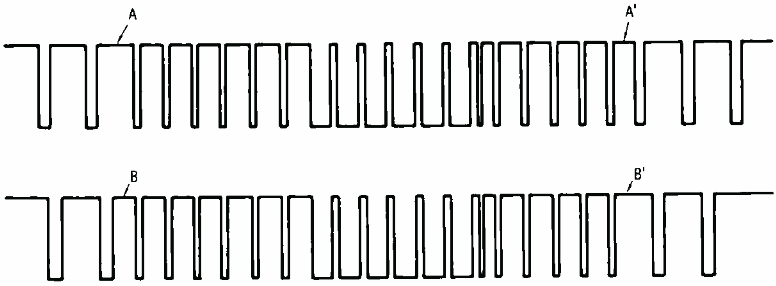


Fig. 14-5. Record switcher phasing.

Chroma Phase—In the NTSC color system, the frequency relationship between the chroma subcarrier and the horizontal and vertical scanning rates is such that the chroma phase advances 180° each line and each frame (dot interlace). This minimizes chroma-luminance cross talk, since the effects are reversed on successive scans.

In still-framing, a chroma-phase problem arises from attempts to generate a continuous signal from a single recorded field. In scanning a complete field, the chroma at the end of the field is advanced 90° with respect to its phase at the beginning of the field. If the field is then rescanned from the beginning, a 90° phase discontinuity appears in the chroma signal at the beginning of the scan. This would not only destroy dot interlace, but in a normal receiver would seriously disrupt the color demodulation process.

The chroma phase shift is further influenced by the insertion or removal of the half-line delay. Insertion of the half-line delay retards the chroma phase 90°; removal of the delay advances the chroma phase 90°. Thus, when the half-line delay is inserted at the beginning of a rescan, its 90° phase shift adds to the 90° shift caused by rescanning, producing a total chroma phase shift of 180°. Conversely, if at the beginning of a rescan the half-line delay is switched out, its phase shift cancels out the 90° shift caused by rescanning. The combined result when still-framing, therefore, is that a 180° shift occurs in the chroma phase at the beginning of every second field. This effect is compensated for by a chroma inverter which extracts the chroma signal (including burst) from the composite video playback signal, reverses its phase each time the half-line delay is inserted, and recombines it with the luminance portion of the signal.

Slow Motion—Slow motion is essentially a combination of normal motion and still-framing. To produce the effect of slow motion, each recorded track is scanned not once but several times, depending on the slow-motion rate selected, after which the playback signal is taken from the next track. Selection of a particular speed determines the average number of scans per track, even though some tracks may be scanned more often than others. For example, if a speed reduction of 2 to 1 is selected, each track is scanned twice; at a 3-to-1 reduction, each track is scanned three times. At a 2.5-to-1 speed reduction, half the tracks are scanned twice and half are scanned three times. Thus speed control is continuously variable from normal to freeze.

During the time a particular track is being rescanned, the system operates exactly as described for still-framing (freeze mode). Carriage motion stops, the signal is derived from one particular head, the half-line delay is switched in or out at the beginning of each rescan, and the chroma phase is reversed each time the half-line delay is switched in. When the playback signal is advanced from one track to the next, carriage movement and head switching progress from one field to the next as in normal motion (Table 14-3). Since switching from one track to the next produces a normal transition from one field to the next, the state of the half-line delay and chroma inverter remains unchanged during the transition. That is, if the half-line delay was in the signal path before the switch, it remains in

Table 14-3. Head Sequencing in Normal Reproduce Mode

Head (or Channel)	**Field 1, 5, 9, etc.**	**Field 2, 6, 10, etc.**	**Field 3, 7, 11, etc.**	**Field 4, 8, 12, etc.**
A	Reproduce	Step	Step	
B		Reproduce	Step	Step
C	Step		Reproduce	Step
D	Step	Step		Reproduce

after; if it was bypassed before the switch, it remains bypassed after. Similarly, no inversion of the chroma phase is carried out at this time.

Reverse Motion—In reverse-motion playback (Table 14-4), the sequence of carriage motion and head switching is reversed from that shown in Table 14-3, and the carriages are made to move in the opposite direction. Thus the fields are played back in a sequence opposite to that in which they were recorded.

The head switching sequence, D-C-B-A, preserves the normal progression of fields from odd to even, but loses the track-to-track phase continuity of the chroma signal. In switching, for example, from head D to head C, switching is from the end of one field to the beginning of the one which preceded it in the original recording. This constitutes a 180° chroma-phase reversal, which must be corrected by reversing the chroma phase in the chroma inverter. Thus, in switching from track to track in the reverse-motion direction, the half-line delay is not altered, but the chroma phase is reversed by the chroma inverter.

Table 14-4. Reverse-Playback Head Sequencing

Head (or Channel)	**Field 1, 5, etc.**	**Field 2, 6, etc.**	**Field 3, 7, etc.**	**Field 4, 8, etc.**
A	Reproduce	Step	Step	
B	Step	Step		Reproduce
C	Step		Reproduce	Step
D		Reproduce	Step	Step

For rescanning a track in slow-motion reverse, the action of the half-line delay and chroma inverter is identical to that for rescanning in the forward direction.

Alternate-Field Playback—Recordings made in the alternate-field mode differ from those made in the normal mode in that only odd fields are recorded (the first field of each frame). Since all fields are odd, it is necessary to change the state of the half-line delay (i.e., either insert it or remove it, as the case may be) each time the signal is switched from one track to the next, both in the forward and reverse motion directions. In going

These signals are fed to the processing amplifier, which combines the composite video and the time-corrected burst (added to back porch of composite video) to provide a time-corrected composite video signal. The processing amplifier provides two composite video outputs, one noncomposite video output, and one sync output.

Fast Search

Fast search is used to move the heads rapidly (at about four times normal speed) from one point on the discs to another. In fast search, as in normal operation, the heads must remain precisely in step; otherwise loss of field-to-field continuity would result in subsequent playback. Therefore, the sequence of motion is kept the same as in normal-speed operation. Because of the inertia of the carriage drive system moving at search speed, it is not convenient to reverse the direction of travel of the carriages at the inner and outer limits of travel. Therefore, a lamp and photocell arrangement, located on carriage drive A, detects the approach of the heads to the inner and outer limits and briefly slows the carriage speed to normal while the carriage direction is being reversed.

14-4. THE HS-100 VIDEO SIGNAL SYSTEM

The functional block diagram of Fig. 14-6 represents the signal system in somewhat more detail than was shown in Fig. 14-4. The signals recorded on the HS-100 are composite video signals and may be either NTSC color or monochrome. The video system has two modulation systems, fm for recording and playback, and a-m for the half-line delay function. The frequencies of the fm modulator are 7.06 MHz for tip of sync, 7.90 MHz for blanking, and 10 MHz for peak white. The video system consists of four head preamplifier assemblies, each located on a carriage drive assembly, an rf switching logic module and a record amplifier module located in the dsu, and eight signal-processing modules located in the esu.

Modulator Module

The modulator module contains circuitry to provide feedback-stabilized amplification and dc restoration of the composite video signal before it is applied to the fm modulator. A fast-switching voltage-controlled multivibrator is used to produce frequency modulation with low distortion. The frequency-modulation process is similar to that used in video-tape recorders in which the video information is contained in the form of sideband energy. The carrier frequency is the same as that used in the high-band, 525-line Ampex VR-1200 and VR-2000 video-tape recorders.

Record Amplifier Module

The record amplifier functions on the same principle as that of conventional quadruplex systems except that fm is gated and switched to the heads during the record mode rather than being fed to all four heads simultaneously. One head is always recording, one head erasing, and two heads moving to new positions.

The record amplifier receives a 0.7-volt (peak-to-peak) fm signal from the modulator. The signal is amplified to 2 volts peak to peak, which is a level suitable to pass through switching circuits and provide sufficient power to drive the recording heads to saturation of the recording medium. The signal is separated into four output channels under control of four gating signals.

RF Switcher Module

The rf switcher and switching logic module in J12 of the dsu receives four rf inputs, one from each of the head preamplifiers, and five control logic signals. The four preamplifier outputs are gated through the rf switcher for recombination, either sequentially or on an individual-field basis, depending on the selected reproduce mode. The module also contains the circuits generating the gate signals for record, erase, and equalizer switching. The logic signals are produced for each of the individual signal channels.

The switching logic is made up of four similar circuit sections, one section for each of the four signal channels. (See Fig. 14-7 for a functional block diagram of the switching logic.) Only the section for channel A is described. Diodes X6 and X7 form an AND gate receiving the record/playback command and the E_{AC} signal. The AND-gate output causes driver Q2 to go into conduction whenever both gate inputs are high. The output from the collector of Q2 is routed to pins 3 and C of J12. Here the signal is split into two paths, one going to the record-amplifier channel-A record gate, and the other going to the channel-B head-preamplifier erase-gate input. This circuit is always inhibited when the HS-100 is not in the record mode.

Diodes X3 and X4 form an AND gate receiving the logic E_{AC} signal and the inverted record/playback command. This gate, whenever both inputs are high, causes driver Q3, Q4 to go into conduction; the channel-A equalizer gate signal is generated at the collector of Q3. The collector output from Q3 is connected to pins 2 and B of J12 and is supplied to the rf equalizer board in the esu. It should be noted that this AND gate is inhibited whenever the record mode is selected.

The record/playback command is also applied to relay driver Q14. Selection of the record mode shifts the record/playback command level to +3.8 volts and drives Q14 into conduction, providing a current path from +28 volts to ground through the coil of K1. The energized relay switches +12 volts from pin 15 to pin Y of J12 to provide the +12-volt record signal to the record amplifier. It also switches +28 volts from pins 22 and Z to pins 20 and X of J12 for the head relays on the head preamplifier assemblies.

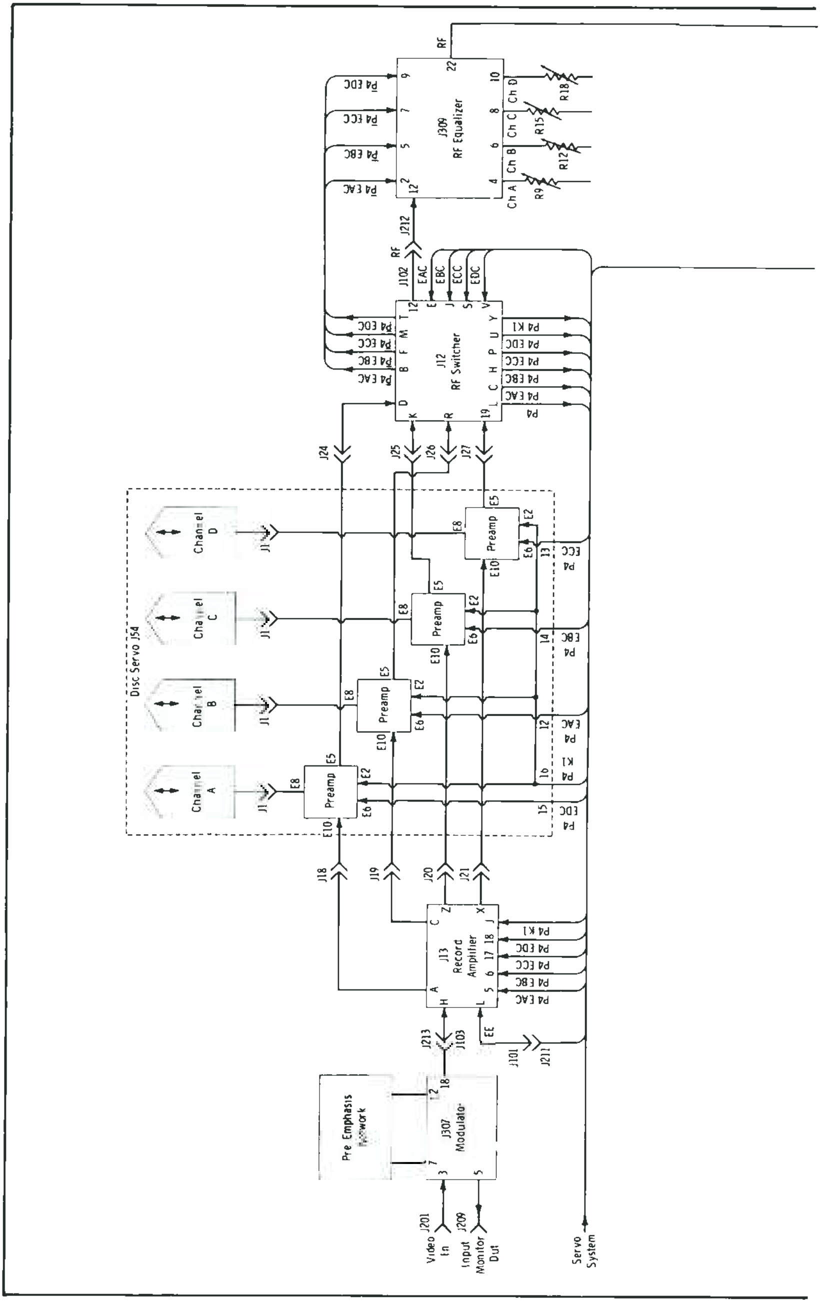


Fig. 14-6. Functional block

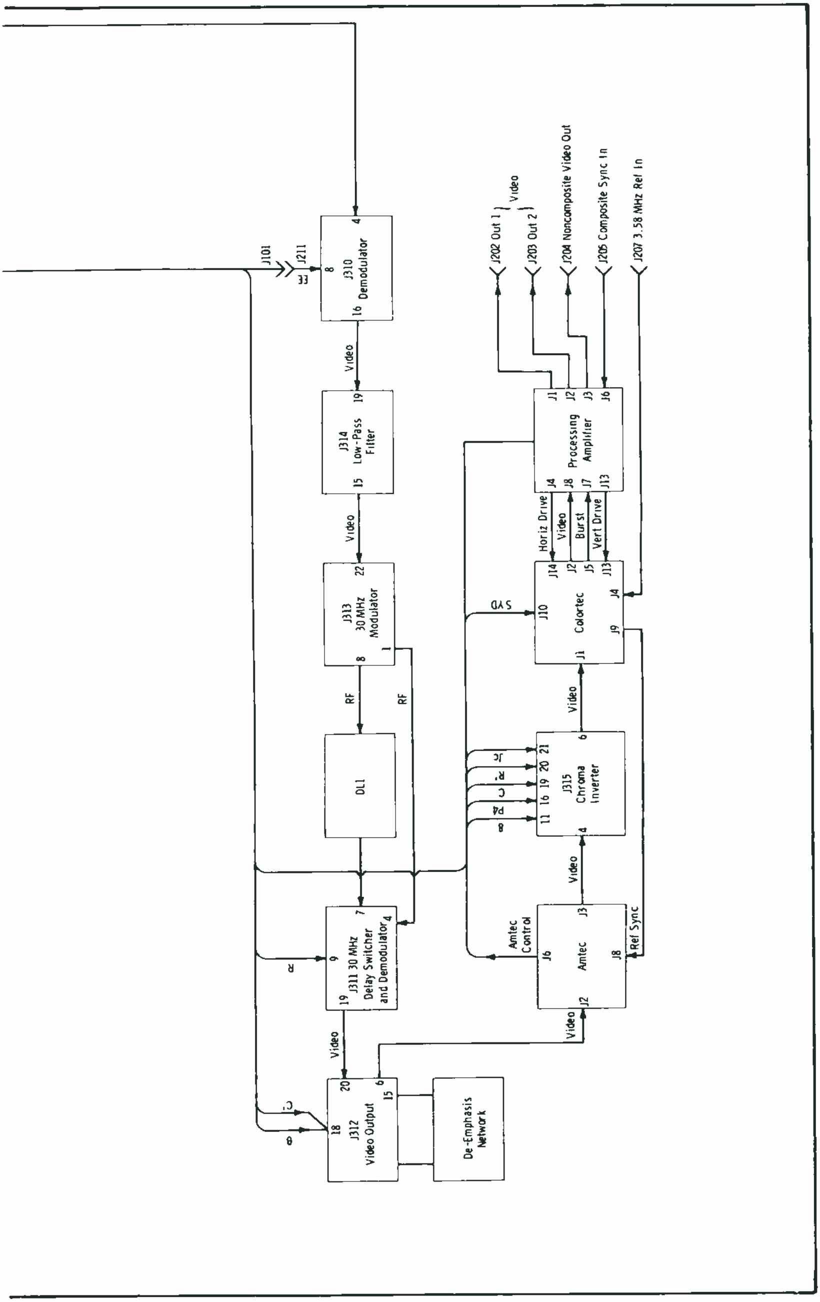


diagram of HS-100 signal system.

RF Equalizer

The rf equalizer operates on much the same principle as that of conventional vtr's. Its purpose is to restore the original carrier-to-sideband relationship of the recorded information. Two cosine equalizers are used. One is an overall master equalizer, and the other has controls for each individual channel.

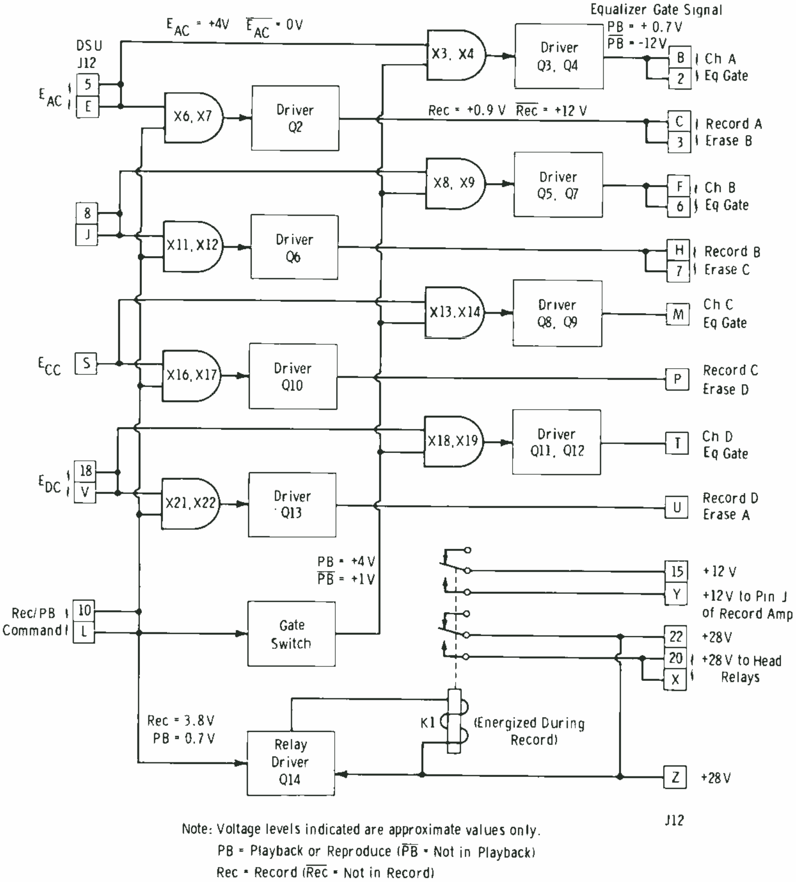


Fig. 14-7. Functional block diagram of switching logic.

Demodulator Module

The demodulator is similar to that of conventional vtr's. The function is to limit the rf signal and detect zero crossovers of the fm carrier. Pulses are then formed by a tunnel diode and associated switching circuitry to produce narrow rectangular pulses, one for each carrier crossover point (therefore at a frequency of twice the carrier frequency). These pulses have short rise times and are approximately 25 nanoseconds in width and 2 volts in peak-to-peak amplitude. The pulses are then fed to a low-pass filter on another module.

30-MHz Modulator

The 30-MHz modulator assembly contains a 30-MHz oscillator, an amplitude modulator, and a simulating network. Fig. 14-8 is a functional block diagram of the 30-MHz modulator.

Transistor Q1, crystal Y1, and additional LC components form a 30-MHz oscillator. Crystal Y1 functions in a series-mode overtone operation. The oscillator output passes through buffer amplifier Q2 and carrier-level control R8 to current-source amplifier Q3, Q4. The carrier signal from the common collectors of Q3 and Q4 is connected to diodes X1 and X2. The amplitude-modulated signal enters complementing amplifier Q5, Q6 at a high impedance. The output from Q5 and Q6 is a low-impedance circuit split into two signal routes. The first route is through output pin 8, into the external half-line delay line, and to the 30-MHz delay-line switcher and demodulator board. The second route is through the delayed/undelayed signal balance control, R22. The arm of control R22 routes the signal into a network simulating the amplitude characteristics of the delay line in use. Some of the network components are factory selected to match the delay line in use. However, in some equipment this network may not be required. Terminals on the board allow for signal routing through the network or around the network, as required. The network output is routed through pin 1 of J313 to the 30-MHz delay-line switcher and demodulator board.

The output from the low-pass filter enters the module at pin 22 of J313 as a carrier-free demodulated video signal, which is routed to video-level control R48. The arm of R48 routes the signal to amplifier Q11, which is supplied by constant-voltage source Q12. A capacitor in the emitter circuit of Q11 allows for peaking of the amplifier to obtain the desired frequency response. The output from Q11 is coupled through C34 to phase splitter Q9, which is a dual transistor. The emitters of Q9 are supplied by constant-current source Q10. The two outputs from the collectors of Q9 are 180° out of phase and are coupled capacitively to the bases of complementary emitter followers Q7 and Q8. Control R34 in the base circuits of Q7 and Q8 provides a balance adjustment for the second harmonic of the carrier. The two outputs from complementary emitter followers Q7 and Q8 are applied to modulator diodes X1 and X2. The voltage level at the anode of X1 is approximately −0.7 volt, and the level at the cathode of X2 is approximately +0.7 volt. These voltages establish a back bias on the diodes.

