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JANUARY 1984/$2.25

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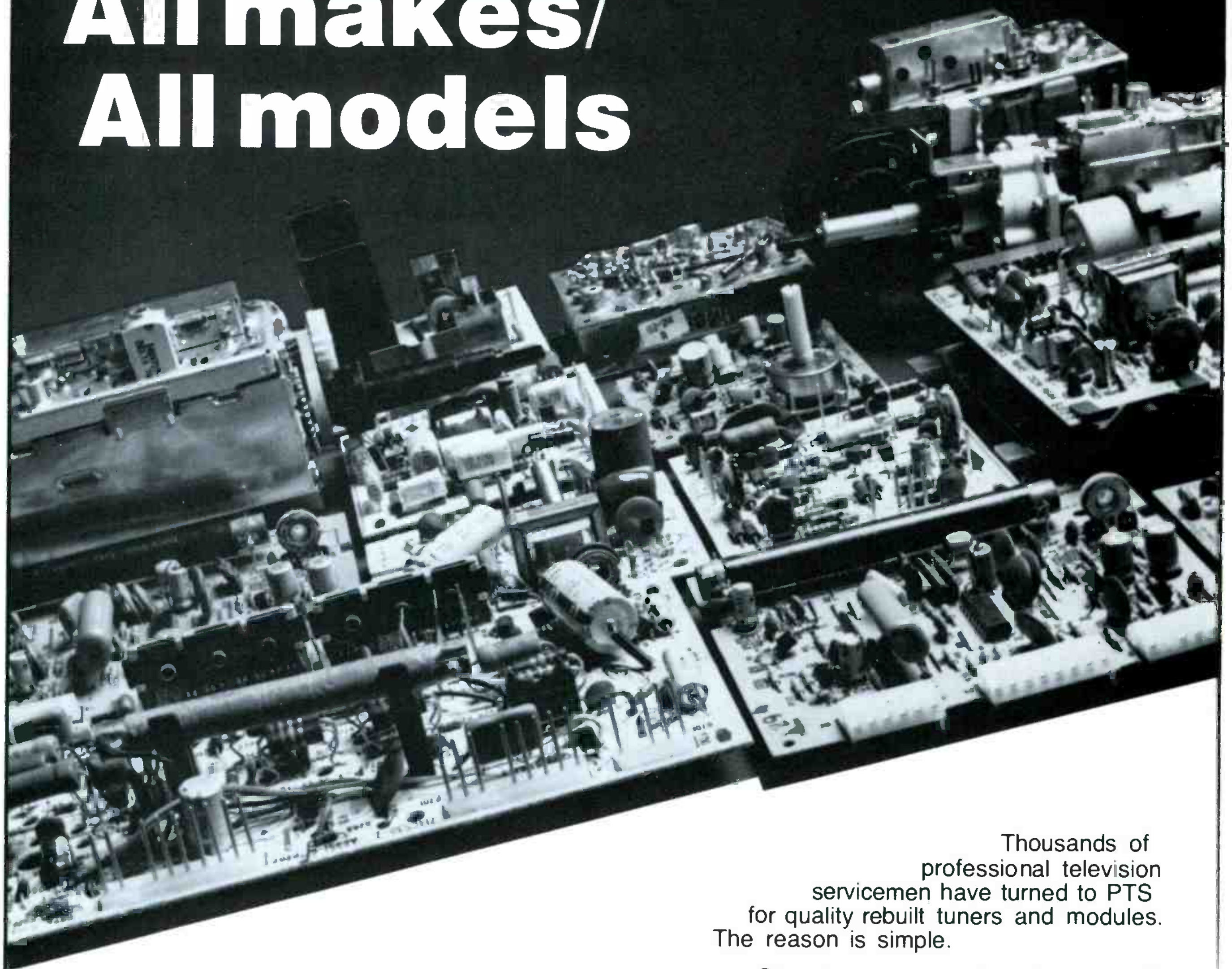

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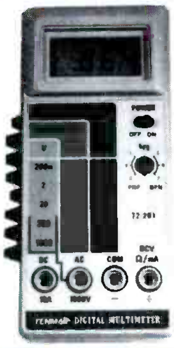

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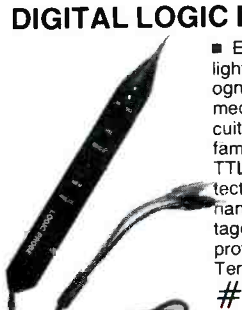