Delay Line

The delay line employed between the 30-MHz modulator and the 30-MHz delay-line switcher and demodulator is of the ultrasonic glass type,

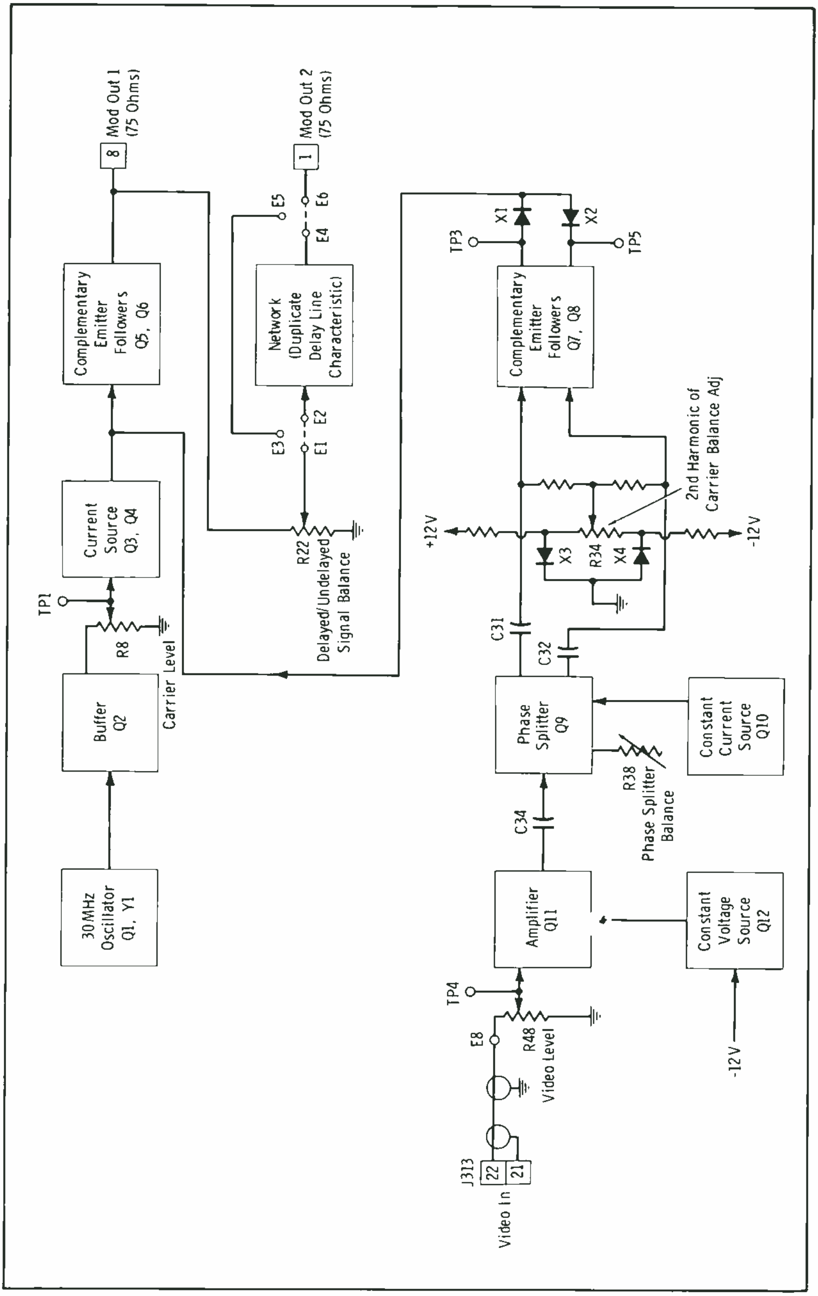


Fig. 14-8. Functional block diagram of 30-MHz modulator.

having integral ceramic transducers. The delay line operates at a center frequency of 30 MHz and provides a delay of ½ line of video (31.798 μs ±10 μs). The output from the delay line is applied to one input of the 30-MHz delay-line switcher and demodulator.

30-MHz Delay-Line Switcher and Demodulator

The 30-MHz delay-line switcher and demodulator assembly contains the switching gate, the gate drivers, the demodulator, and associated amplifiers. No delay-line switching occurs during the record mode of operation. Fig. 14-9 is a functional block diagram of the assembly.

Switching Gate—The switching gate is made up of three diode assemblies, X1 through X3, and each assembly contains four diodes. The undelayed and delayed modulated video signals are applied as inputs to the gate. Only one of the two signals is allowed to be gated through into the demodulator section at any given time.

Gate Drivers—The diode gate is driven by gate drivers, under control from a logic switching signal. The logic signal (R) enters the board at pin 9 and is applied to two gate-driver circuits. The input signal is binary 1 when a positive signal of 3.5 to 5.0 volts appears at pin 9. This positive signal switches on Q10, which in turn switches Q8 and Q9 off. The voltage at the emitter junctions of Q8 and Q9 will then become negative 5.6 volts. The emitter output is series connected with a control, which controls the current through the diodes and effectively controls the rise time of the switching waveform. This emitter output is connected to six diodes in assemblies X1 through X3 through resistors R28 and R31. The input signal from pin 9 also switches on Q11, which in turn switches on Q14, causing Q15 to switch on and Q16 to switch off. The resulting positive 5.6 volts at the emitter junction of Q15 and Q16 is applied through resistors R29 and R30 to the six other diodes in X1 through X3. The negative voltage applied through resistors R28 and R31 causes diodes X1D, X2D, and X3B to be forward biased. The positive voltage applied through resistors R29 and R30 causes forward biasing of diodes X1A, X2C, and X3C. Therefore, the undelayed signal from pin 4 will be gated through and appear at coupling capacitor C22. Diodes X1B, X1C, X2A, X2B, X3A, and X3D are back-biased and block the delayed signal from pin 7. Any spurious signal appearing from pin 7 through X3A and X3D finds its path blocked by X2A and X2B; furthermore, diodes X3B and X3C are conducting and effectively ground the junctions between the X2 and X3 diodes.

When the logic-signal input at pin 9 becomes less than +3.5 volts, or inhibitive (binary 0), the transistors in both gate drivers reverse their states. The signal into resistors R29 and R30 becomes negative, and the signal into resistors R28 and R31 becomes positive. This causes a polarity reversal of all diode biases, shutting off the path from pin 4 through the gate and switching on the path from pin 7 through the gate. The input into the bandpass amplifier is then from the delay line.

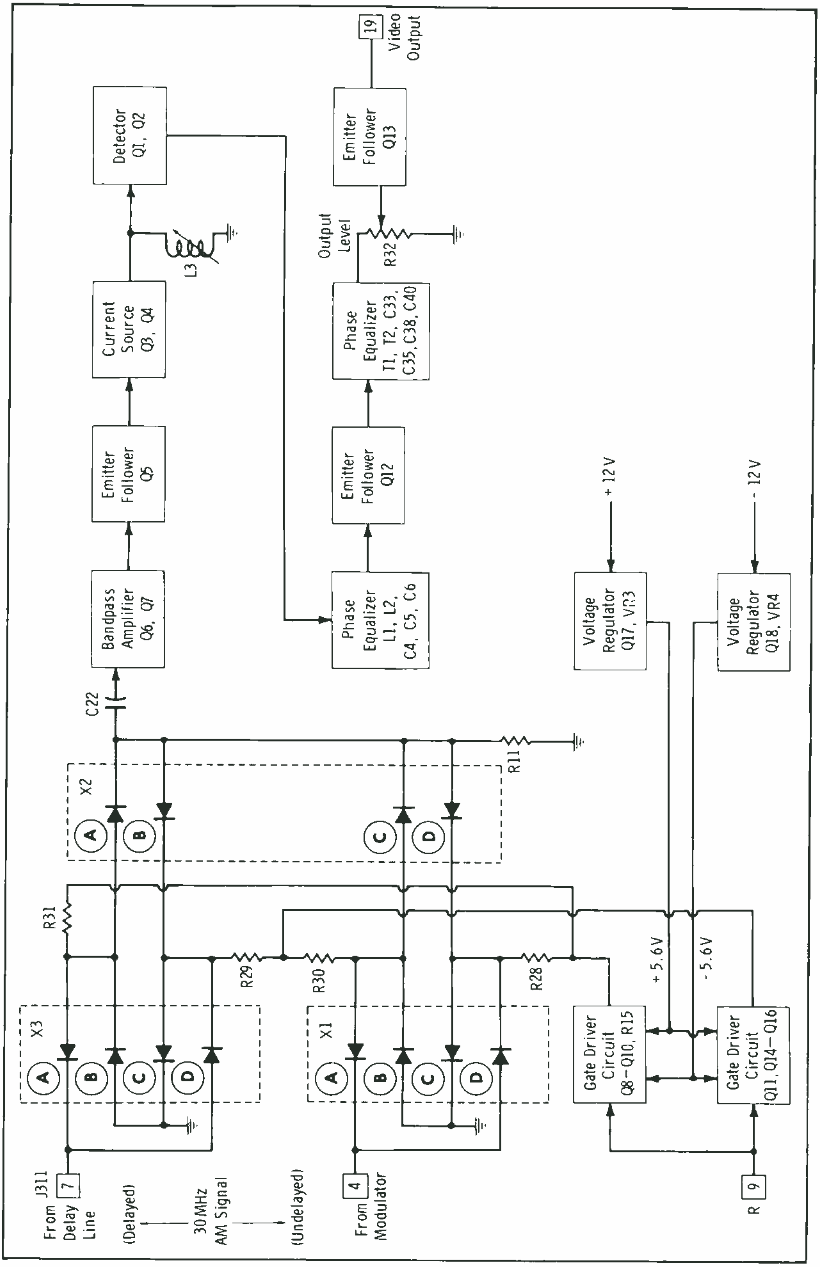


Fig. 14-9. Functional block diagram of 30-MHz delay-line switches and demodulator in HS-100 system.

Demodulator—The bandpass amplifier (Q6 and Q7) is tuned to provide a second-order Butterworth response and drives emitter follower Q5. This buffer drives current source Q3, Q4, which has its output connected to detector Q1, Q2. Coil L3 in the detector input circuit removes the dc component of the demodulated signal and eliminates the effect of stray capacitances at the carrier frequency. The detected video signal is routed from the collector of Q1 through a filter to emitter follower Q12. The output from the Q12 emitter is routed through a second filter and output-level control R32 to emitter follower Q13 and pin 19. The signal at pin 19 is the demodulated video, timed to specific requirements of the selected reproduce mode.

Output Video Module

The output video assembly receives the demodulated video signal from the demodulator. The video signal is amplified, fed through a de-emphasis network (external to this module), and further amplified before it appears as an output. This signal is then routed to the Amtec unit in the opu.

Chroma Inverter Module

The chroma inverter assembly contains a low-pass filter, a bandpass filter, a chroma inverter, amplifier stages, and the logic circuits controlling the inverter. Fig. 14-10 is a functional block diagram of the chroma inverter.

Chroma Phase Inverter—The composite video, processed by the Amtec unit, enters the board through pin 4 of J315 and follows two signal routings. One route is into amplifier Q1 and a low-pass filter; the other is directly into a bandpass filter. The video signal from the collector of Q1 is routed through the low-pass filter, which passes only the luminance portion of the signal. The path through the bandpass filter allows the subcarrier with its sidebands to pass and couples this signal to a driver stage composed of Q9, Q10, and Q11. The output from Q10 and Q11 is a low-impedance signal feeding drive transformer T1. This transformer converts the single-phase signal into two signals of opposite phase. The two opposite-phase signals are applied to the diode gate composed of X1, R6, and R38. Depending on the polarity of the gate-driver signal, the gate will pass the signal through one of two pairs of diodes to gate transformer T2. The gate-driver signal from the collector of Q12 is approximately +6 volts for the inverting condition, in which the diodes effectively cross-connect T1 and T2. No inversion takes place when the gate-driver signal is approximately −6 volts, since the diodes then connect corresponding ends of the windings of T1 and T2 together. The single-phase output from T2 is applied to emitter follower Q8. Control R38 in the diode gate is set to obtain chroma balance between the noninverted and inverted chroma signals. Control R23 in the base circuit of Q8 is factory set to the correct bias level for Q8. The output from Q8 is applied to the anode of zener diode X2.

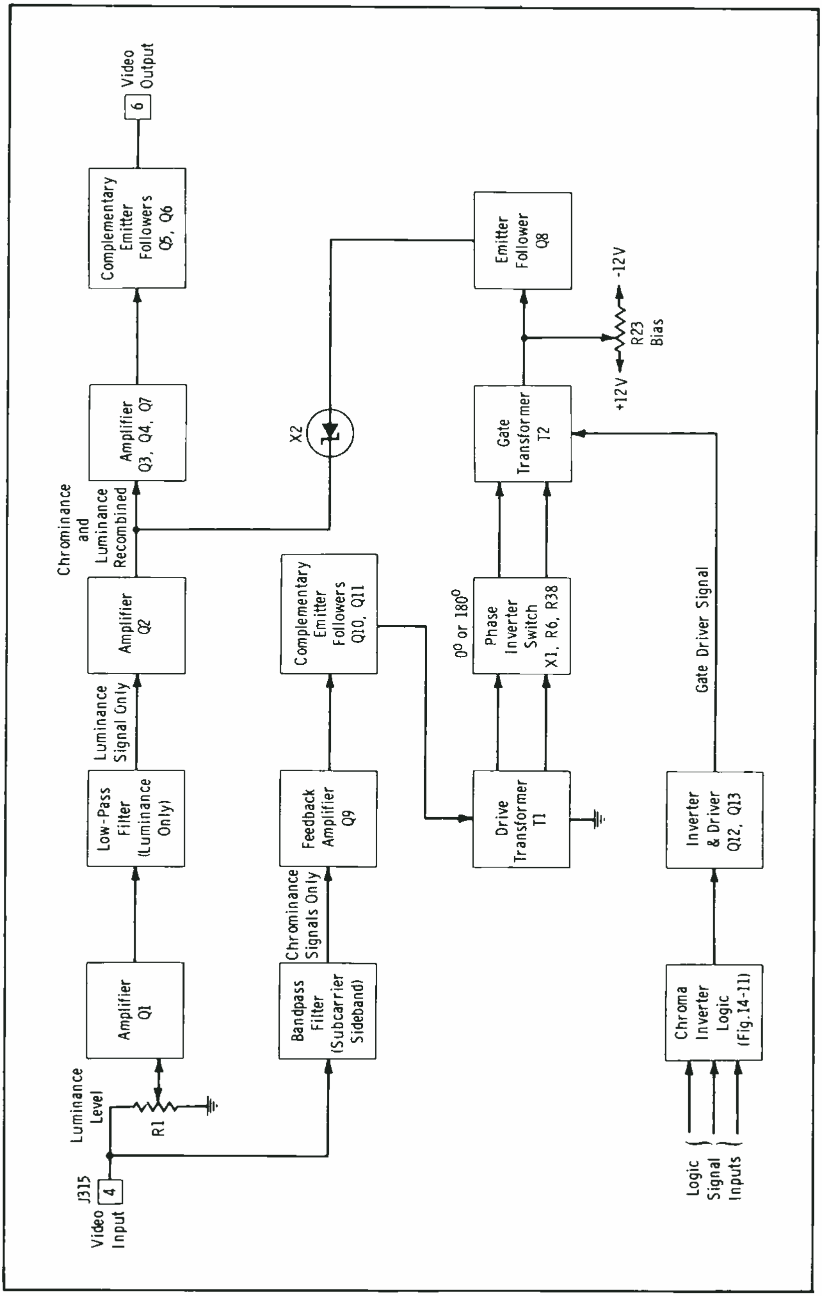


Fig. 14-10. Functional block diagram of chroma inverter.

The output from the low-pass filter (luminance signal only) passes through amplifier Q2. The luminance gain is factory set to 1:1 by a control in the base circuit of Q4. Chroma and luminance information are combined by the output adder consisting of X2 and Q2. The recombined signal is coupled through amplifier Q3, Q4, Q7 and complementary emitter followers Q5 and Q6. The output from Q5 and Q6 provides a low-impedance signal to pin 6 of J315. At this point, the signal is a standard NTSC color signal ready for further processing by the Colortec and the processing amplifier.

Signal C_H from the logic circuitry on this board controls the chroma-inverter function. This signal is binary 1 if the chroma inverter is required to provide a shift of 180° in the phase of the chroma subcarrier; it is binary 0 for any other condition. Signal C_H is applied to the base of Q13. Q13 conducts if C_H is 1, and the resulting collector potential of Q13 drives Q12 into conduction. Transistor Q12 is tied between positive and negative 12 volts. A zener diode in the emitter circuit of Q12 limits the collector potential of Q12 to approximately +6 volts when Q12 conducts. Transistor Q13 is held in cutoff if C_H is 0, and the resulting collector potential of Q13 holds Q12 in cutoff. Transistor Q12 is not conducting, and the collector potential of Q12 is at approximately −6 volts. Thus, the polarity of the gate-drive signal from Q12 changes with the logic state of signal C_H and controls the chroma-inverter circuit.

Chroma-Inverter Logic—Logic circuitry contained on the choma-inverter circuit board controls the switch-in and switch-out of the 180° phase-reversing network of the chroma inverter. See Fig. 14-11 for a functional block diagram of the chroma-inverter logic circuit. (Also refer to the function-designators table in Section 14-5 for the meanings of some of the abbreviations used in the following descriptions.)

Since the HS-100 operates in the E-E mode whenever a record or fast-search mode is selected, the output from the chroma-inverter logic is inhibited during the record and fast-search modes. Two signals, $\overline{\theta}$ and $\overline{P_4}$ enter the board at pins 11 and 16 of J315 and are connected to NAND gate A4A. Either of these two signals can thus inhibit the $\overline{C_H}$ output of A4A. Three operational conditions of the chroma inverter provide for correct chroma phase switching during (1) forward reproduce, (2) reverse reproduce, and (3) alternate-field reproduce. Each of the three conditions includes normal motion, slow motion, and freeze motion.

Forward Reproduce—(Refer to Figs. 14-11 and 14-12.) During forward reproduce, the input at pin 18 of J315 is binary 1. This signal (K) is inverted by A5B, and the resulting signal goes to NAND gate A2A, causing this NAND gate to be inhibited. The output of A2A is, therefore, binary 1 for forward motion. The normal/alternate-field record switch in the esu is in the normal position and selects R′ for application to pin 20 of J315. This signal is then applied to the P_K input of JK flip-flop A3 and, through inverter A5D, to the P_J input of the same flip-flop. Pin 7

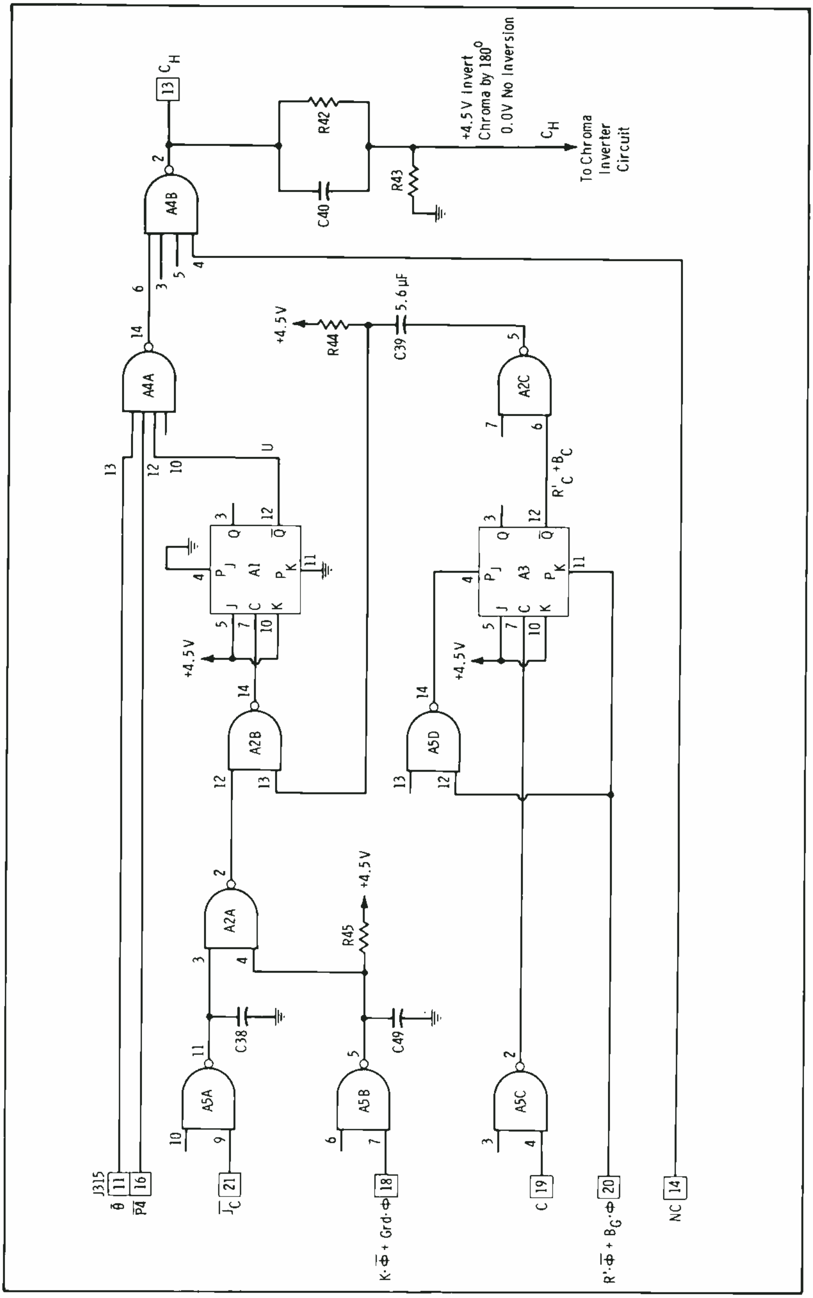
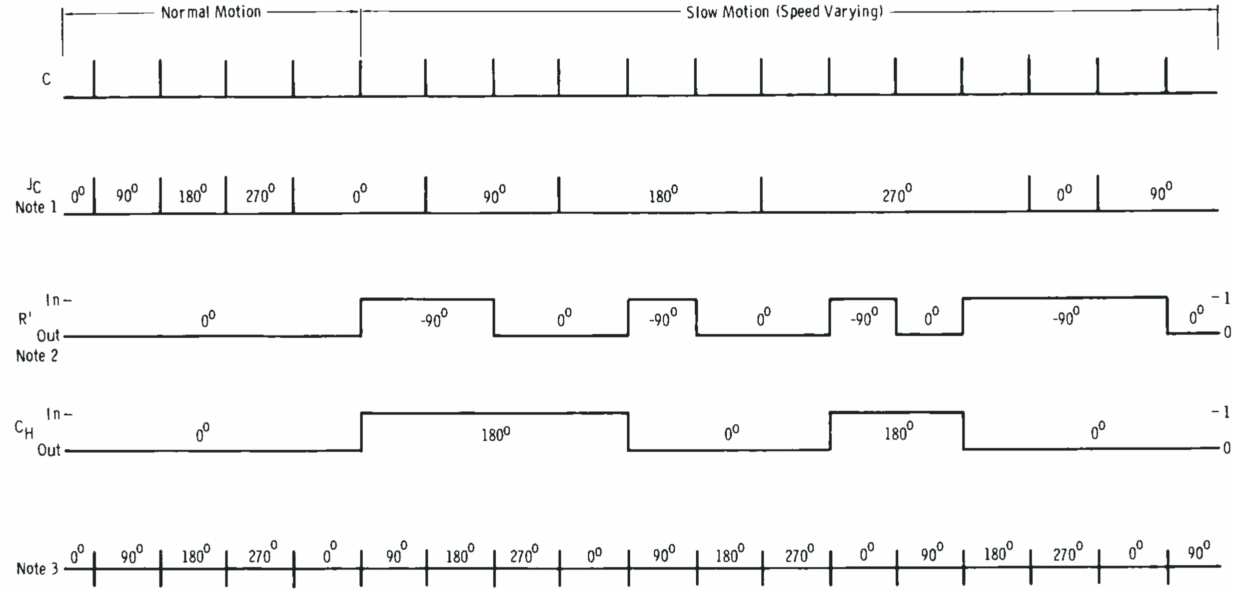


Fig. 14-11. Functional block diagram of chroma-inverter logic.



Notes: 1. Angular information represents phase angle of chroma subcarrier for video coming off discs.

2. R' controls the 1/2-line delay. This delay retards the chroma phase by -90°, when inserted. Chroma phase of video input to chroma inverter includes the function of this delay.

3. Chroma phase required by video output signal.

Fig. 14-12. Chromo-inverter waveforms, forward reproduce mode.

of A3 receives the inverted C-pulse input from pin 19 of J315 through inverter A5C. Thus, signal $\overline{C}$ becomes the clock pulse for flip-flop A3. Signal R′ is binary 0 when the ½-line delay line is out and sets flip-flop A3, resulting in an output of binary 0 on pin 12 of A3. This output is R'_C, which changes its level whenever the ½-line delay is switched in or out. Switching in of the ½-line delay causes R'_C to change from the binary 0 level to the binary 1 level, and vice versa. Signal R'_C is routed through inverter A2C and is then differentiated by C39 and R44. The differentiated $\overline{R_C'}$ is fed to pin 13 of NAND gate A2B.

Pin 12 of NAND gate A2B is at the binary 1 level during forward motion, since its signal comes from pin 2 of NAND gate A2A. Pin 13 is held normally at a level equivalent to binary 1 by the 4.5 volts supplied through resistor R44. The output at pin 14 of A2B is, therefore, equal to a binary 0. With these levels established, it is apparent that only a negative pulse from differentiating network C39-R44 will cause a change in the NAND-gate output. A negative pulse occurs only when R′ changes from binary 0 to binary 1, which is equivalent to the switching in of the ½-line delay. The positive output pulse at pin 14 of A2B is wired to the clock input (pin 7) of JK flip-flop A1. Flip-flop A1 complements its own output for every clock pulse applied. Output pin 12 of the flip-flop is wired to pin 10 of NAND gate A4A and represents signal U. Signals $\overline{P_4}$ and $\overline{\theta}$ also are applied to NAND gate A4A. The output from pin 14 of this gate is fed to another NAND gate, A4B. Since all other inputs to this gate are open-circuited, it acts as an inverter; its output is C_{II}, the chroma-inverter control.

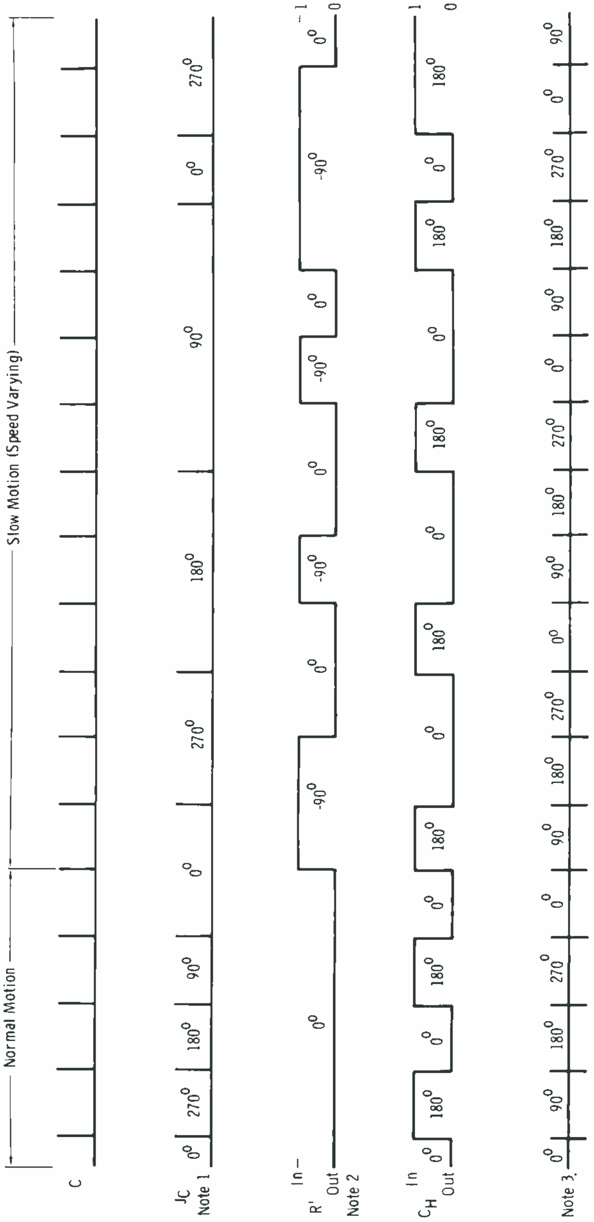
Signal C_{II} follows the Boolean equation:

$$C_{II} = U \cdot \overline{P_4} \cdot \overline{\theta}$$

Thus, C_{II} will change its state with every change of U, whenever the HS-100 is in reproduce and not in a fast search. Since U is a function of R′, C_{II} is also a function of R′, and C_{II} changes every time that the ½-line delay is switched in. The C_{II} waveform, therefore, is a divided-by-2 version of the R′ waveform. Signal C_{II} is routed to the base of Q13 (Fig. 14-10) and to pin 13 of J315 (Fig. 14-11).

The condition of the chroma inverter is changed every time that the ½-line delay signal (R′) changes from binary 0 to binary 1. Changing of R′ from binary 1 to binary 0 has no effect on the chroma-inverter state during the forward reproduce mode.

Reverse Reproduce—(Refer to Figs. 4-11 and 14-13.) The only difference between the forward and reverse reproduce modes is the signal at input pin 18. This signal is binary 0 during reverse; therefore, it does not inhibit NAND gate A2A, and J_C pulses can now pass through this gate. The output from this gate is $\overline{J_C'}$, which passes through NAND gate A2B and complements output U of flip-flop A1 for every J_C pulse. Signal C_{II} changes with every change of U and results in changing of the chroma phase. However, during slow-motion reverse, the R′ waveform must also



Notes: 1. Angular information represents phase angle of chroma subcarrier for video coming off discs.
2. R' controls the 1/2-line delay. This delay retards the chroma phase by -90°, when inserted. Chroma phase of video input to chroma inverter includes the function of this delay.
3. Chroma phase required by video output signal.

Fig. 14-13. Chroma-inverter waveforms, reverse reproduce mode.

be considered. This waveform exercises its control in exactly the same manner as it does in forward motion, and U is, therefore, changed every time the ½-line delay is switched in.

Signal C_H changes from binary 1 to binary 0, or vice versa, every time that a $\overline{J_C}$ pulse occurs or the ½-line delay switches in. The $\overline{J_C}$ pulses occur whenever the head signal carries a new field from the discs. No $\overline{J_C}$ pulses occur when the head signal is a repetition of a single field, as is the case during slow motion or freeze.

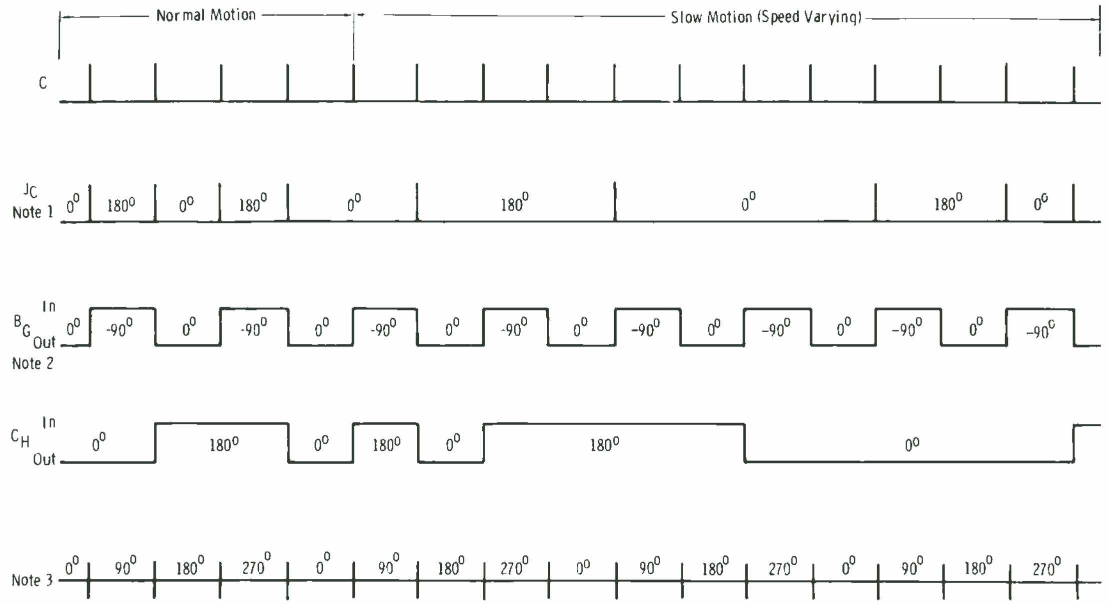
Alternate-Field Reproduce—(Refer to Figs. 14-11 and 14-14.) The input to pins 18 and 20 of J315 is changed by the alternate-field record/normal switch in the esu. The input to pin 18 is changed from signal K to ground potential, and the input to pin 20 is changed from R' to B_G. Flip-flop A3, followed by inverter A2C and differentiator C39-R44, now produces clock pulses for flip-flop A1 which are derived from B_G and retimed at C. Flip-flop A1 also receives clock pulses derived from J_C, since the controlling input at pin 18 of J315 is now at ground potential. This ground potential is the level of binary 0 as in the reverse reproduce mode. However, it should be noted that the J_C inverter, A5A, has capacitor C38 connected between the output and ground. Capacitor C38 and internal components of A5A form a delay network producing a delay of 20 microseconds. This delay of waveform J_C is of no importance in modes other than the alternate-field reproduce mode. A delayed J_C pulse may complement flip-flop A1 about 20 microseconds after a B_G-derived clock pulse changes the state of flip-flop A1, and thus re-establishes the state of flip-flop A1 which was present prior to the B_G-derived clock pulse. The end effect of this coincidence control is to prevent a change in the chroma inverter if (and only if) the ½-line delay switches in during the presence of a J_C pulse. The chroma inverter will change whenever the ½-line delay switches in during the absence of a J_C pulse, and whenever the ½-line delay switches out during the presence of a J_C pulse.

14-5. CONTROL LOGIC SYSTEM

The HS-100 system is totally dependent on "computer-type" circuitry, and as stated several times previously in this text, it is mandatory that the technicians concerned with modern video equipment have a good working knowledge of logic theory. Such a background is assumed in this description. The instruction books for this system are complete (and large), with complete schematics presented. Space in this text permits only a basic description, sufficient to familiarize the reader with fundamentals of slow-motion, stop-action disc recording logic functions.

Control Functions

The control logic receives its commands from the operator through the control-unit push buttons and generates waveforms for the control of:



Notes: 1. Angular information represents phase angle of chroma subcarrier for video coming off discs.
2. B_G controls the 1/2 line delay. This delay retards the chroma phase by -90°, when inserted. Chroma phase of video input to chroma inverter includes the function of this delay.
3. Chroma phase required by video output signal.

Fig. 14-14. Chroma-inverter waveforms, alternate-field reproduce mode.

(A) Head stepping
(B) Record signal switching
(C) Playback signal switching
(D) Half-line delay switching
(E) Chroma-inverter switching

Logic circuit boards are located in the control unit, electronics signal unit (esu), and disc servo unit (dsu). The control-unit logic responds to the push-button commands by generating basic command signals (record/reproduce, forward/reverse, alternate-field/continuous, slow-motion/normal, fast forward, fast reverse) and by generating the slow-motion speed-control waveform. In addition, the control-unit logic board contains electronics to drive the indicator clock and cue needle, lamp-indicator drivers, and a 4.5-volt power regulator.

The switching-logic module located in the esu generates the switching waveforms for the record, erase, and playback signals. Also generated are the control signals for the half-line delay and chroma-inverter circuits. The clock-generator circuit, which times these waveforms, is locked to incoming reference sync by signals generated in the sync-generator module.

Supplementary timing information is received from the slow-motion oscillator in the control unit during slow-motion playback and from the fast-search logic module during the fast-search mode. In the alternate-field mode, timing information is received from the alternate-field logic circuit located on the fast-search logic module.

The logic which controls the stepping of the head carriages is located in the dsu on the carriage logic A_1 and carriage logic A_2 modules.

For description and analysis purposes, the logic circuits in the control unit, esu, and dsu are shown in block diagram form in Figs. 14-16, 14-17, and 14-25. Each block represents a functional circuit element of the system and is identified by name. Each logic input or output is designated by a letter which indicates its function. These function designators, plus the other secondary functions, are listed and defined in Table 14-5.

Push-Button Logic—Nine of the twelve push-button switches on the control unit are interlocked with flip-flop circuits. See Fig. 14-15 for a typical circuit arrangement. Pressing one of the nine buttons causes the associated holding flip-flop to be set, and the active output of the flip-flop is utilized in the control-unit logic. Depression of the push button momentarily transfers the switch output from the normally closed contact to the normally open contact, resulting in a voltage-level change. Application of a 0-volt level (binary 0) sets the flip-flop. The duration of the applied 0-volt level is immaterial. The return to a positive 4.5-volt (binary 1) has no effect on the flip-flop state. Only a binary 0 at a reset input of the flip-flop can cause a change of state to the reset condition. The push-button initiated signal which sets one flip-flop may be routed to the reset inputs of other flip-flops, causing these flip-flops to be reset. This electronic inter-

Table 14-5. Function Designators

Designator	Function Designated
A	Slow-motion control waveform output from control unit.
A_1	Output from freeze button. In freeze mode $A_1 = 1$.
A_2	Output from single-frame advance button. Normally $A_2 = 1$.
A_a	Output from alternate-field logic.
A_F	Output from alternate-field switch.
B_G	Output from clock generator.
B'	Internal connection in alternate-field logic.
C	Clock-pulse output from clock generator.
C_H	Output from chroma-inverter logic.
D_G	Output from slow-motion logic. Equals B_G in normal and Z_G in slow-motion mode.
E_{AC}	Positive head-switching pulses for channels A, B, C, and D, respectively. Suffix "C" means that the pulses are timed by the "C" clock pulse. Pulses are output from the head-retiming logic.
E_{BC}	
E_{CC}	
E_{DC}	
E_{AG}	Timing pulses for channels A, B, C, and D, respectively. Suffix "G" means that the pulses are timed by the "G" clock pulses. Pulses are output from the head logic.
E_{BG}	
E_{CG}	
E_{DG}	
E_{AK}	Head-switching logic output from the reverse-motion logic. Suffix "K" indicates the functions are subject to forward/reverse control function K.
E_{CK}	
F	Field identification pulse. $F = 1$ when a horizontal-line pulse occurs at the same time as the first vertical pulse during equalization (even field).
F_{AG}	Carriage-stepping logic pulses for channels A, B, C, and D, respectively. Suffix "G" means that the pulses are timed by G clock pulses. Pulses are output from the carriage logic.
F_{BG}	
F_{CG}	
F_{DG}	
F_{AC}	Carriage-stepping logic pulses for channels A, B, C, and D, respectively. Suffix "C" means that the pulses are timed by C clock pulses. Pulses are output from the carriage-retiming logic.
F_{BC}	
F_{CC}	
F_{DC}	
F_{AK}	Carriage-stepping logic pulses for channels A and C. Suffix "K" means that the pulses are timed by K. Pulses are output from the reverse-motion logic.
F_{CK}	
F_A'	Carriage-stepping logic pulses for channels A, B, C, and D, respectively. Pulses are output from the carriage control logic.
F_B'	
F_C'	
F_D'	
F_{ACO}	Carriage-stepping logic pulses for channels A, B, C, and D, respectively. Pulses are output from the error-correction logic. Suffix "O" indicates that a pulse on this line will cause carriage to move **out** from the disc center.
F_{BCO}	
F_{CCO}	
F_{DCO}	
F_{ACI}	Carriage-stepping logic pulses for channels A, B, C, and D, respectively. Pulses are output from the error-correction logic. Suffix "I" indicates that a pulse on this line will cause carriage to move **in** toward disc center.
F_{BCI}	
F_{CCI}	
F_{DCI}	
F_F	Fast-forward search command. Originates in control unit.
F_R	Fast-reverse search command. Originates in control unit.

(Table continued on page 518.)

Table 14-5. Function Designators (Cont)

Designator	Function Designated
F_S	F function that has been modified by the fast-search logic circuitry.
G	Output from clock-pulse generator. A preclock pulse coincident with T_S.
J	Slow-motion clock pulse. Output from slow-motion logic.
J_C	Slow-motion clock pulse timed by C.
K	Forward/reverse-motion logic control. Output from reverse-motion logic.
K′	Output from alternate-field switch.
L	Internal connection in sync separator.
L′	
M	Output from carriage-reversing logic. $M = 1$ when carriages move out; $M = 0$ when carriages move in.
N	Output from reverse-motion logic.
P_1	Output from normal push button on control unit and is the unquantized normal/slow command. $P_1 = 1$ in normal mode.
P_2	Output from forward/reverse push button on control unit and is the unquantized forward/reverse command. $P_2 = 1$ in forward.
P_3	Output from control logic in control unit. $P_3 = 1$ in alternate-field record mode; otherwise $P_3 = 0$.
P_4	Output from control logic in control unit. Unquantized record/reproduce command. $P_4 = 1$ in record mode.
Q	Output from monitor carriage pulses switch on dsu. $Q = 0$ when pressed to enable carriage monitor lamps.
R	Half-line delay switching waveform. Output from alternate-field logic. $R = 1$ when delay is out.
R′	Same as R but output is from the half-line logic.
R_A	Output from alternate-field switch on the esu.
S_R	Servo reference-pulse output from sync separator. Pulse is positive coincident with the first serration of composite vertical sync.
S_{RD}	Identical to S_R except delayed 15 μs when in record mode.
S_Y	A 5-μs output pulse from the sync separator occurring at a horizontal-line rate.
S_{YD}	A 5-μs output pulse from the horizontal delay. Delayed 63.5 μs.
T	Output from sync separator. Master timing signal of 9 horizontal-line duration occurring at a vertical rate.
T_S	Identical to T in all modes except fast-search modes. In fast search, T_S is a 450-μs pulse occurring 4.5 times faster than vertical rate.
T_{SD}	Output of T-pulse delay.
U	Internal connections in alternate-field logic.
V	
W	Output from control-unit logic. $W = 1$ in slow motion.
W_S	Identical to W except in fast-search modes. $W_S = 0$ in fast search.
X_A	Output from outer carriage-limit switches on channels A, B, C, and D, respectively. Command $= 1$ when end stop is reached.
X_B	
X_C	
X_D	
Y_A	Output from inner carriage-limit switches on channels A, B, C, and D, respectively.
Y_B	
Y_C	
Y_D	
Z_G	Output from slow-motion quantizer. A preclocked form of A, the slow-motion control waveform.