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Circle (4) on Reply Card

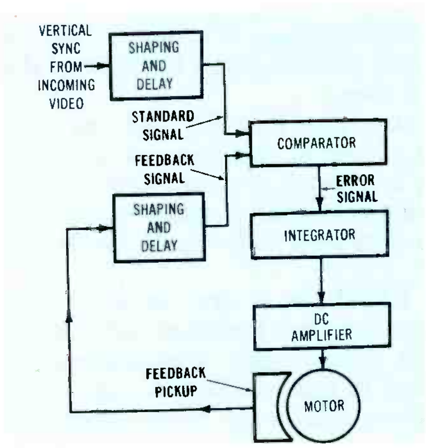
The how-to magazine of electronics...

ELECTRONIC Servicing & Technology

January 1984

Volume 4, No. 1

Electronic telephones with new features such as automatic redial, memory dialing, push-button convenience and cordless operation make conventional phones seem old-fashioned. See related story on page 22. *(Photo courtesy of General Electric)*



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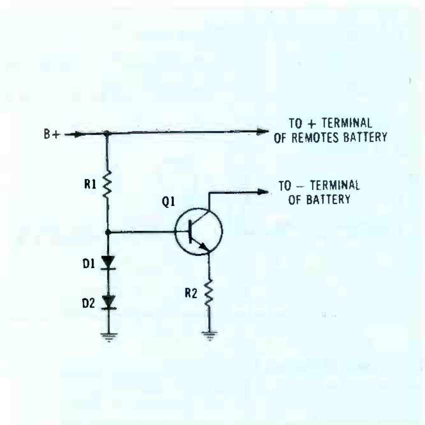

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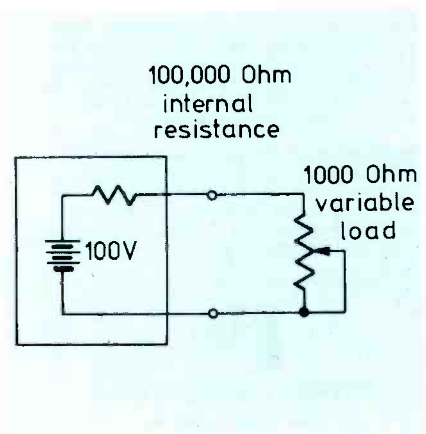

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Departments

Next month...

Some of the most misunderstood and least appreciated of the tools available to assist electronics technicians are electronic chemicals. This article describes some essential electronic chemicals that are available to technicians who service home electronic equipment. It outlines the various solutions chemicals offer to both simple and complex engineering problems of modern electronic equipment.

Farewell, Ma Bell

Faster than a speeding bullet, more powerful than a locomotive, able to leap tall buildings in a single bound. Superman, of course. When the call came that he was needed, Superman stepped into a telephone booth, doffed the horn-rim glasses and clothing of Clark Kent, the mild-mannered reporter for the Metropolis Daily Planet, and flew off to defend, "...truth, justice and the American way."

Perhaps the reason we seldom see Superman any more is that he has no place to change. The old, solid wood phone booths gave way to glass and ultimately to the small exposed stations we have now.

But the change in booth construction is only a superficial manifestation of the profound changes that have taken place in the telephone system in the past 50 years.

In the early days, the phone system was a purely local and manual communications system. You'd pick up the earpiece, give the ring generator a couple of turns and wait for the operator to come on the line. She would then connect you to whomever you wanted to speak to. In larger communities as the phone system grew, the switchboard became a horror with dozens of operators supervised by supervisors who wore roller skates to get back and forth to the various positions quickly.

The improvements to this day, including such features as automatic switching and tone dialing, have been dramatic and have made the phone system far easier to use as well as far more useful.

But in addition to these technological changes, have come, recently, legislative and administrative changes. "Ma Bell" has been broken up. There are now several other companies that provide long distance service. You can buy your own phone and install it yourself, as long as you abide by certain rules set forth by the telephone company. If you own your phones you may also be responsible for obtaining service when necessary.

The effects of these most recent changes, including private ownership of phones and increasing use of cordless telephones are far reaching and only beginning to be felt. We're entering a whole new era of telephone communications. Whether it will be better or worse than the one that's fading into the past remains to be seen.

Whatever the case, now that Ma Bell has been forced to kick us all out of the nest, so to speak, we're going to be to a much greater extent on our own. And now that we're able to make many decisions on our own that used to be made for us, we need information.