Table 14-5. Function Designators (Cont)

Designator	Function Designated
α	Internal connection in fast-search logic.
β	Output of alternate-field logic.
Δ	Internal connection in fast-search logic.
C_Δ	Delayed clock pulse generated in the posicast timing module. Pulse is 3-μs long with front edge coincident with the trailing edge of C pulse.

lock of the flip-flops serves to terminate one mode of operation when another mode is selected. A change from normal reproduce to slow motion, for example, terminates the normal mode (resets the normal flip-flop) and initiates the slow-motion mode (sets the slow-motion flip-flop).

For the following descriptions of push-button functions, refer to the block diagram of Fig. 14-16.

Fast-Forward and Fast-Reverse Controls (FF and FR)—The fast-forward switch (FF) and the fast-reserve switch (FR) are used without flip-flop circuits. Both circuits are similar and therefore only the fast-forward circuit is described. Pressing the fast-forward switch removes the normally present ground potential from the input of an inverter and changes the inverter input to positive 4.5 volts. Inverter output $\overline{F_F}$ equals binary 0 during fast search and equals binary 1 during the absence of a fast-search mode. The fast-forward and fast-reverse command signals, $\overline{F_F}$ and $\overline{F_R}$, are routed into two paths. The first path is to the control-unit connector for routing to the esu, and the second path is to a NAND gate. The output from this gate is binary 1 when the freeze, fast-forward, or fast-reverse push button is pressed. The output is inverted and fed to the reset input of the record, forward, and reverse holding flip-flops, as well as the set

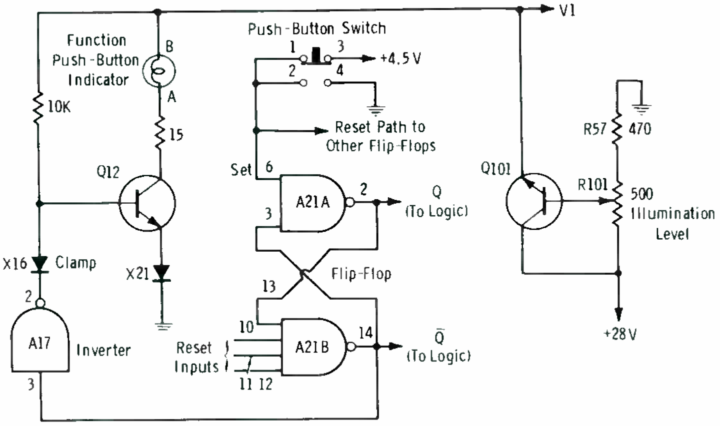


Fig. 14-15. Simplified diagram of typical push-button circuit.

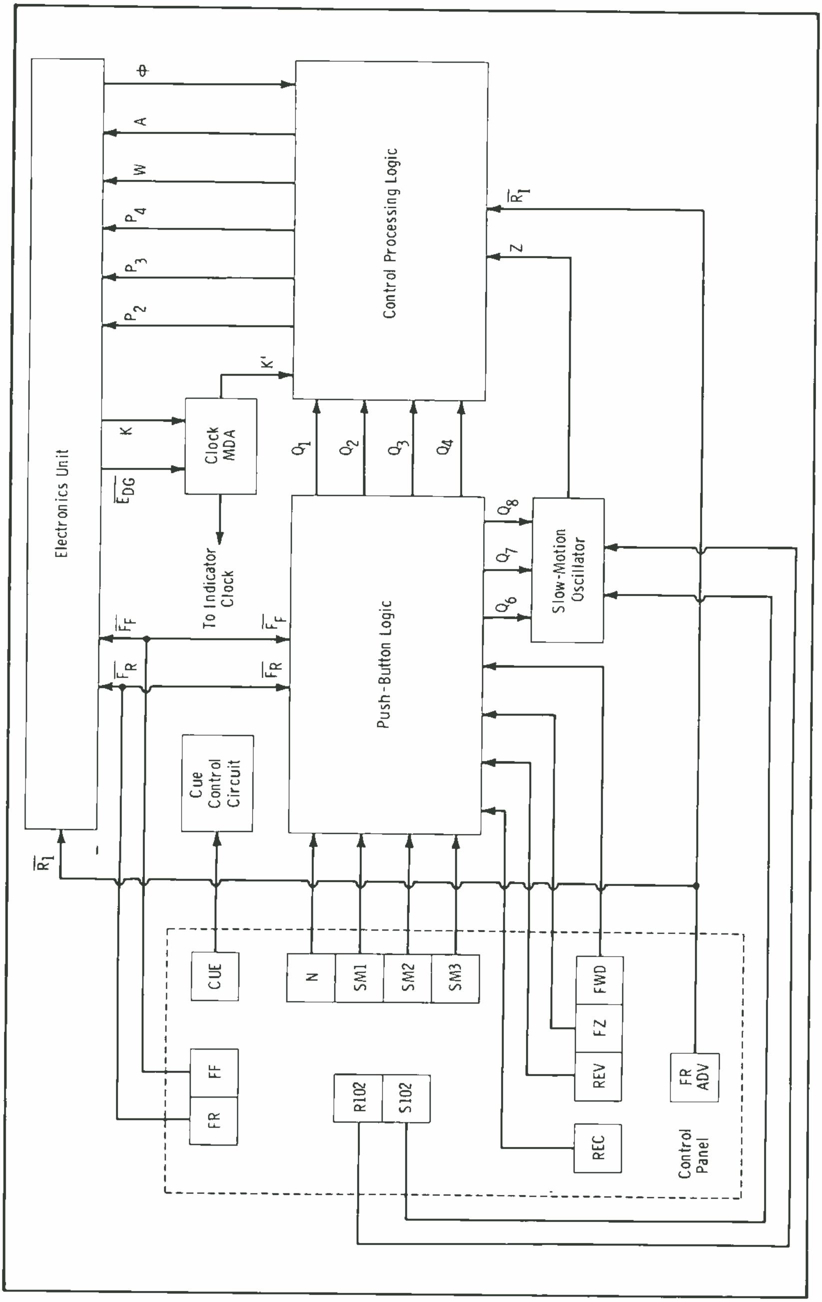


Fig. 14-16. Logic block diagram of control unit.

input of the freeze flip-flop. Thus the termination of a fast-search mode always leaves the system in the freeze mode.

Frame-Advance Control (FR ADV)—The frame-advance switch operates without a flip-flop, and the switch output is normally at ground potential. Pressing of the switch results in a change of its output to positive 4.5 volts; the output reverts to ground potential on release of the push button. The output from the switch is designated as signal R_1 and is routed to the esu and to the control processing logic.

Cue Control Circuit—The cue control switch is connected to the clock input of a JK flip-flop. Pressing the cue push button changes the positive 4.5-volt clock input level to ground potential. Successive pressings of the cue push button cause the flip-flop to set and reset. The flip-flop is reset to obtain a freezing of the cue pointer, and it is set when the cue pointer is slaved to the timer hand. Remote cue is obtained by producing the level change from 4.5 volts to ground at a remote point and routing this level through the normally closed contacts of the switch. Since the flip-flop state is changed at each level change, a cue may be set at the control unit and cancelled from the remote point, or vice versa.

Slow-Motion Oscillator—Three slow-motion switches (SM1, SM2, and SM3) provide two fixed and one continuously variable motion speeds. The slow-motion circuits use a unijunction-transistor relaxation oscillator to produce slow-motion waveform Z. A change in oscillator frequency is obtained by controlling the resistance value in the RC section. Fixed slow-motion speeds are provided by switching in preset resistors, and variable slow-motion speed is provided by switching in a variable resistor operated by the speed-control lever.

The slow-motion oscillator output (Z) is connected to the control processing logic circuitry, where it is combined with the freeze waveform (A_1) and the frame-advance waveform (R_1) before being sent to the switching logic module as the slow-motion reference waveform (A).

Control Processing Logic—The outputs of the push-button holding flip-flops and the slow-motion oscillator are combined in the control processing logic circuitry to produce the basic command signals which (along with F_F and F_R) control the recorder. These are:

(A) Forward/reverse command (P_2)
(B) Record/reproduce command (P_4)
(C) Alternate-field record command (P_3)
(D) Slow-motion reference waveform (A)
(E) Slow-motion/normal command (W)

Clock MDA—The clock MDA drives the timing-indicator clock in synchronization with the carriage stepping. The input signals are $\overline{E_{DG}}$ (from the esu), which goes to binary 0 each time head D is recording or reproducing, and signal K, the quantized forward/reverse command (from the dsu), which indicates the direction of clock motion.

The indicator clock is driven by a stepper motor having two pairs of bifilar windings. One pair is used for stepping in the forward direction, and the other pair is used for reverse stepping. Stepping in either direction is accomplished by alternately applying pulses to first one side and then the other side of the winding.

Electronics Signal Unit Logic

Refer to the logic block diagram of the esu, Fig. 14-17, during the following basic description of this logic.

Sync-Separator Module—The sync-separator module receives the composite sync and performs the processing required to obtain pulse signals suitable for control of the HS-100 system. Refer to Fig. 14-18 for the relevant waveforms in this module. These waveforms are described in paragraphs that follow.

Four primary pulse signals are derived from the composite sync and are assigned the symbols S_R, S_Y, F, and T. The S_R, or servo reference, pulse occurs at the trailing edge of the first vertical-sync pulse. The S_Y pulses are derived from horizontal-line pulses and occur at the horizontal frequency. A T-, or vertical-interval, pulse embraces the time interval from the first to the last equalizing pulses, including the vertical-sync pulses. The F, or field-identification, pulses identify the beginning of odd fields and are absent at the beginning of an even field. Two secondary pulse signals, the L and L′ pulses, are derived in addition to the other pulses for utilization within the sync-separator circuitry.

Servo Reference Pulse (S_R)—The servo reference pulse is obtained in a vertical-sync separator by gating through the first serration of the vertical-sync pulse.

Line Sync Pulse (S_Y)—The line pulses (S_Y) are generated by a horizontal-sync separator consisting of two monostables. The first monostable triggers on the negative-going leading edges of pulses and produces output pulses of 45 microseconds duration. Since the period of 45 microseconds is longer than one-half line period but shorter than a whole line period, and the monostable cannot be retriggered until it resets, the resulting output represents every line pulse plus alternate equalizing pulses and alternate vertical-sync pulses. Therefore, the output is a succession of pulses at line frequency, with the vertical-sync information effectively removed.

Field Identification Pulse (F)—The field-identification pulse (F) is generated by gating the line sync pulse coincident with the first vertical-sync serration pulse. The Boolean equation for this pulse is:

$$F = L \cdot S_Y$$

The 17-microsecond L pulse generated in the S_R processing circuitry is gated against S_Y, and a NAND gate produces $\overline{F}$. The F pulses occur only at the transitions from even to odd fields.

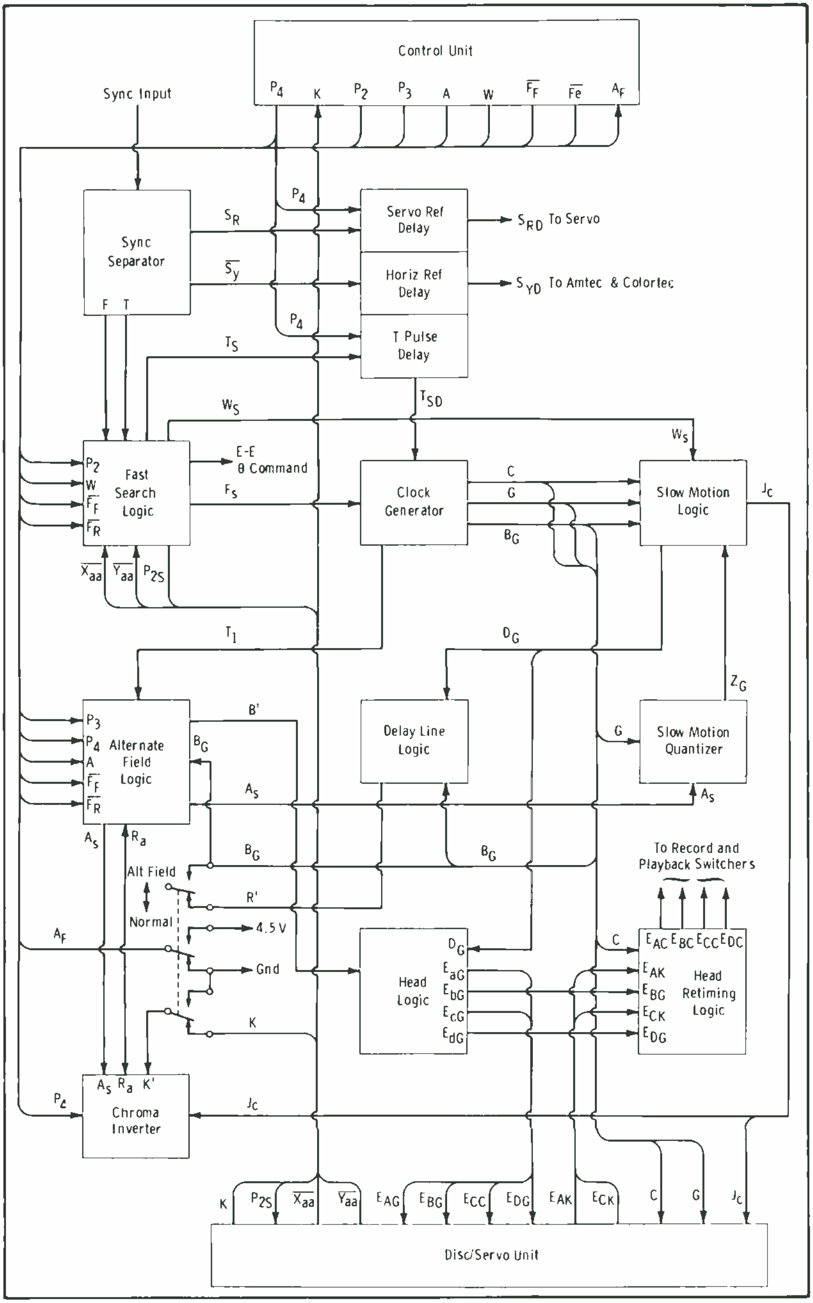


Fig. 14-17. Logic block diagram of electronics signal unit.

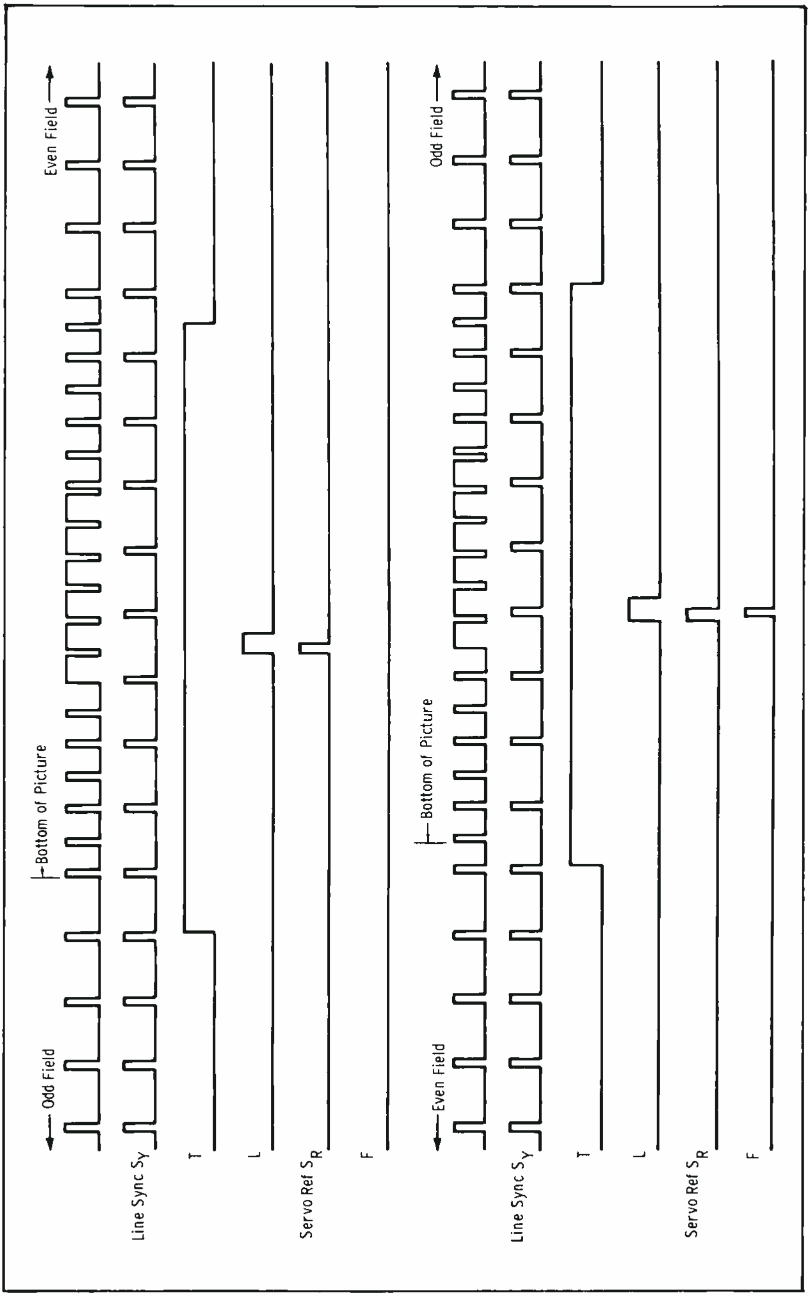


Fig. 14-18. Sync-separator waveforms.

Vertical Reference Pulse (T)—The vertical pulse (T) is a positive-going return-to-zero pulse that begins at the end of the last line-sync pulse, extends through the equalization and vertical-sync pulses, and terminates prior to the first line-sync pulse of the next field. The leading edge of the T-pulse is generated from S_Y by a flywheel oscillator and a ripple-through counter. Transistors with their associated components form a free-running multivibrator. A starting circuit assures correct starting of the multivibrator on initial power application. Normally the multivibrator is pretriggered by the incoming S_Y pulses. However, should one or more of the line-sync pulses be missing, the multivibrator will continue to run at its natural frequency, which is determined by the setting of a calibration control. The multivibrator is set at a frequency approximately 5 percent lower than the horizontal frequency, allowing for insertion of up to 20 line pulses without error in the total number of sync pulses per field in case of line-sync dropouts in the S_Y signal. The output is differentiated and inverted and used as a clock pulse to trigger a JK flip-flop.

The JK flip-flop is the input stage of a chain of ten JK flip-flops connected as a ripple-through counter. The second input to this counter is the L′ pulse (a 47-microsecond pulse) wired externally to the board. The L′ pulse is inverted and applied to the J inputs of the flip-flops as $\overline{L'}$. After a second inversion, signal L′ is applied to all P_J inputs of the flip-flops. The ripple-through counter must count equal numbers of pulses for odd and even fields. It also must start its counting exactly 258 line pulses prior to the first equalizing pulse. To meet this constraint, the counter must be reset after the second vertical-serration pulse, and this is accomplished by the L′ signal.

When the 258th sync pulse has been counted, the output of the last flip-flop, through an inverter, changes the state of the NAND-gate flip-flop generating the leading edge of the T-pulse. This differentiated signal is also routed to an inverter followed by a second inverter, and the output of both inverters is applied to a four-stage chain counter to preset all of its four JK flip-flops. These flip-flops form the second counter, which receives a signal derived by gating processed sync with the 600-microsecond pulse starting at the first vertical-pulse serration. Twelve pulses into the counter cause the state of the output flip-flop to change in coincidence with the end of vertical equalization. The output is inverted, differentiated, and applied to a NAND-gate flip-flop producing the trailing edge of the T-pulse.

Fast-Search Logic Module—The fast-search logic module is located in the ESU. The module produces pulses and signals required during fast-search modes. Its circuitry replaces the normal-motion T-pulses with fast-search T_S-pulses of increased repetition rate. Other functions generated are the θ command, which directs the electronics into the E-E mode; the fast forward/reverse command (P_{2S}), with inhibition of the normal forward/reverse command (P_2); inhibition of the field-identification pulse (F); and inhibition of the half-line delay command. Fig. 14-19 is a timing diagram showing the relationships of relevant waveforms.

Switching Logic Module—The switching logic module is located in the esu (Fig. 14-17). The module contains circuit functions which include the clock generator, the slow-motion quantizer, the slow-motion logic, the head logic, the head retiming logic, and the half-line delay logic. Each of these functions is described below; timing diagrams show the relationships of the waveforms.

Clock Generator—The clock generator is supplied with input signals T_S and F_S (Fig. 14-20). Both input pulses originate at the fast-search logic board. From the two input pulses, the clock generator produces three basic timing pulses, which are required to synchronize the switching of the system logic. The preclock pulse (G), the system clock pulse (C), and the timing pulse (B_G) are the clock-generator outputs.

The preclock pulse (G) is derived from the leading edge of the T_S waveform and is coincident with this leading edge. Logic circuits are preset by the G-pulse, which occurs prior to system clock pulse C and therefore assures that switching transients subside before system switching takes place. A further consideration for this arrangement is the fact that the logic components used in the circuitry possess inherent and finite transfer delays, which could prevent the correct completion of switching sequences during the presence of a system clock pulse.

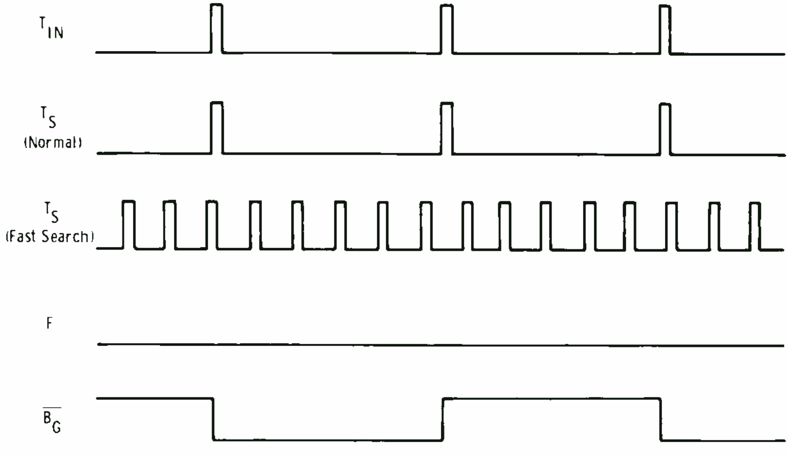


Fig. 14-19. Timing diagram of fast-search logic.

The T_S-pulse is applied to an inverter. After differentiation, the leading edge of the $\overline{T_S}$ waveform produces a negative-going pulse, which is used to trigger a 20-microsecond one-shot multivibrator. The inverted output represents pulse G and is routed to the slow-motion quantizer and the slow-motion logic.

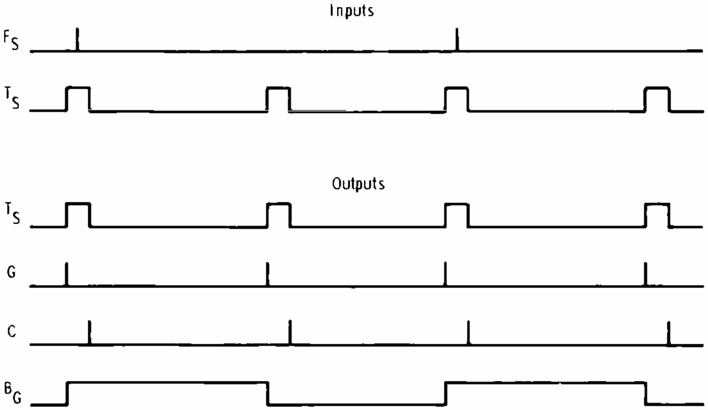


Fig. 14-20. Waveforms of clock-pulse generator.

The system clock pulse (C) is derived from the trailing edge of the T_S-pulse. Its timing is such that the leading edge of the C-pulse is coincident with the trailing edge of the T_S-pulse. The timing of the C-pulse therefore is such that it occurs approximately 600 microseconds (the duration of the T_S-pulse) after the G-pulse. The C-pulses are used to time the signal-switching and carriage-drive pulses.

The B_G-pulse is a divided-by-two version of preclock pulse G and is phased by field-identification pulse F_S. Phasing of B_G by means of F_S causes even fields to be recorded by heads A and C and odd fields to be recorded by heads B and D. This condition is valid for the normal record mode only, since the alternate-field record mode does not allow recording of even fields. The B_G waveform is a binary 1 during even fields and a binary 0 during odd fields.

Slow-Motion Quantizer—(See timing diagram, Fig. 14-21.) The slow-motion quantizer takes slow-motion reference waveform A (generated in the control unit and routed through the alternate-field logic as A_S) and converts it to Z_G. Output Z_G is a rectangular wave, each zero crossing of which is coincident with a G-pulse. The number of zero crossings of Z_G

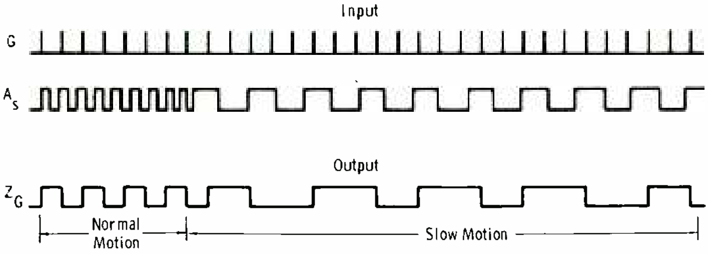


Fig. 14-21. Waveforms of slow-motion quantizer.

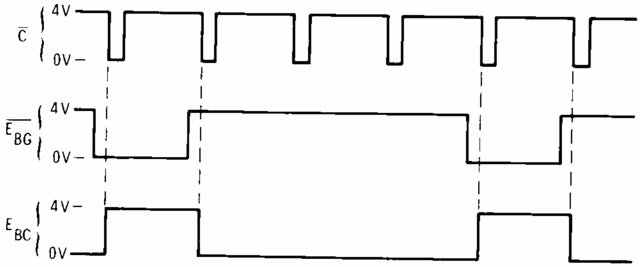
motion by circuits on the carriage logic board and re-enter the switching logic board as waveforms E_{AK} and E_{CK}.

Head Retiming Logic—(See timing diagram, Fig. 14-24.) The head retiming logic reclocks all the head pulses against waveform C prior to the application of these pulses to the head switcher. The four head-pulse inputs and their complements are applied to preset inputs of JK flip-flops. The complements of the input pulses are obtained from inverters made up of NAND gates. All four flip-flops are clocked by waveform C and therefore produce head-pulse output changes coincident with the leading edge of clock pulse $\overline{C}$. The resulting output pulses—E_{AC}, E_{BC}, E_{CC}, and E_{DC}—are routed through the harnesses to the rf switcher and switching logic board in the dsu. Pretimed waveform E_{DG} is also passed through an inverter. Thus $\overline{E_{DG}}$ is routed to the control unit for synchronization of the indicator clock.

Half-Line Delay Logic—During playback in any mode but normal-speed forward, an odd field may be gated through the reproduce electronics at the time an even field is required; or, conversely, an even field may be gated on when an odd field is required. Since this would destroy the picture interlace, it is necessary to convert odd fields to even fields, and vice versa. Conversion of one to the other is accomplished by a half-line delay of the video signal during the horizontal-scanning interval (but not the vertical-synchronizing interval) of each field requiring correction.

The half-line delay logic generates waveform R′, which controls the half-line delay. The delay is switched out when $R' = 1$ and switched in when $R' = 0$. To do this, the logic determines (A) whether an odd or even field is required and (B) whether an odd or even field is being reproduced. If a correction is required, R′ becomes 0, and for no correction R′ is 1. Also, during the vertical-synchronizing internal, R′ always is held to the value 1. Waveform B_G determines what type of field is required, since B_G is backed up to reference sync and always has the value 1 during even fields and the value 0 during odd fields.

The D_G pulse determines what type of field is actually being reproduced. In normal speed, $D_G = B_G$, so odd fields are always reproduced when odd



Note: Waveforms not to scale.

Fig. 14-24. Timing diagram of head-retiming logic.

fields are required, and even fields are always reproduced when even fields are required. The half-line delay, therefore, remains switched out. In slow motion, odd fields are reproduced when $D_G = 0$, and even fields are reproduced when $D_G = 1$.

Waveforms B_G and D_G are connected to a NAND gate, and $\overline{B_G}$ and $\overline{D_G}$ are connected to another NAND gate. The outputs are tied together and form an exclusive OR function labelled R′. This function follows the Boolean equation:

$$R' = B_G \cdot D_G + \overline{D_G} \cdot \overline{B_G}$$

or,

$$R' = B_G \cdot \overline{D_G} + \overline{B_G} \cdot \overline{D_G}$$

Thus, R′ equals binary 1 if the half-line delay is not required.

Alternate-Field Logic and Switch S1—The alternate-field logic circuit is located on the fast-search logic module in the esu. In the alternate-field mode, only one field of each frame is recorded, providing twice the normal recording time. In playback, since half the fields are absent, motion appears to be at double the rate it would be for normal recordings.

The alternate-field switch (S1) controls three functions:

(A) Provides A_F, the alternate-field-mode command, to the control unit. The level of A_F is logic 1 in the alternate-field mode and logic 0 in the normal mode.

(B) Provides the K′ waveform to the chroma-inverter logic. The K′ signal is K (the quantized forward/reverse command) in the normal mode and is 0 in the alternate-field mode.

(C) Provides the R_a waveform for the half-line delay and chroma-inverter logic. In the normal mode:

$$R_a = R' = B_G \cdot D_G + \overline{B_G} \cdot \overline{D_G}$$

In the alternate-field mode:

$$R_a = B_G$$

Chroma-Inverter Logic—The chroma-inverter logic circuitry is on the chroma-inverter module, which is located in the esu. The chroma inverter controls the chroma phase continuity of the reproduced signal, which would otherwise be interrupted in any mode other than normal-speed forward playback. The chroma-inverter logic controls the action of the chroma phase inverter by means of a binary waveform which changes level each time the chroma phase is to be reversed.

For recordings made in the normal record mode, chroma phase must be reversed each time the half-line delay is inserted in forward-motion playback. In reverse-motion playback, the chroma phase is also reversed each time the heads step.

In the alternate-field mode, the action of the chroma inverter is the same for forward and reverse motion. The chroma phase must be reversed each time the half-line delay is inserted and each time the heads step, unless the two occur at the same time. The chroma-inverter control waveform is designated C_H. The chroma-inverter logic has been explained previously.

Disc Servo Unit Logic

The disc servo unit logic is located on the carriage logic A1 and carriage logic A2 modules, which are located in the dsu (Fig. 14-25). The purpose of the logic is to provide the head-stepping command pulses (F-pulses) to the carriage-motor drive amplifiers. This logic maintains proper head synchronization for all motion speeds, forward and reverse directions, and inward and outward travel of the heads across the disc. The arrival of the head carriage at the outermost or innermost tracks of the discs is detected by means of photocell end-stop switches, which control the reversal of head-carriage motion at these points.

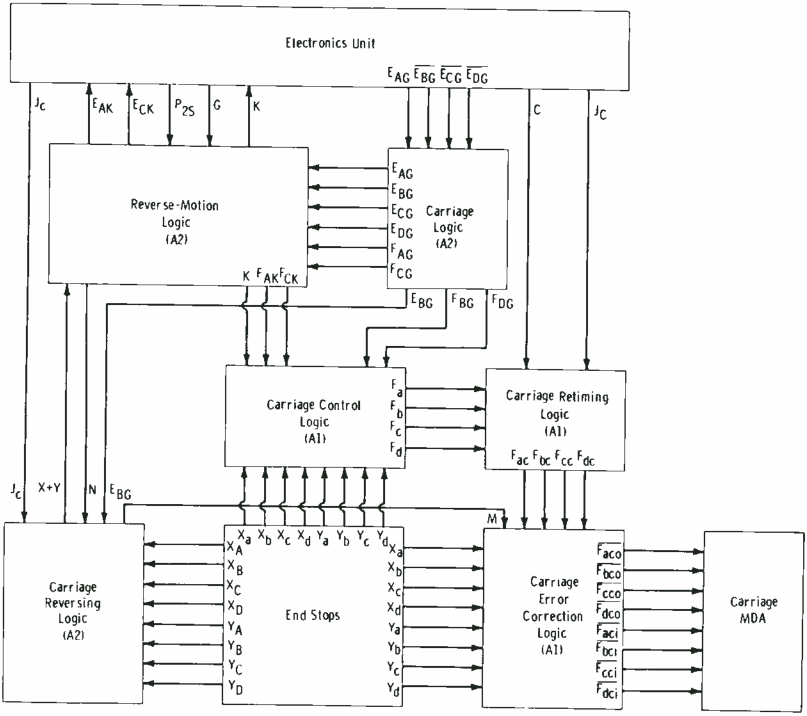


Fig. 14-25. Logic block diagram of disc servo unit.

In the record mode (see Table 14-6), one head is recording, one is erasing (in preparation for recording the next field), and two are stepping to the adjacent track during each field interval. For example, during field 1 (when $E_A = 1$), head A is recording, head B is erasing, and heads C and D are stepping. Similarly, during field 2, E_B causes head B to record, head C to erase, and heads D and A to step. Then during each cycle of four fields, each head erases, records its field, and steps two tracks before repeating the cycle. These pairs of stepping pulses, the F pulses, are generated in the block labelled "carriage logic" in Fig. 14-25.

Table 14-6. Head Sequencing, Normal Record

	Field 1, 5, 9, etc.	Field 2, 6, 10, etc.	Field 3, 7, 11, etc.	Field 4, 8, 12, etc.
Head A	Record	Move	Move	Erase
Head B	Erase	Record	Move	Move
Head C	Move	Erase	Record	Move
Head D	Move	Move	Erase	Record

The motion of the heads across the discs is shown in Fig. 14-26 for normal-speed playback. The fields are displayed horizontally, the track number vertically. Head motion is identical to that described above for the record mode. During field 1, head A is reproducing on track 6. During field 2, head B reproduces on its track 6, while head A moves one track to track 5. During field 3, head C reproduces its track 6, head B moves to track 5, and head A moves to track 4. The heads move toward track 1 in this manner, each reproducing a field in turn and then moving twice to the next even-numbered track. After reproducing field 9, head A steps once, then reaches its end stop. Further motion of head A in that direction is inhibited by the carriage error-correction logic. By the end of field 13, all heads have reached their end stops at track 1. At this point, the direction of head-carriage motion is reversed, and head A begins moving away from the end stop, this time reproducing the odd-numbered tracks, followed by heads B, C, and D in the manner described above. When the other set of end stops is reached, a similar carriage reversal takes place, and the heads once again reproduce the even-numbered tracks.

If, instead of forward motion, the operator selects reverse-motion playback, the recorded tracks must be played back in the sequence opposite to that in which they were recorded. Such a reversal of motion is shown at the end of field 21 (Fig. 14-26). The direction of carriage motion is reversed at this point, and the E pulses are made to reverse their sequence (E_C-E_B-E_A-E_D, instead of E_A-E_B-E_C-E_D). This reversal of E-pulse sequence is accomplished by interchanging the E_A and E_C pulses. Upon selection of

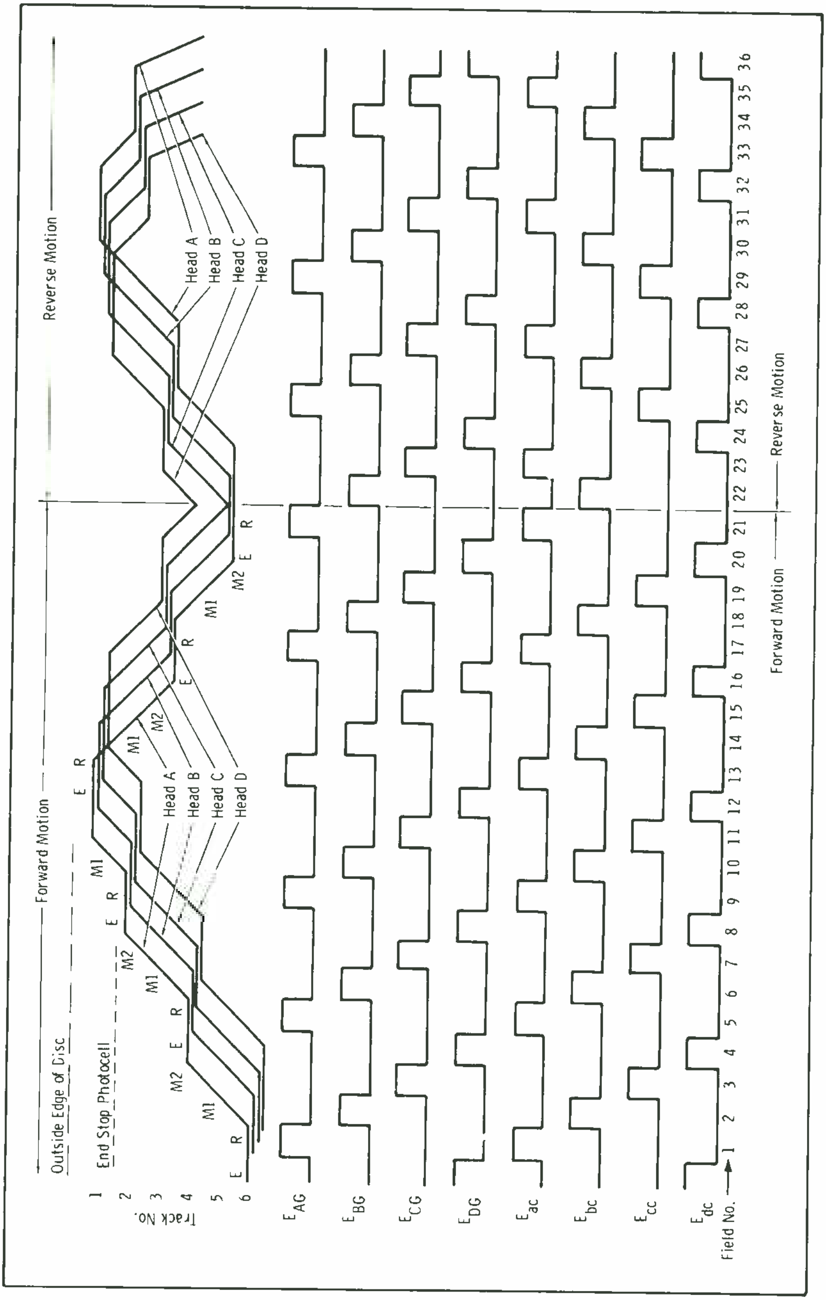


Fig. 14-26. Head-stepping diagram.

reverse motion at field 21, field 22 is reproduced by head B, field 23 by head A, field 24 by head D, and so on.

In reverse-motion playback, carriage reversal at the end stops is accomplished in a manner somewhat different than for forward motion. Following reproduction of track 24, head D steps twice and arrives at its end stop, followed in turn by heads C, B, and A. When all heads have arrived, the direction of carriage motion is reversed as before. Unlike the case for motion in the forward direction, each head is now allowed to take just one step away from the end stops before reproducing a track, thereby maintaining a mirror image of the forward-motion carriage-reversal sequence. To summarize, the carriages, in forward motion, make single steps when arriving at the end stops, and take two steps on leaving. In reverse motion, they take two steps when arriving at the end stops, and one step when leaving.

At the end stops, the carriages are automatically resynchronized with one another to correct for any possible carriage stepping errors. If, for example, a head has gotten out of step due to a momentary power failure, the inhibiting action of the end-stop photocells holds all heads at the end track until the last head has arrived. The logic then ensures that the heads leave in correct order, A-B-C-D in forward motion and D-C-B-A in reverse-motion playback.

In slow-motion playback, head motion follows the sequence described above, except that each time a field is repeated, no carriage-stepping pulses are generated.

Carriage Logic A2 Module—The carriage logic A2 module in the dsu contains: (1) the carriage logic, (2) the carriage reversing logic, and (3) the reverse motion logic. It should be clearly understood that reversal of carriage motion at the inner and outer track limits is not a reversal of video motion, as the reproduced video still progresses in a forward video motion. Forward video motion is identified by a binary-1 level of signal K and by the head and carriage sequence A-B-C-D. Reverse video motion is characterized by a binary-0 level of signal K and by the head and carriage sequence C-B-A-D. The A and C functions are interchanged for the reverse modes to produce reverse motion while maintaining correct odd-to-even field relationships.

The carriage logic receives four inputs. These inputs are head pulses from the switching logic board in the esu and are labelled $\overline{E_{BG}}$, $\overline{E_{CG}}$, $\overline{E_{DG}}$, and E_{AG}. These signals are gated in pairs by the use of NAND gates to produce carriage-motion signals F_{AG}, F_{BG}, F_{CG}, and F_{DG}. Signals F_{BG} and F_{DG} are routed to the output. Signals F_{AG} and F_{CG} are routed into the reverse-motion logic. The Boolean equations for the four signals are:

$$F_{AG} = E_{BG} + E_{CG}$$
$$F_{BG} = E_{CG} + E_{DG}$$
$$F_{CG} = E_{DG} + E_{AG}$$
$$F_{DG} = E_{AG} + E_{BG}$$

It can be seen from these equations that each carriage will step twice during each series of four E pulses, satisfying the stepping requirements for forward-motion operation. Further processing of these signals is required to produce carriage-stepping pulses which satisfy the requirements for carriage movement during reverse motion and while negotiating the end stops.

Carriage-Reversing Logic—The carriage-reversing logic generates the carriage-reversing command (M) which governs the direction of motion of the carriages. Carriage motion may be inward or outward for forward or reverse video motion. Inward motion is defined as carriage travel from the periphery toward the hub of the discs; outward motion is the opposite. The arrival of a head at the outer track is detected by photocell X (at the inner track by photocell Y) for each disc surface. The carriage-reversing command (M) is a function of two signal sources, the motion-reverse command (K) and the end-stop switch signals.