This issue of **ES&T** is a first step in that direction. We hope that the technical information presented in this issue helps you understand telephone operation. In future issues we plan to include further information on the many aspects of telephones, including operation, installation and servicing.

If the phone company has taken away Superman's changing rooms, phone manufacturers have probably more than made up for it by making available cordless phones so he can be called when he's needed, anywhere, anytime.

Now, up, up, and away.

Nils Conrad Persson

ELECTRONIC
Servicing & Technology

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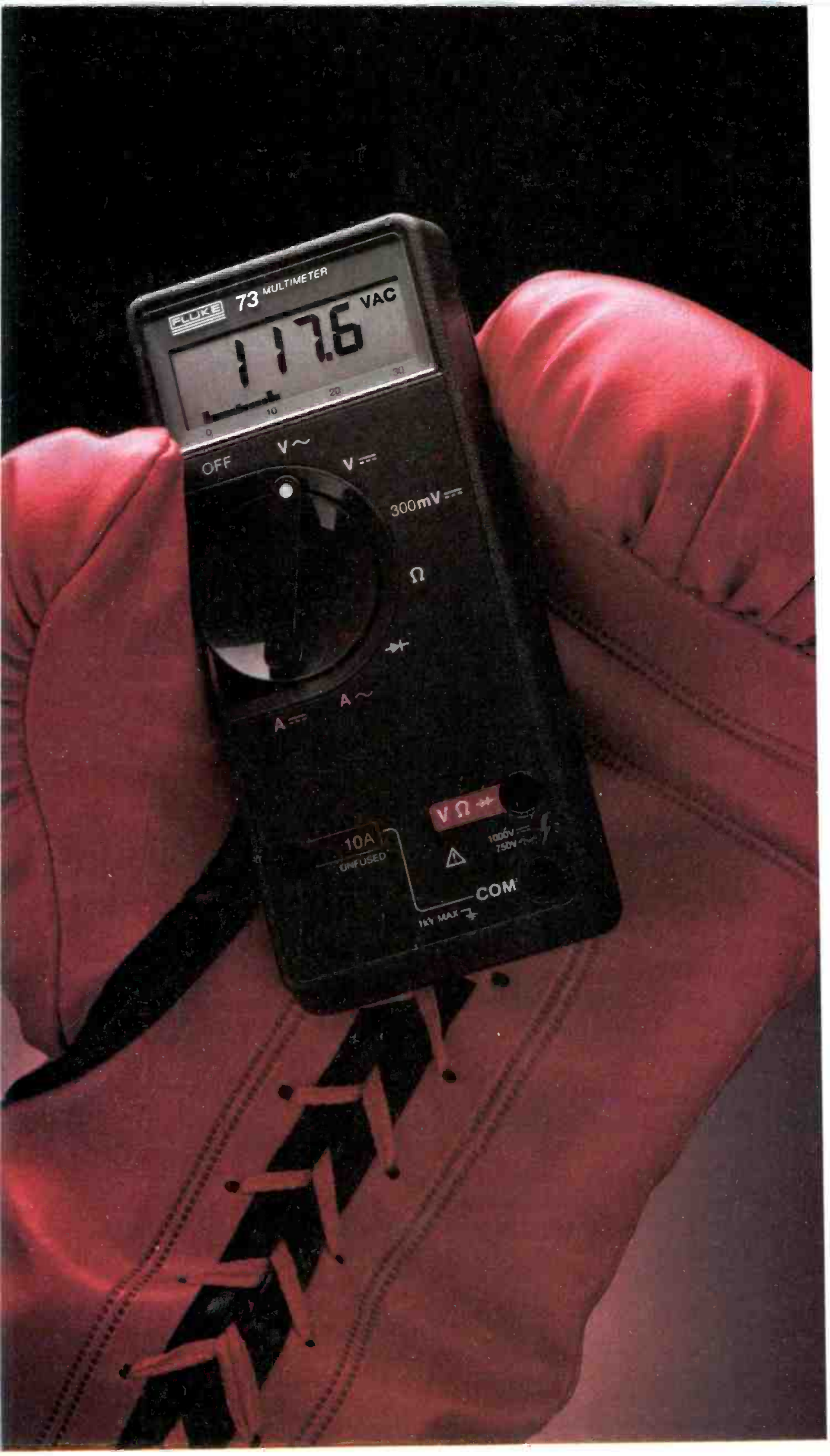

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News

homes are far part, the cost of stringing cable over many miles can cost millions of dollars. Because MDS operates over the air, the only equipment a consumer needs is a special receiving antenna."