The reverse-motion logic circuitry generates quantized reverse-motion command K and produces the reversal of the channel switching and stepping sequence (A-B-C-D changed to C-B-A-D) during reverse motion. This is accomplished when $K = 1$ by interchanging the E_A pulse with the E_C pulse, and the F_A pulse with the F_C pulse.

Reverse-Motion Command K—Command K is equal to the P_{2S} command quantized by head signal E_{BG} and preclock pulse G. Command K is also inhibited from changing while the carriages are at their end-stop switches, as motion-reverse switching coincident with carriage end-stop reverse could cause errors in the carriage reversing process.

Head Switching Sequence in Reverse Motion—Reverse video motion is obtained by reproducing the video in a sequence opposite to the record sequence. Substitution of the channel-A timing signals for the channel-C signals and vice versa converts the sequence from A-B-C-D to C-B-A-D for reverse video motion. The head pulses for channels B and D are not affected by reverse motion, but the pulses for channels A and C are.

Carriage Stepping Sequence in Reverse Motion—The reasons for exchanging the channel-A and channel-C pulses described in the preceding paragraph for the head logic apply also for the carriage pulses. Output signals F_{AK} and F_{CK} are derived in a manner similar to that used for the head logic, except that carriage-motion pulses $\overline{F_{AG}}$ and $\overline{F_{CG}}$ are used instead of head pulses E_{AG} and E_{CG}. Four gates are contained in assembly A2, which is used in this circuit. Pairs of gates have their outputs tied together, performing the function of an OR gate. The Boolean equations for each of the output signals are as follows:

$$F_{AK} = (F_{AG} \cdot K) + (F_{CG} \cdot \overline{K})$$
$$F_{CK} = (F_{CG} \cdot K) + (F_{AG} \cdot \overline{K})$$

where,

$$F_{AG} = E_{BG} + E_{CG}$$

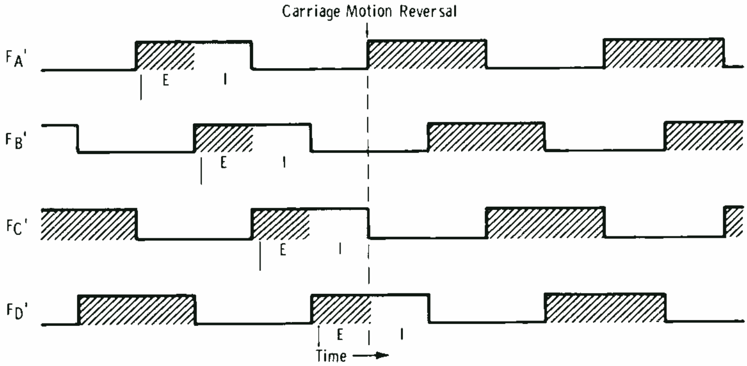
and

$$F_{CG} = E_{DG} + E_{AG}$$

Carriage Logic A1 Module—The carriage logic A1 module of the dsu contains: (1) the carriage control logic, (2) the carriage retiming logic, and (3) the carriage error-correction logic. Outputs from this module are control pulses representing inward and outward carriage-motion pulses.

The carriage-control logic controls the movement of the carriages away from the end stops in such a way that they start in the sequence A-B-C-D (with A first) for forward motion, and in the sequence D-C-B-A (with D first) for reverse motion. In addition, for reverse motion, each carriage is allowed to move only one track, rather than the normal two, as it leaves the end stops. This control is obtained by gating off the F pulses to any head whose motion must be inhibited.

See Fig. 14-27. When all heads are at their end stops, the direction of the carriage motor is reversed by the carriage-control logic, and head A then steps away from its end stop. Head B, which otherwise moves along with head A, must be inhibited in order to preserve the A-B-C-D sequence of head motion.

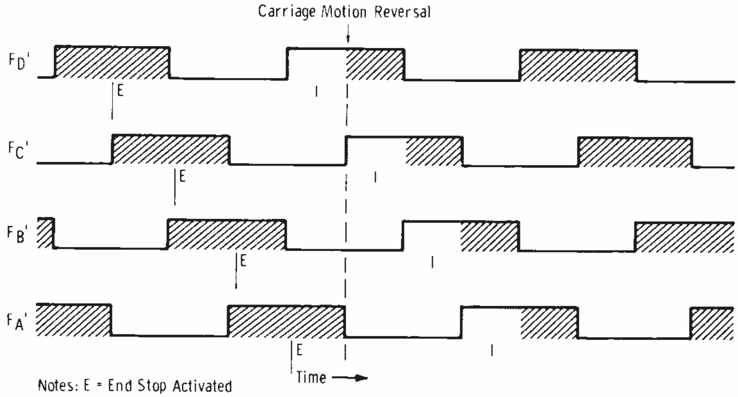


Notes: E = End Stop Activated
I = Stepping Inhibited

Fig. 14-27. Carriage pulse sequence, forward video motion.

See Fig. 14-28. When all heads reach their end stops and the direction of carriage motion is reversed, each head, in the sequence D-C-B-A, must take only one step away from the end stops before resuming normal 2-track stepping. Head D, the first to leave, automatically moves only one track because carriage reversal takes place after what otherwise would have been its first step.

Carriage Retiming Logic—The carriage retiming logic changes the timing of the carriage signals from preclock time G to system clock time C, then samples them with the J pulse to produce the short-duration car-



Notes: E = End Stop Activated
I = Stepping Inhibited

Fig. 14-28. Carriage pulse sequence, reverse video motion.

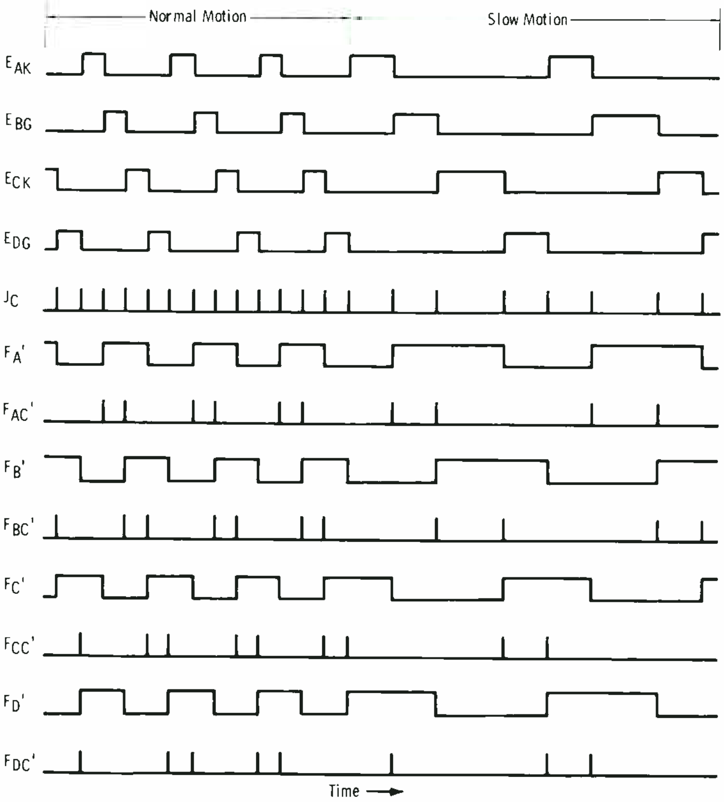


Fig. 14-29. Head and carriage timing waveforms of carriage-retiming logic.

riage pulses F_{AC}', F_{BC}', F_{CC}', and F_{DC}'. It employs binary devices and associated NAND gates and inverters. The four channels operate in a similar manner. See Fig. 14-29 for waveforms of the retiming logic.

Carriage Error-Correction Logic—The carriage error-correction logic serves to inhibit the further motion of each carriage as it reaches an end stop. When all four heads reach their respective end stops and the direction of carriage motion is reversed by the carriage reversing logic, the carriages are allowed to step away from their end stops in correct sequence as determined by the carriage control logic. Output pulses $\overline{F_{aco}}$, $\overline{F_{bco}}$, $\overline{F_{cco}}$, and $\overline{F_{dco}}$ control the outward movement of the carriages. Pulses $\overline{F_{aci}}$, $\overline{F_{bci}}$, $\overline{F_{cci}}$, and $\overline{F_{dci}}$ control the inward movement of the carriages.

14-6. THE AMPEX HS-200 TELEPRODUCTION SYSTEM

The Ampex HS-200 teleproduction system is an instant-replay disc recorder that can be operated manually or automatically to provide a variety of special effects, editing, and animation possibilities. This system offers the same freedom to create the special effects usually limited to film, but at lower cost and greater speed.

The HS-200 system is a natural outgrowth of the color disc technology of the HS-100B instant-replay recorder/reproducer. Like its predecessor, the HS-200 reproduces material at normal, fast, and slow speeds—even to stop action—in both forward and reverse, with instant replay of key action. Versions are available which are fully compatible with monochrome or NTSC and PAL color video signals.

> NOTE: The HS-100B is the video disc system used in the HS-200 teleproduction system.

Features

Because of the instant review feature of the HS-200 teleproduction system, animations or other edited program material are available for review in full color immediately after recording. When the material is reviewed in its finished form and corrections are necessary, all or any part of the material (even to a single frame) may be replaced. The preprogramming feature of the HS-200 system permits automatic editing of complete programs, such as commercials and animation sequences.

System Console—The console contains all the primary operating controls for the system. The primary controls and indicators are arranged by function on six panels: record panel, memory panel, slow-motion panel, dissolver panel, numerical-display panel, and patch panel. In addition, a picture-monitor panel and a waveform-monitor panel are provided.

Variable Frame Increment (Animation)—The HS-100 has a total capacity of 900 frames, which may be recorded in one operation or in a selected number of frame increments between one and 900. By this means, it is possible to complete in a relatively short time an animation sequence that would ordinarily require hours of cutting, reviewing, and editing.

Animation can be preprogrammed and requires only two passes of video tape on the video recorder. On the first tape pass, the vtr records the cues at appropriate places on the tape. The HS-200 is used on the second pass to compile the animation sequence automatically. In the second pass, each vtr cue commands the HS-200 to record the preset number of frames. This second tape pass has been simplified to permit a technician to complete the assignment without the assistance of the editor. With all machines operating in any one recording session, correct color editing is always maintained between one camera and the HS-200 or between one vtr and the HS-200, provided that neither the HS-200 nor the vtr transport is turned off. Unless the vtr is provided with 15-Hz editing pulses, there will be only a 50-50 chance of correct color editing each time the transport is turned off.

Time Lapse—Time lapse is an extension of the animation feature. The HS-200 records a predetermined number of frames; then a reasonable number of frames is allowed to pass unrecorded. Replaying this sequence at normal speed will produce the effect of time lapse. An automatic time-lapse unit is available as an accessory.

Random Access to Any Frame—The system includes a numerical-entry keyboard and a numerical-readout frame counter which provides every frame with an identity. Any number from 1 to 900 can be called up, stored, and then displayed. When using the automatic search feature, the HS-200 will retrieve the desired frame and place it in a freeze condition. This frame may be used as an individual frame or the first frame of a sequence.

Freeze Frame or Field—On the HS-200, a freeze picture can be obtained in two ways. One method is by repeating one recorded field; the video is fed through a half-line delay during every other field interval to produce a frame. Because each frame is made of two identical fields, there is a loss of definition. The other method available on the HS-200 is by repeating two adjacently recorded fields to make up the frame. In this way, full definition is achieved. These two modes are called the field and frame modes, respectively.

If a freeze picture of some recorded fast action is required, the field mode is normally used because the frame mode would produce a blurred picture due to the fact that the frame was made of two pictures recorded 1/60 second apart. The frame mode is used during animation to provide full definition.

Slow motion is produced by repeating fields or frames. The same choice of repeating frames or fields is available in slow motion.

Time-Controlled Freeze Frame—Any frame can be accessed and held in freeze for any time period between 2 and 900 frames before another mode, such as switch or forward or reverse motion, is actuated.

Automated Dissolves of Variable Length—The HS-200 contains a digital dissolver. The dissolve rate can be preset to any one of the following: cut, 4, 8, 11, 16, 22, 32, 43, 64, 86, 128, and 256 frames. A dissolve between any two signal sources (one of which would normally be the output of the HS-200) will take place at the push of a button, at the receipt of a remote cue, or at any frame selected on the HS-200.

Matting and Keying—A matting and keying amplifier, which comes as an accessory, allows adjustment of luminance, chrominance, and saturation of the matting signal. This device will key or mat at the push of a button, at the receipt of a remote cue, or at any selected frame of the HS-200. The HS-200 enables the user to animate any keying pattern and record it on tape for future use.

Sequential Programming Control Circuits—The patch-panel unit built into the HS-200 system can receive up to eight switching, mixing, and editing commands. These commands are stored until cued. Once the preprogramming is prepared, the HS-200 will assemble an entire segment automatically.

Variable-Speed Playback—As with the HS-100, all recorded material can be played back at any slow-motion speed between freeze and normal in either the forward or reverse direction. There are also preselected slow-motion speeds of exactly ½ and ¼. In addition, the HS-200 allows these features to be programmed through the patch panel. With the alternate-field mode, alternate-frame mode, or time-lapse unit, motion can be speeded up above normal speed.

Two-Way Remote Control and Rehearsal—The HS-200 can receive cues from another HS-200, or from a vtr, in the form of logic commands or tone bursts, and act upon them through the patch panel. It can also send signals to another HS-200 or vtr. This, for example, permits preprogramming of an A-B roll consisting of cuts, dissolves, and slow-motion effects between two HS-200's or one HS-200 and a vtr.

Built-In Monitoring—The system console includes a waveform monitor and a video switch to permit the following points of the system to be monitored: input video, Colortec output, disc output, dissolver output, key-amplifier output, system output, and assembly vtr output; in addition, there is provision for one spare.

NOTE: The disc servo unit, electronics signal unit, and output processing unit are referred to collectively in this text as the HS-100 or HS-100B slow-motion video recorder/reproducer. Also included as part of an HS-100 or HS-100B is a small control unit, previously described. If the control unit is part of an HS-100B, it can be replaced by the HS-200 console to form the HS-200 system.

Assembly—The simplest concept of motion-picture editing (either film or tape) is that of *assembly,* the putting together, in sequence, of various scenes available from prerecorded material, or the production of scenes in the required order at the time of editing. The process of assembly from prerecorded material involves locating the desired sequence and attaching it to the preceding one either physically, photographically, or electronically. This is actually the only way the operation can be done with film with any degree of precision or artistic flexibility. With either tape or disc, however, assembly and recording can be accomplished concurrently by producing the scenes in order and recording each one to its desired timing and making the desired transitions (Chapter 10). The HS-200 adds an order of magnitude to the ease, speed, and precision with which this can be done, and progress may be reviewed as the operation is carried out.

Insertion—Insertion of new material into previously recorded material is a common requirement. Accurate placement of the insertion with regard to preceding and following material requires the ability to determine the "in" and "out" edit points of both the new material and the material into which it is to be inserted (Chapter 10). The HS-200 offers two possibilities for carrying out such an operation: (1) The material to be inserted is recorded on the HS-200 and cued accurately to the desired "in" point and then electronically edited into the prerecorded sequence on tape from cues previously placed and precisely adjusted. (2) The original material is recorded on the HS-200, and the new material is inserted at the desired points from any other source, once again with one-frame accuracy of placement.

Cutting—The *cut* (an instantaneous change of scene) is the simplest of video transitions both physically and subjectively; timing is the only variable. With film, proper timing is accomplished by selecting the frame at which the cut is desired. The HS-200 offers this facility by allowing examination of material at a frame-by-frame rate, and it also allows realistic preview of the cut before it is accomplished.

Dissolving—The *dissolve* is a more complex transition, requiring the fading out of the first picture simultaneously with the fading in of the second one. Timing again is the critical point, with respect not only to when the dissolve occurs, but also to how long it will last. With film, this is an operation that is done in the optical printer with precise control of the number of frames involved, and therefore must be entrusted to the lab technician. With the HS-200 and an accompanying video source, dissolves may be achieved with the same accuracy and automatically controlled as to the length. Again, the major advantage offered by this system is the ability to preview or rehearse the effect with the possibility of making desired adjustments before actually performing the final transition.

Fading—The *fade* involves simply fading from picture to black or vice versa. It is easily accomplished in a number of ways. It can be done at the time of recording or during the editing process. The advantage offered by the HS-200 in this operation is accuracy of timing.

A-B Roll—The *A-B roll* technique, commonly used in film production, involves dividing the production into "odd" and "even" scenes. The odd scenes are placed in sequence on one video source and the even ones on another. With proper timing between the two sources, odd and even scenes are then combined into the desired final form. With the precision of control available, this is easily accomplished with two HS-200's or by one HS-200 and a second video source.

Keying—In this process, one picture signal is inserted into another, e.g., a title into a background scene. In film, this is a laborious process requiring time and expense. In television, it is achieved electronically by combining two video signals. The main use of the HS-200 in this process is as the source of the signal to be keyed. Because of the frame-at-a-time playback capability of the HS-200, material to be keyed may be recorded on succeeding frames and keyed into the background as desired and changed on cue. It is possible to record animated titles or products on the system and key them into other material with full control of movement and timing.

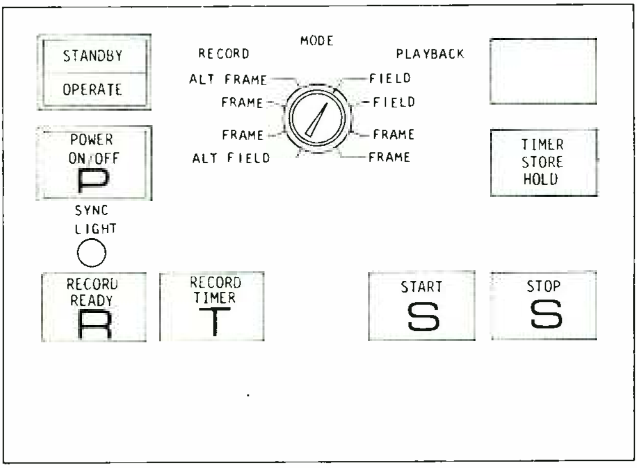
Matting—This process is the same as keying as far as the HS-200 is concerned.

Superimposure—Superimposure is a process that combines video material from two sources. The end result of superimposure is similar to that of keying or matting, although the effect is not as crisp. The HS-200 acts as one of the sources, probably for printed material.

Time Lapse—This technique, which might also be called "time compression," allows the reproduction of lengthy events to be condensed as much as desired. The blooming of a flower, for instance, can be reproduced in a period of five seconds. This effect is accomplished by taking picture frames at selected intervals during the event being recorded, rather than recording it continuously. When the reproduction is played back continuously, time compression is achieved. In other words, if one frame is recorded every five seconds during a 15-minute process, the final recording will have a total of 180 frames. If these frames are played back at the normal rate (30 frames per second for television or 24 frames per second for film), the whole event can be viewed in six seconds. This is done on film by exposing one frame (either manually or by a timer) at every selected interval. The same technique is possible on magnetic recordings with the HS-200. Two advantages accrue: (1) the reproduction is immediately reviewable, and (2) playback is not locked to any particular frame rate (as it is in film), allowing the length of the event to be manipulated to fit any time segment.

Simulated Time Lapse—This interesting technique, which produces the effect of time lapse, is achieved by combining the backward-motion and single-frame recording capabilities of the HS-200. For example, a potted plant may be placed on camera and a series of frames recorded with a little of the plant snipped off between each "take" until the plant has been cut entirely away. If this sequence is played in reverse, the plant seems to grow before the camera. This technique can be applied to a number of given instant. In freeze operation, for example, the frame counter is stationary. When the HS-200 is either turned off or placed in the standby mode, the system may develop a counting error. To resynchronize the frame counter after turn-on, the controls are set for normal forward operation, and all four heads are allowed to move to the outer edges of the disc.

There are eight stores accessible through the memory panel. The number in the store being accessed at any time is shown on the store display. However, the particular store being accessed on the memory panel is indicated by an illuminated store push button.



STANDBY/OPERATE	Controls power to disc motor and hour meter
MODE	Selects recording/reproducing mode
POWER ON/OFF	Controls system power
TIMER STORE HOLD	Stores number of frames displayed in Store Display for automatic timing of recordings
RECORD READY	Switches system out of reproduce mode and prepares it for recording
RECORD TIMER	Selects manual or automatic timing of recorded intervals
START	Initiates recording sequence
STOP	Terminates recording sequence

Courtesy Ampex Corp.

Fig. 14-30. Record panel on HS-200 control console.

Record panel—Operations performed on the record panel (Fig. 14-30) control the major recording functions of the system.

The on position of the POWER ON/OFF switch supplies all required power to the system; however, even in the off position a small low-current 28-volt relay supply remains on. To remove all power, the main breakers in the HS-100 (CB-1, rear connector panel of esu) and HS-200 console (inside lower left front panel) must be switched off.

The OPERATE/STANDBY push button controls the power to only the disc motor and hour meter, and has no effect on the remaining circuits, computer logic, or information in stores. Setting this control to Standby will save unnecessary wear on the heads and discs.

The green SYNC indicator lamp is in parallel with the lamp of the disc servo unit. When the lamp is fully on (not flickering), in indicates to the operator that the disc servo is in sync. Neither a correct recording nor a correct reproduction can be achieved unless this lamp is on.

The RECORD READY control takes the system out of the reproduce mode and prepares it for instant recording in response to a record command. When the RECORD READY push button is pressed, the SYNC lamp will flash momentarily, then glow steadily, indicating that the system is ready to record. NOTE: The system will not switch to record ready from the reverse reproduce condition; it must first be placed in forward.

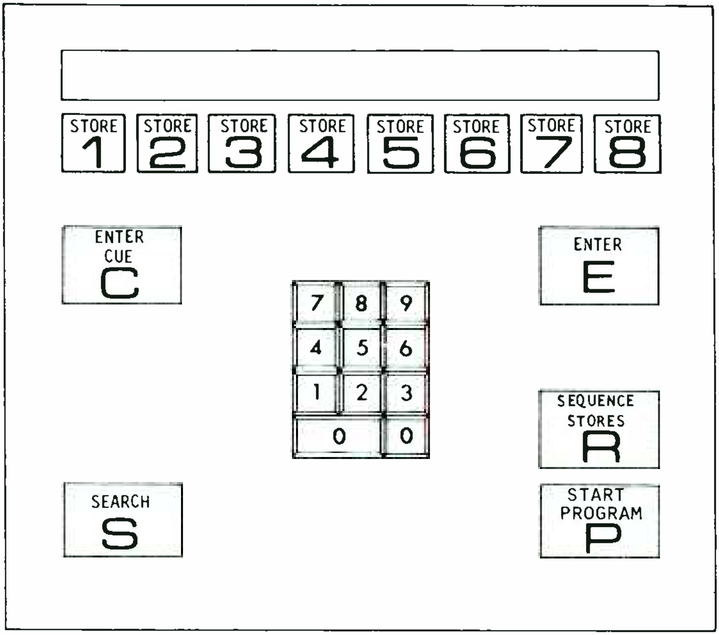
The start, stop, and record timer functions are best explained by describing manual, automatic, and programmed-sequence recording operations. To make a manual recording. the record timer must be off and the system must be in record ready. With the green SYNC light steady and the START push button pressed, the system will begin recording on the next 15-Hz color editing pulse. The system will stop recording when the STOP button is pressed. To make each successive recording, press the START button and then the STOP button.

To record a preset number of frames automatically, the record timer must be on and the system must be in record ready. When the START button is pressed, with TIMER STORE HOLD off and SEQUENCE STORES (Fig. 14-31) off, the HS-200 will wait for the next 15-Hz color editing pulse, after which it will record for the number of frames displayed on the store display. The same number of frames is recorded each time the START button is pressed.

Up to eight different recording lengths can be programmed in sequence instead of one at a time. The length of the first recording in frames is put in store 1. The length of the second recording in frames is put in store 2, and so on up to store 8. When this is completed, the RECORD TIMER, RECORD READY, and SEQUENCE STORES push buttons are all set to the on position, and the TIMER STORE HOLD button is off.

The first time the START button is pressed, it will cause the number of frames in store 1 to be recorded. The second time it is pressed, it will cause the number of frames in store 2 to be recorded, and so on. As always, the manual operation of the START push button can be replaced by a cue from a vtr (by feeding a tone-burst cue, for example, and patching from Remote VTR A to Start Record).

Pressing the TIMER STORE HOLD push button to the on position stores the number shown on the store display in a ninth store called the *timer* *store.* The number will be stored there until the TIMER STORE HOLD button is pressed to off. If the system is in automatic record, it will record for the number of frames in this ninth store. With a pencil, the operator should write the number stored in the space provided above the TIMER STORE HOLD push button. After the number is stored, the display may be changed without affecting the number stores. The use of the timer store hold feature is recommended, instead of methods described which do not use this feature, for making an automatic recording. If the wrong store is accessed by mistake when the TIMER STORE HOLD push button is off,



STORING FUNCTION

STORE 1-8	Store Selector
ENTER CUE	Enters displayed frame counter into store
ENTER	Enters keyboard selection into store
Keyboard	Selects three-digit number for stores

OPERATIONAL FUNCTIONS

SEQUENCE STORES	Returns program selected on patch panel to beginning
SEARCH	Initiates search and display operations for the frame number shown in Store Display
START PROGRAM	Begins program selected on patch panel

Courtesy Ampex Corp.

Fig. 14-31. Memory panel on HS-200 control console.

a recording of incorrect length may be made. This is impossible when the timer store hold feature is used.

The MODE selector switch selects the recording and reproducing modes of the HS-200. The four switch positions are labelled to describe the mode of recording:

1. ALTernate FIELD	FIELD Reproduce
2. FRAME	
3. FRAME	FRAME Reproduce
4. ALTernate FRAME	

Recordings made in positions 1 and 4 must be reproduced in positions 1 and 4, respectively. Recordings made in positions 2 and 3 may be reproduced in either position 2 or 3.

When recordings are made in position 2 or 3, every field and frame is recorded on the discs. These recordings can then be reproduced in two ways. In position 2, reproduction is in the *field* mode, in which slow-motion or freeze pictures are produced by repeating individual fields and using a half-line delay to obtain the interlaced frames. This provides for best picture resolution when there is motion in the picture between one field and the next, as in a fast-action scene. In position 3, reproduction is in the *frame* mode, in which slow-motion and freeze pictures are produced by repeating complete frames. This provides for best picture resolution when there is no scene motion between fields of a given frame, as in an animated scene. The frame mode gives full vertical resolution, but the field mode does not.

In position 1, the HS-200 records every other field (one field of each frame). Playback is in the *field reproduce* mode, using the half-line delay. This produces some loss of vertical resolution in the picture.

In position 4, the HS-200 records every other frame. Playback is in the *frame reproduce* mode without using the half-line delay. This produces some loss of motion resolution but no loss of vertical resolution in the picture.

Memory Panel—The push-button controls on the memory panel (Fig. 14-31) are divided into two groups. The first group—STORE 1 through 8, keyboard, ENTER, and ENTER CUE—is used to enter and store frame numbers. In the second group, SEQUENCE STORES changes the operational mode of the eight store buttons, and SEARCH and START PROGRAM are operating controls.

System Operation

We will go through a brief description of operating conditions and the philosophy associated with system control. Detailed step-by-step procedures are provided in the instruction book for the HS-200 system. Obviously, space does not permit such details in this text, and only fundamentals important to a general understanding of operations procedures are presented.

Assemble—Because of the precision with which material can be manipulated on the HS-200, it is not necessary to assemble in sequence once the accuracy of segments and overall timing has been determined. For example (refer to Fig. 14-32): If it is known that the third scene in a sequence will occur from the 18th to the 24th second of the total time, the scene can be programmed on the HS-200 to start recording at frame number 560 and stop 180 frames (6 seconds) later, at frame number 740. If it is being recorded "live," the action is cued, and the HS-200 is started manually. Only the number of frames desired will be recorded, and the next scene can then be recorded in a similar manner by again adjusting the number of frames to be recorded. If the material is coming from a video-tape recorder, a cue may be placed at the "in" point on the tape, and this will start the HS-200 in record automatically. In this way, precise timing adjustments of scenes and cuts are possible.

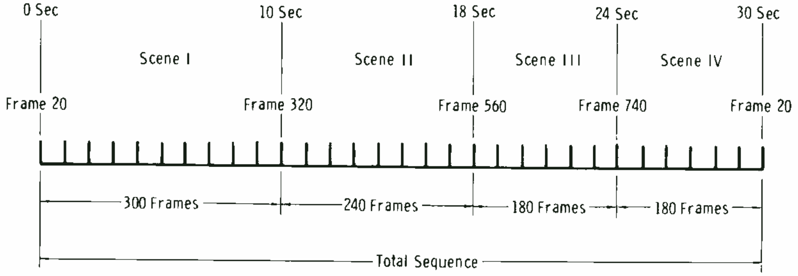


Fig. 14-32. Assembly of scenes.

Now, if it is desired to go back and record scene II, just determine the length of scene II (in frames), subtract that from the starting point of scene III, use the resulting frame number as the starting point of scene II, and program the HS-200 to record the number of frames in scene II.

An entire sequence would be recorded as follows:

A. Cue the HS-200 when the frame counter displays 560; then program the system to record 180 frames. This will record scene III.
B. Without changing the frame number on the HS-200 or the number of frames to record, record scene IV, which is exactly the same length as scene III and follows directly after it.
C. Next, to record scene II, which is 8 seconds (240 frames) in length, cue the HS-200 at frame count 320, which is exactly 240 frames before the beginning of scene III. Set the record timer for 240 frames and record.
D. Finally, record scene I in an identical manner, cuing the HS-200 at frame readout 20 and setting the record timer for 300 frames (10 seconds), the desired length of scene I.

Frame 20 was arbitrarily chosen as 20. Because the HS-200 records in a complete loop, the frame count in scene IV goes to a count of 900 followed by 001, etc.

Insert—Inserting new material into previously recorded material may be done in the following ways.

A. Inserting into material already recorded on the HS-200. This is similar to the assemble process explained above.
B. Inserting from an HS-200 onto a vtr

Record the original sequence on an Editec-equipped vtr. Place Editec cues at the desired "in" and "out" points on the tape. Record the material to be inserted on the HS-200, and cue it to the start of the sequence by searching out the appropriate frame number. Use the patch panel (Fig. 14-33), and patch from REMOTE VTR jack A to NORMAL and FORWARD (or to any slow-motion jack, depending on the effect desired). This will cause the first cue on the tape to start the HS-200 instantly by taking it out of freeze. The first cue can be either on Editec cue or a 4-kHz tone-burst cue.

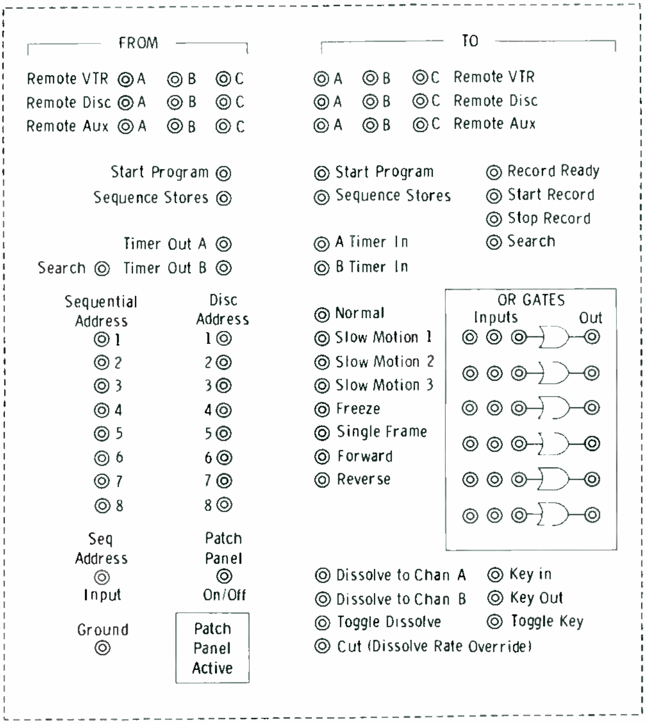


Fig. 14-33. Patch panel on HS-200 control console.

Next, connect the HS-200 playback output to the video input of the vtr, and play back the tape from the beginning. The "in" cue will start the HS-200 in playback and permit the output to be viewed on the monitor of the vtr. The Editec "out" cue will switch the monitor back to vtr output, providing continuous rehearsal of the entire sequence. If it is satisfactory, recue the vtr and HS-200 as before, and start the vtr in the Editec record mode. On this pass, the insert will be recorded exactly as seen in the rehearsal.

Transitions—The HS-200 can be used to make a cut from one scene to another or to assist in making a cut. If the total time of the two scenes is less than 30 seconds, both can be recorded on the disc with precise timing. The completed sequence of two scenes may then be transferred back to tape by means of Editec, allowing precise placement of the finished product.

Cuts may also be achieved on A-B rolls, using two vtr's and an HS-200. In this case, either the A or B scene may be recorded on the HS-200, and the other recorded on a vtr. Then, with both signals fed through the automatic dissolver to a second vtr and with playback timings preprogrammed (by means of Editec and HS-200 cues), the entire sequence can be recorded in one automatic operation.

Dissolves are accomplished in much the same way at cuts, using the HS-200 as the source of one signal and a vtr or live camera as the other. The advantages are that the automatic dissolver in the HS-200 allows complete control of both placement and length of the dissolve and allows this operation to be carried out without tying up studio switching equipment. Because the dissolver will dissolve in either direction (from or to the material on the disc), it is possible to include a number of dissolves on an A-B roll.

Since a fade is really one-half a dissolve (or a dissolve to or from black), this effect is also readily available with the HS-200. Black is used as the alternate source to the HS-200 signal, and the fade is programmed for the rate and placement desired.

Although the patch panel (Fig. 14-33) can be programmed to control every function of the HS-200 automatically, either separately or in combination, it is not a complex operation. System functions are enabled through the patch panel by means of cue pulses, which are directed by patch cords to the proper inputs. These cue pulses may come from an outside source such as another HS-200, a video-tape recorder, a manual control at a remote location, etc., or from within the HS-200 by means of the memory stores. (It may help to think of these pulses as an extension of the operator's finger which will push the proper buttons at a preselected time.) In order to program the system, the cue pulses must be routed from the source on the FROM side of the patch panel to the proper inputs on the TO side of the patch panel. In other words, during preprogramming, if the operation requires selection of two functions together, it also requires a cue to be directed simultaneously to the same two control inputs on the patch panel.

Special Effects—There are a number of special effects that can be done easily on the HS-200, by itself or in combination with other commonly available equipment. These effects include keying and matting, A-B roll, time lapse, stop action, titling, and animation.

For producing visual material to be keyed into another picture, the system can manipulate the frames, one at a time, to record a series of titles on succeeding frames. Then, with the first title cued in the freeze mode and th HS-200 signal fed to a keying device, the title can be changed at any desired rate merely by operating the SINGLE FRAME ADVANCE control. Assume that it is required to key a product zooming out of a prerecorded scene. To do this, the zoom could be recorded on the HS-200 (with the product photographed against black) and both the key and the zoom preprogrammed by cues from the taped material.

An A-B roll between a vtr and an HS-200, or between two HS-200's, can be programmed by using the patch panel. The A roll, for example, is assembled on the HS-200. The patch panel is used to cue slow-motion effects, forward, and reverse on the HS-200, as well as dissolves, cuts, matting, etc., between the HS-200 and the other HS-200 or the vtr. If a vtr is used for the B roll, a cue is recorded on the cue track at the beginning of the B roll. This cue is routed to start the HS-200. The A-B roll can be run over and over again by recuing the HS-200 and the vtr. The cue positions of all the special effects can be adjusted until the desired effect is achieved. The A-B roll is then run one more time and recorded onto another vtr. If a second HS-200 is used for the B roll, the two patch panels are patched together by using the REMOTE DISC jacks so that when the START PROGRAM push button on one machine is pressed, it starts both HS-200's.

With the HS-200, true time-lapse effects are easily produced directly on video tape. The subject is placed on camera, with the camera orbiter off. The number of frames desired in each take and the interval between takes are selected, and the process to be photographed is started. During the process, the HS-200 is operated at the time interval selected until the process is finished. Now, when the recording is replayed, the action occurs in compressed time. To make a time-lapse recording of a biscuit baking, for example, the total baking time would first be determined. Assume that it is 8 minutes, and that it is to be reproduced in an 8-second sequence. If the HS-200 is set to take 1 frame (1/30 second) at each take and make one take every two seconds during the process, there will be a total of 240 takes, or frames, when the sequence is finished. Playback at the normal rate of 30 frames per second will take exactly 8 seconds. Due to the flexibility of the HS-200, the playback can be easily adjusted to longer periods of time. The *elapsed time rate generator,* an accessory, makes this process automatic. This generator provides time intervals from 1 frame every 300 seconds (for longer sequences) up to a rate of 30 frames per second. Time can also be adjusted by varying the number of frames recorded in each take.

With the HS-200, a stop-action effect can be easily started at any given cue and then normal playback continued at a later cue. After the scene is recorded, the placement of a freeze frame is determined by viewing the action and pressing the ENTER CUE button to store the cued frame. In the final playback, the FREEZE control is operated to start at the selected points by means of the patch panel, and after the required interval, the machine is put into the forward mode by the timer to continue the action. In addition, the entire playback, including freezes timed to the thirtieth of a second, may be programmed to play back automatically.

Proper use of the HS-200 single-frame recording capability offers a source of up to 900 individual titles. Each title is accessible within less than 4 seconds and may be changed in sequence instantaneously and at any rate desired. The selected titles may be placed on camera in the desired order, and a single frame recorded for each. In playback, the HS-200 is cued to title 1 in the freeze frame mode. As each change of title is required, the FRAME ADVANCE push button is operated, and the next title appears. Out-of-sequence titles or frames are located by frame addresses, by means of the search capability of the recorder. The titles may be incorporated into the final product as a complete picture or as a "super." With the keying capability of the HS-200, it is also possible to use the title as a keyed insert.

The single- or variable-frame record capability of the HS-200 is suited to any kind of animation currently done on film. It must be remembered, however, that the actual recording of the individual images (whether film or tape) is only one part of the animating process. Even with this capability, there still remain the problems of manipulating the material to be animated and the placement of the camera to view the material. For full cell animation, some adaptation of the film animator's camera stand, movable "compounds," and peg registration will be necessary. There are, of course, many useful animations of a simpler nature that can be more easily achieved. Animated titles are a good example. A title may be made to appear one letter at a time or one word at a time by starting with a blank card and adding one increment after each take of the desired number of frames. A little more complex is the "self-writing" title. The best way of doing this is to record the complete title first. Then paint or block out a small portion of lettering at the end of the title and make a 1-frame recording. Repeat this process, progressing to the beginning of the title, until the entire word or phrase has been blacked out. Now, if the recording is played in reverse, the letters will write themselves against the background. Puppets or products can be animated in a similar manner by individual recordings (of one or more frames) with a small increment or movement between successive recordings. The speed of the animated action is, of course, controlled by the speed of playback, either forward or reverse.

Preplanning—One of the most important operations in any HS-200 recording or editing session is the preplanning of exactly what is required and exactly how it is to be carried out. After the system operation is understood, it is time-wasting to tie up this valuable equipment when it could be used for other editing-sequence operations. Preplanning should be done, as much as possible, at the desk. In other words, develop a procedure for visualizing the entire operation on paper, making complete lists of cue times, frame addresses, segment lengths, and sequences before using the system.

EXERCISES

Q14-1. In the HS-100 system, how much video material is available on the disc in the (A) normal record mode and (B) alternate-field record mode?

Q14-2. How many disc surfaces are involved in the HS-100 system?

Q14-3. If a recording made on the video-disc system runs longer than the maximum capacity of the disc, what happens?

Q14-4. What is the speed of rotation of the video disc?

Q14-5. How many lines of video information are recorded during one revolution of the video disc?

Q14-6. Does the video head move while it is recording on the video disc?

Q14-7. What is the major difference between the feeding of record currents to video-disc heads and the feeding of record currents to video-tape heads?

Q14-8. How wide is the recorded track on the video disc?

Q14-9. What is the (A) center-to-center spacing of recorded tracks and (B) guard band between tracks on the video disc?

Q14-10. Is speed-up motion available as well as slow motion?

APPENDIX A

Table of Prefixes

Prefix	Symbol	Definition	Power of Ten Multiplier
atto	a	One millionth of one millionth of one millionth	10^{-18}
pico*	p	One millionth of one millionth	10^{-12}
micro-micro	$\mu\mu$	One millionth of one millionth	10^{-12}
nano	n	One thousandth of one millionth	10^{-9}
micro	μ	One millionth	10^{-6}
milli	m	One thousandth	10^{-3}
centi	c	One hundredth	10^{-2}
deci	d	One tenth	10^{-1}
kilo	k	One thousand	10^{3}
mega	M	One million	10^{6}
giga	G	One billion	10^{9}
tera	T	One trillion	10^{12}

*Preferred prefix for 10^{-12}

APPENDIX B

Answers to Exercises

CHAPTER 1

A1-1. Remember that in video tape recording, the signal recorded on the tape is fm. The video signal is pre-emphasized in the modulator and de-emphasized accordingly in the demodulator to improve the signal-to-noise ratio. Ahead of the demodulator (where the signal is still frequency-modulated rf), compensation is provided to allow for tape-characteristic variations and head variations. Remember in this connection that the highest video frequencies are in the lowest sidebands. If the response at the higher fm frequencies is increased, lower video frequencies are increased and highs decreased. If the response at the lower fm frequencies is increased, lower video frequencies are decreased and highs increased.

A1-2. 50/5 = 10-MHz bandwidth uncompensated. You will find that modern solid-state video amplifiers, using good high-frequency transistors (very small capacitances), use peaking circuits only in isolated instances.

A1-3. Since

$$\text{Velocity} = \text{Wavelength} \times \text{Frequency},$$

then

$$\text{Wavelength} = \frac{\text{Velocity}}{\text{Frequency}}$$

$$= \frac{1560}{10\ \text{MHz}} = 156\ \text{microinches}$$

A1-4. Twice the head-gap size, or 100 microinches.

A1-5. $\text{Frequency} = \dfrac{\text{Velocity}}{\text{Wavelength}} = \dfrac{1560\ \text{in/sec}}{100\ \mu\text{in}} = 15.6\ \text{MHz}$

A1-6. The shelf.