FCC approves multi-channel MDS broadcasting

A new method of broadcasting multiple-channel TV programming at low cost has won approval from the FCC, opening the way for MDS service to compete effectively with cable TV throughout many still "un-wired" areas of the United States.

"The potential now exists for extremely low-cost development of MDS stations for pay-TV. With multi-channel capability, such stations can directly challenge cable TV in the many markets where neither system currently exists," says James L. DeStefano, executive vice president of Electronics, Missiles & Communications, Inc., White Haven, PA.

The cost of constructing a multipoint distribution service (MDS) station is around $100,000, compared with $30 million for a cable system, DeStefano says.

"Yet, even with this tremendous cost advantage, MDS has not been able to compete with cable, since by law it could only offer one channel of programming. The FCC's decision to add eight additional channels to the MDS band will mean vastly increased competition in the pay-TV industry," DeStefano predicts.

The eight new MDS channels were formerly allotted to the Instructional Television Fixed Service (ITFS) band, used by schools for educational TV. Under the FCC ruling, ITFS stations will still have 20 channels, and existing and applied-for stations are protected under a "grandfather" clause. Schools and universities also will be permitted to lease unused broadcasting time to commercial MDS operators.

"This FCC ruling is especially important to residents of rural or semi-rural areas," DeStefano says, "because MDS broadcasters will now be able to build inexpensive multi-channel systems in these sparsely settled areas. Where homes are far part, the cost of stringing cable over many miles can cost millions of dollars. Because MDS operates over the air, the only equipment a consumer needs is a special receiving antenna."

RCA expects videodisc player sales to reach 500,000

By the end of 1983, American consumers will have purchased 500,000 RCA videodisc players and 10 million discs since the introduction of the company's "CED" system, according to an RCA executive forecast.

Steve Bernard, managing director of RCA VideoDisc, said that an accelerating level of software support for videodisc by the major entertainment sources has resulted in an important new business opportunity for many firms involved in video entertainment. Bernard noted that Thorn-EMI had reached agreement with RCA whereby RCA will manufacture "CED" discs containing Thorn-EMI programs for their distribution in the United States and Canada.

In support of RCA's first introduction of the "CED" system outside the United States, RCA will offer an initial catalog of 100 titles to British consumers. Bernard said that 36% of the titles will be in stereo and approximately 1000 retail outlets will be involved in the product's introduction there.

Market research on videodisc in the United States indicates that:

- The average "CED" player owner uses the player about 8½ hours per week. Owners who subscribe to premium cable services use videodiscs about 8.8 hours per week.
- Approximately 70% of videodisc player owners already had cable TV when they bought their players.
- Owners of videodisc players are nearly four times as likely to own a videocassette recorder than the general population, more than three times as likely to have a home computer and twice as likely to own a video game.
- Videodiscs are primarily purchased at an annual rate of between 25 to 30 albums per players.

Feedback

Appropriated issue

I am in the field of electronics and I believe this magazine is one of the best for electronic technicians or field engineers. I am greatly satisfied with my subscription and will undoubtedly resubscribe.

I know there is at least one other field engineer who agrees with my sentiments. The August issue was appropriated from me by one of my co-workers before I had even begun to read it. Please let me know if the August issue can be sent to me for a cost in line with my subscription. Thank you for your service.

Ramon Mendoza
El Paso, TX

Troubleshooting

I appreciate your thoughts and offer sincere praise on your July editorial "What's the Trouble?", the front cover on "Troubleshooting Methods" and the many splendid writers of your magazine. With modern day technology your magazine fills the void for the guy who's troubleshooting. Keep up the good work.

Nick Zam
Lafayette Hill, PA

Grenada reader

I wish to inform you that I have started receiving my magazines and to thank you for your concern. I look forward to receiving them very much as I have found the articles and contributions informative and interesting.

As one of the technicians who reads your magazine, I would like to compliment C. A. Honey for his contribution on special capacitors for television. It is a great article. From the first time I saw your magazine, I have always tried to make sure that I secured a copy until I became a subscriber. Again, thank you for your cooperation.

Cosmos C. Cape
St. George's, Grenada
West Indies

Test your electronic knowledge

By Sam Wilson, ISCET test director

These questions are similar (but not identical) to questions used on the various CET tests. All questions on the actual CET test are multiple choice, and a grade of 75% or better is required for passing. This month's questions are related to general subject questions in the associate-level test. (Answers on page 57).