A1-7. Since the standard video-to-sync ratio prevails, there is 0.45 volt sync and 1.05 volts video. Since the modulation sensitivity is set such that 0.7 volt of video causes a deviation of 1.8 MHz, then for 1.05 volts:

$$\frac{0.7}{1.8} = \frac{1.05}{x}$$

so

$$0.7x = 1.89$$

$$x = 2.7 \text{ MHz}$$

Then

$$5 \text{ MHz} + 2.7 \text{ MHz} = 7.7 \text{ MHz for peak white}$$

What happens here in most low-band recorders is that the shelf is exceeded, and the modulator "goes to noise." This is a typical overload condition in which there is a momentary dropout to "noise" for the duration of the overload (on playback).

The sync-tip frequency is found as follows:

$$\frac{0.3}{0.7} = \frac{0.45}{x}$$

so

$$0.3x = 0.315$$

$$x = 1.05 \text{ MHz}$$

Then

$$5 \text{ MHz} - 1.05 \text{ MHz} = 3.95 \text{ MHz for sync tip}$$

This problem has been solved with the old ratio-and-proportion technique. A simple check is to reason that if the recorder modulation sensitivity was set for 2.5 MHz total deviation when the input level was 1 volt, then the sensitivity is 2.5 MHz/volt. So, if 1.5 volts of signal is applied, the new deviation is:

$$(2.5)(1.5) = 3.75 \text{ MHz total deviation}$$

This checks the above computations, since:

$$\begin{array}{rl} 7.7 \text{ MHz} & \text{peak white} \\ -3.95 \text{ MHz} & \text{sync tip} \\ \hline 3.75 \text{ MHz} & \text{total deviation} \end{array}$$

CHAPTER 2

A2-1. Sound track, video track, cue track, control track. NOTE: Modern tape guides have a radius at the top so that video is no longer recorded on the audio track at the top of the tape. In early machines, this transverse video track was laid down across the audio track, then removed by the following audio-track erase head prior to audio recording. The audio erase head is, of course, still employed to remove any old c spurious signal component.

A2-2. No. The tape vacuum guide is moved.

A2-3. Recording diameter = 0.004 + 2.064 = 2.068 in

Then circumference = 3.14 × 2.068 = 6.493 in
Then velocity = 240 × 6.493 = 1558 in/s

A2-4. (A) Frequency of H = 15,750 Hz
Then wavelength = 1558/15,750 = 98.92 mils for 63.5μs
(B) Velocity = 1557 in/s
Then wavelength = 1557/15,750 = 98.85 mils for 63.5 μs

Note that the actual space occupied by one line, or 63.5 μs, is different for different tip projections. It is the *space in time,* or *velocity vs wavelength of scanning the information,* that must remain the same.

A2-5. Assuming the original recording was made to SMPTE standards, the playback head was aligned to SMPTE standards, and tape stock has not stretched, no realignment is required. The reduced head-to-tape velocity of the playback head directly offsets the difference in tip projection.

Please note that this depends on a drum reference diameter of exactly 2.064 inches. Remember that there can be a small tolerance in any dimension. In the same headwheel assembly, this reference diameter is not changing, and if you are recording and playing back only your own local tapes, there is no problem. But this situation seldom exists. The guide adjustment is often changed to "match" an outside tape for optimum performance, particularly in color. Even if everyone in the business were very critical in standardizing recordings (unfortunately, only a dream), tolerances would still need to be considered for critical playback.

A2-6. Note from Fig. 2-7 that at minimum, the effective diameter must be 2.0658 inches. Assuming the standard drum diameter of 2.064 inches, there is 2.0658 − 2.064 = 0.0018 inch allowed for tips. Thus, each tip must be 0.0009 inch, or 0.9 mil, to fall within SMPTE standards. A recording made with a tip projection of 0.8 mil would likely *not* meet the standard radius of rotation.

A2-7. The vacuum guide is too high or too low (height, or scallop, adjustment). This upsets the standard concentricity between head and vacuum guide.

A2-8. 1590 ns. See the table in Appendix A.

A2-9. The active picture area is 63.5 μs minus blanking of 11 μs, or 52.5 μs. So 10 inches corresponds to 52.5 μs, and one inch corresponds to 5.25 μs. Therefore 1 μs is about $\frac{1}{5}$ inch, or between $\frac{3}{16}$ and $\frac{1}{4}$ inch.

A2-10. Review Section 2-5 and Fig. 2-13B. Departure at the center of the tape is a measure of actual tip projection.

CHAPTER 3

A3-1. A frequency-modulated carrier, the reference frequency and deviation of which depend on whether a low-band monochrome, low-band color, or high-band mode is used.

A3-2. A 60-Hz (nominal) reference pulse derived from the vertical-sync interval of the signal being recorded (or local sync for local recordings).

A3-3. The head-tachometer signal. This locks the capstan to the velocity and phase of the headwheel (drum) operation.

A3-4. The horizontal rate has a reference about every 33 lines. The vertical reference is 60 Hz from the field rate of the recorded signal.

A3-5. Same horizontal and vertical rates as in A3-4. The initial field reference is usually from local sync, but no feedback information is given to the capstan or headwheel for frequency and phase lock to local sync.

A3-6. Same horizontal as above. Feedback information is given to the head motor and capstan to lock the played-back tape sync to the local vertical (field) rate.

A3-7. The horizontal rate is 15.75 kHz and the vertical rate is 60 Hz (nominal values), locked in phase to local sync. This is "genlocked" operation of the vtr.

A3-8. (A) Line-to-line, or every 63.5 μs. (B) Eight to nine reference pulses of 0.28 μs corresponding to the 8 to 9 cycles of color-subcarrier burst, once each line on the back porch of horizontal sync

A3-9. Older machines and modern monochrome-only systems still use the control-track and head-tachometer comparison of Fig. 3-6. Later systems use the basic method of Fig. 3-8, with refinements. More information on this is given in Chapter 7.

A3-10. Velocity lock, then phase lock.

CHAPTER 4

A4-1. (A) Master erase, audio erase, audio record/play, audio simulplay.
(B) Master erase, control-track record/play, cue erase, cue record/play, control-track simulplay.

A4-2. The position of the vacuum guide.

A4-3. The capstan only. The supply and take-up reel motors merely provide constant torque.

A4-4. To take up excess tape if any speed variation occurs due to changes in operating modes, and to stop the machine automatically if the tape breaks or a reel runs out of tape.

A4-5. To lift the tape from contact with the master erase head in either the forward or reverse wind mode. This minimizes tape wear by eliminating contact during any operation not requiring contact with the master erase head.

A4-6. Air guides, tape lifter, and vacuum guide.

A4-7. Headwheel air bearing and vacuum-guide air cylinder.

A4-8. The one nearest to the +70-volt trigger, in this case setup.

CHAPTER 5

A5-1. Only if the heads are within plus or minus 0.005 μs (5 ns) error. This is within plus or minus 1.5 seconds of arc (approximately). The latest high-band heads (also used for low band) meet this specification, and no electronic quadrature correctors are employed with these heads. In practice, even when this tolerance is slightly exceeded, built-in time-correction circuitry removes the error (Chapter 6).

A5-2. (A) 1 to 8 MHz
(B) 1 to 16 MHz

A5-3. (A) 4.28 MHz
(B) 5.0 MHz
(C) 6.8 MHz
(D) 5.5 MHz
(E) 5.79 MHz
(F) 6.5 MHz
(G) 7.06 MHz
(H) 7.9 MHz
(I) 10 MHz

A5-4. Irregularities in tape coating that cause video loss, or "white flashes," for the duration of the dropout. This may result in tiny white dots or much larger flashes, depending on the area of irregularity.

A5-5. (A) Approximately 100 V (p-p). (B) Approximately 5 mV (p-p).

A5-6. The headwheel (drum) tachometer signal.

A5-7. (A) From the modulator. (B) From the fm switcher.

A5-8. To eliminate noise which would cause amplitude variations of the fm component.

A5-9. So that switching is timed during the blanking (actually sync) interval. (In the Ampex system, switching is timed to occur just ahead of horizontal sync.)

A5-10. No. It is used to compensate the region of resonance (around 10 MHz).

CHAPTER 6

A6-1. Time error.

A6-2. A voltage-controlled video delay line.

A6-3. The voltage-controlled video delay line is made to have a time function opposite to the error being corrected.

A6-4. Tape sync supplies both the sampling pulse and the sawtooth or trapezoid. A dc error is obtained by making a phase comparison between the edge of tape sync and a reference sync pulse generated by a long-time-constant afc loop locked to tape sync.

A6-5. Same as in A6-4 except that the reference sync is obtained from the station generator instead of tape sync.

A6-6. 1000 nanoseconds (1 microsecond).

A6-7. Reverse biased.

A6-8. Tape burst and local subcarrier reference.

CHAPTER 7

A7-1. Yes.

A7-2. The control-track record current is increased until a just perceptible inflection (shoulder) occurs in the region of the zero-axis crossing as observed on the output of the simulplay control-track head.

A7-3. Program audio head to assure that the audio signal is being recorded, cue-track audio head to monitor the cue-track audio while recording, and control-track head to assure that the control track is being laid down and to permit proper adjustment of the record current.

A7-4. You don't. This is determined by the arrangement shown in Fig. 7-1.

A7-5. By the TRACKING (CONTROL TRACK PHASE) knob, which adjusts the delay in the control-track playback signal.

A7-6. Velocity lock followed by phase lock of the headwheel (drum), from which a trapezoid signal is formed. Then this trapezoid is sampled with a pulse from:

1. Reference vertical from local sync.
2. Reference vertical from comparison of local vertical sync with demodulated tape vertical sync.
3. Final step: Same as (2) but added "time-modulated" vertical comparison to horizontal-sync errors.

A7-7. (A) Reference frame pulse is compared in phase with pulse obtained by dividing frequency of control-track signal by eight; reference frame pulse is compared with tape frame pulse. (B) Vertical framing. (C) Because the servos must be able to lock in to the closest horizontal pulse. Therefore, the framing pulse must be dropped as a reference.

A7-8. (A) A 30-pps signal recorded along with the control-track signal, indicating occurrence of field 1. (B) Same as A. (C) A 30-pps signal derived from the vertical interval of the local sync generator. (D) A 30-pps signal derived from the vertical interval of the demodulated tape playback signal.

A7-9. Yes. The tight control of time base requires timing (not necessarily phasing) to the local sync generator.

A7-10. To obtain greater sensitivity in microseconds per volt of error signal.

CHAPTER 8

A8-1. A reduction in rf amplitude, and therefore a video loss. "White flashes" occur in the picture for the duration of the dropout. Dropouts are caused by irregularities in the tape coating, either flaws in the tape itself or dust and other foreign matter. They result in small white dots or much larger flashes depending on the area of the irregularity.

A8-2. The rf level from the recorded tape signal.

A8-3. Not if the machine playing back to the dubbing system contains a dropout compensation system. However, if it does not, any dub (second-generation tape) will contain the same dropouts, and any subsequent dub (third generation) cannot be replayed without the dropouts even though a DOC is used. That is, the DOC acts only on rf signal levels from the tape being played, and not on any "recorded-in" dropout in the video signal.

A8-4. The video from the previously scanned line is substituted. This is possible because successive lines (or several lines) contain a large amount of redundant information.

A8-5. Since the substituted signal is delayed one line, the color phase is shifted by 180°. Therefore, luminance and chrominance information are separated, and the chroma is phase-inverted to obtain the correct color polarity.

CHAPTER 9

A9-1. (1) Hue shifts. (2) Saturation variations.

A9-2. (A) Velocity error. (B) Differences in head-to-head frequency response, tape surface variations, and tape-to-head contact differences.

A9-3. To the average value of the previous 24 revolutions (100 milliseconds) of the headwheel.

A9-4. The analog circuits produce the output signals which correct the errors. The digital circuits supply to the analog circuits the timing and control pulses required for line-to-line correction.

A9-5. Since the ATC error signal is applied to the variable delay line at the start of each video line and remains constant throughout the line, the error waveform appears as a series of steps. This restores video timing to normal at the start of each line, but it allows errors to accumulate along the line.

A9-6. It generates voltage ramps which connect the beginning and end of each step of the signal described in A9-5, to achieve continuous correction of the signal throughout the line.

A9-7. The VEC analog circuits measure the difference between successive step voltages (beginning of one line to beginning of next line, up or down in voltage) and store the difference voltage (positive or negative) in a capacitor memory.

A9-8. Because generation of a ramp that will connect successive ATC steps requires advance knowledge of the slope.

A9-9. The X signals correspond to lines, and the Y signals correspond to heads. One X signal is provided for each horizontal line in a head scanning period, and one Y signal is provided for each of the four head scan periods.

A9-10. No. The readout and write-in of the CAC error for a particular line occur during the same line.

CHAPTER 10

A10-1. (A) The new scene cannot be synchronous to the existing program on the tape, and this causes servo upset, at both the start and stop of the insert, until new lockup is achieved. (B) The distance between the record and erase heads would cause a double (and nonsynchronous) recording to be made for approximately 9 inches of tape.

A10-2. (A) The insert mode retains the already existing control-track signal on the tape during the record mode. The new recording starts at the desired place and ends before the old recording ends. Thus, it requires an *ingoing* and an *outgoing* splice. (B) The add-on (assemble) mode requires only an ingoing splice because it simply adds on to the original recording. A new control track is recorded as in normal recording. Synchronism with the original recording is maintained by making the capstan servo a slave to a capstan memory circuit, which has measured and stored the speed of the original recording.

A10-3. Improper phasing of the tachometer signal with respect to the original recorded signal.

A10-4. (A) The original control-track signal. (B) A dc voltage from the capstan memory circuit (controlling a vco).

A10-5. A computer system which enables the operator to "practice" a complete editing procedure by watching a picture monitor (and listening to an audio monitor) without disturbing the original recording. Then, when the entire procedure is satisfactory, the information is stored again in the computer, and a single push button initiates automatic editing.

CHAPTER 11

A11-1. Start with midrange. The purpose of this control is to permit setting the individual channel equalizers for equalization of all chroma (and burst) levels. If any of the individual controls is nearing the limit of its range, change the master equalizer accordingly.

A11-2. In the latest systems, playback levels are controlled by agc. The controls marked MGC (manual gains) are effective only on test-signal positions. Obviously, in an older tape system, you must first equalize all *levels* (rf) as indicated on the cro at the switcher monitoring position.

Incidentally, the best way to adjust these levels (for color) is to look at a color monitor at the system output and adjust for minimum transients between individual bands of 16 lines. Then adjust the equalizers. Go back and forth between these two adjustments.

A11-3. Depending on the severity of this difference, you will see some banding in red and blue. Slightly trim the damping "R" adjustment on the playback amplifiers to equalize the "bottoming" levels (most recent high-band systems only).

A11-4. Review Section 11-2 (subsection "Adjusting Monochrome and Color ATC Error Gains") and Fig. 11-17.

A11-5. First of all, never adjust the demodulator gain until you have first checked frequency and deviation in the E-E circuit mode. These adjustments affect the output level of the demodulator. Then a standard tape will play back at the same level from the demodulator with properly equalized individual playback amplifiers ahead of this demodulation. If the level is low, the tape was underdeviated; if the level is high, the tape was overdeviated.

A11-6. First, this point should be made: The best way to adjust demodulator balance is to put the system in the monochrome mode and adjust balance for minimum rf in sync and blanking. (Some color filters [when in the color mode] do not permit adjustment in this manner.) Then on playback, balance should remain the same provided the tape was recorded on the proper frequency.

Another reason for lack of balance between the E-E mode and actual playback is excessive levels from the individual playback amplifiers ahead of the demodulator. This can produce an overload condition leading to unbalance. Reduce these levels and note the effect on the demodulator output.

Incidentally, you cannot see rf in the superblack region when the system is in the color mode. You normally adjust balance in the monochrome mode and trust this is retained for color. You can double-check this by observing a color monitor at the system output and adjusting the balance of the demodulator for minimum moiré on color bars.

A11-7. 0.714 volt for video, 0.286 volt for sync.

A11-8. $f_c = \frac{1}{0.2} = 5$ MHz

A11-9. (A) Tilt of bar when on the proper graticule time base (shift centering when necessary)
(B) Pulse height, width, and overshoots when on proper time base
(C) K-factor of pulse-to-bar amplitude ratio

A11-10. Always make the burst phase correct first, so that the chroma sideband information is correct relative to burst. Then adjust the system phase to match the standard color-bar generator at the output of the special-effects amplifier.

A11-11. By measuring the playback performance characteristic with the sine-squared and window signals on the SMPTE standard alignment tape. Then compare a local recording on the same playback. On modern high-band systems, the performance should be better than that of the monochrome standard alignment tape. The overall K-factor should be well within 4 percent for the T-pulse and 2 percent for the 2T-pulse.

A11-12. From 1.8 MHz to 15 MHz (double-sideband rf signal).

A11-13. In the external-sync mode, local external reference sync from the sync generator is added to the video signal. In the regenerated-sync mode, the processing system forms new composite sync.

A11-14. Yes. The RCA test tape is recorded on a 1.0331-inch guide. Strictly speaking, this would cause some difference between new and worn heads. In practical everyday use, this is negligible, and you need have no hesitation in setting the guide for any head (new or worn if more than 1 mil of tip remains) against the standard tape.

A11-15. 1 mil. Some users still employ a gauge to measure tip protrusion, but this is not advisable due to possible damage to a good head. The use of the standard multiburst signal from a test tape (as described in this chapter) is most satisfactory. The back-away method (to find the point of departure) with precision measurement of the headwheel radius is sometimes (but rarely) used.

A11-16. No. When you record at a lower-than-standard penetration, tape contact is lost as the head wears, and the result is about the same life as with standard penetration. In addition, interchangeability is lost.

A11-17. Here are the things that must be done: All sources to be lapped must be synchronous, so the tape machine(s) must be operated in the Pixlock (RCA) or automatic (Ampex) mode (tightest servo requirement). Then each tape system must be phased horizontally for the same timing at the leading edge of sync. Then the tape system phase must be adjusted for proper burst phase at the mixing point. It is also quite desirable that the blanking widths be approximately the same, that the front-porch and back-porch positions be the same, and that the positions of the two bursts on the back porch be very close.

A11-18. Some high-band tapes have a tendency to stick in the transport, and this is normally the fault of the tape. High-band tapes have a very smooth surface. A smooth surface lying against another smooth surface has more of a tendency to cling to the guide, posts, etc., than a rough surface against a smooth surface would have. This effect is termed *tape seizure* or *tape adhesion*. The drag is actually so great under this condition that capstan slippage occurs. If it happens often, check all transport tensions, including the capstan pressure roller, and thoroughly degauss the entire tape path.

CHAPTER 12

A12-1. Axial alignment and axial position. Review Section 12-2.

A12-2. "Tip ringing," a fault of the head itself, caused by deterioration of the magnetic-gap material.

A12-3. Feed a multiburst signal to the system input. Response in the E-E mode is immediately apparent by noting the difference between the video output and the video input, with the machine in the stop mode. Playback characteristics are judged by use of the standard test tape. Recording characteristics then will be apparent by making a recording of the local multiburst signal and playing this back on the same and other machines of the common installation. The latter step is simply to ascertain the degree of likeness or difference of all machines.

A12-4. (A) 0.125H/cm × 25.
(B) 0.25H/cm × 25.

A12-5. The modulated 20T-pulse.

A12-6. Displacement of colors from the proper luminance position.

A12-7. Bent supply or take-up reels, improper tape-tension adjustments (always refer to specific instruction book for system), dirty heads or tape path, worn heads, contaminated capstan shaft or pinch roller, insufficient capstan-to-tape pressure, bad tape.

A12-8. Magnetized head, dirty head, worn head, poor tape.

CHAPTER 13

A13-1. Yes, if the tape is wound onto a conventional reel. The same type of head and the same recording standards prevail for both the cassette/cartridge and reel-to-reel systems.

A13-2. Yes, if the tape length does not exceed the capacity of the cassette or cartridge.

A13-3. It can be purchased either way. If shared electronics is used, the other machine must be an Ampex AVR-1.

A13-4. It can be purchased either way. If shared electronics is used, the other machine must be an RCA TR-60 or TR-70.

A13-5. (A) Start of tape. (B) End of tape.

A13-6. (A) A hole in the tape (sensed by a photocell). (B) A reflective tape (sensed by a photocell).

A13-7. (A) Two. (B) Two. (C) One. (D) Two.

A13-8. Two seconds maximum.

CHAPTER 14

A14-1. (A) 30 seconds. (B) 60 seconds.

A14-2. Four, the top and bottom surfaces of the top and bottom discs (two-disc, four-head system).

A14-3. The latest 30 seconds (60 seconds for alternate-field recording) is maintained in storage. Prior recorded material is progressively erased.

A14-4. 60 revolutions per second (3600 rpm).

A14-5. 262½ lines (one field), beginning and ending during the vertical-blanking interval.

A14-6. No. It is held stationary while the disc makes a complete revolution. When the next head starts recording, the head that was recording previously is stepped to a new position.

A14-7. For conventional tape recording, the record currents are fed continuously to all four rotating heads, and a separate head does the erasing. In video disc recording, the record currents are gated on and off to each head, and the head used for recording a track is also used to erase that track by gating the erase current to the head at the proper time.

A14-8. 7 mils.

A14-9. (A) 10 mils. (B) 3 mils.

A14-10. Yes, continuously variable up to twice normal speed.

Index