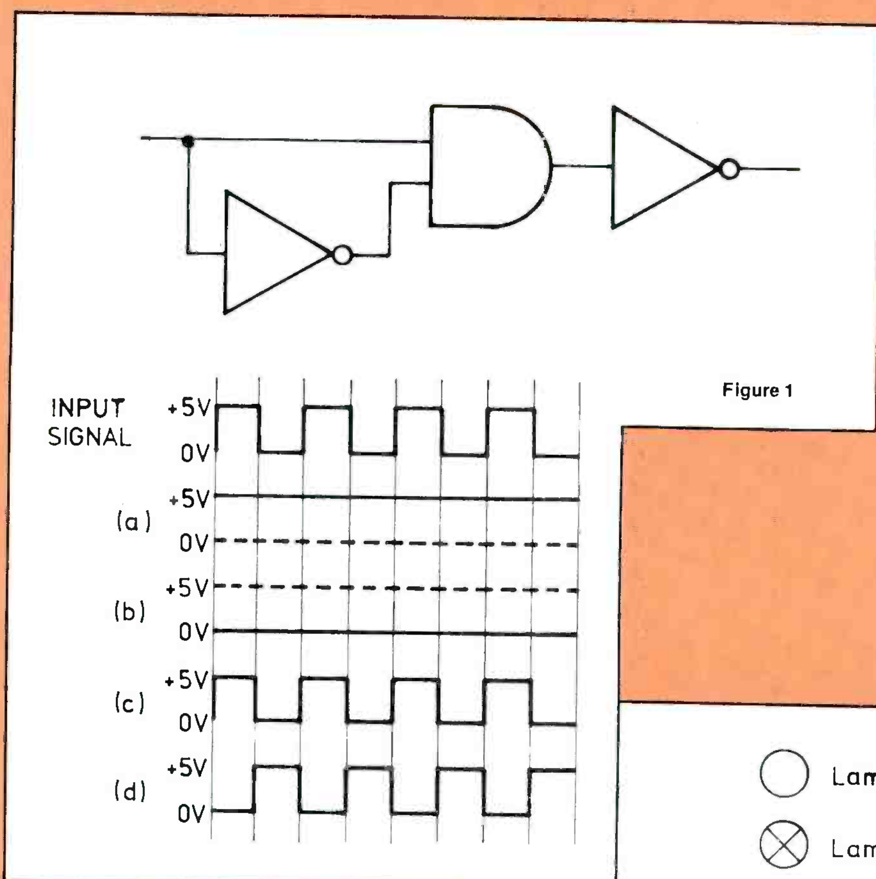


Figure 1

1. Figure 1 shows a logic circuit and its input signal. Which of the output signals will result from this input? (Disregard glitches in this circuit.)
   A. The solid line in Figure 1(a).
   B. The solid line in Figure 1(b).
   C. The signal in Figure 1(c).
   D. The signal in Figure 1(d).

2. What hexadecimal number is represented by the display in Figure 2?
   A. ED
   B. DE
   C. CE
   D. EC

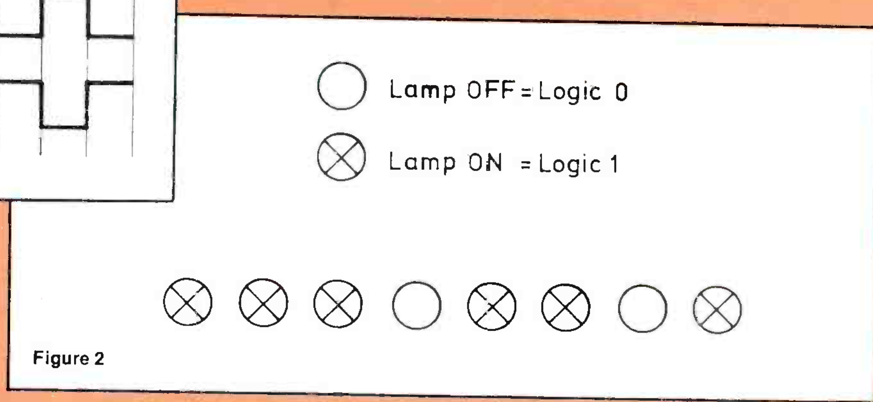


Figure 2

3. The lissajous test setup in Figure 3 is used for testing the Class A audio amplifier. When the scope controls are properly adjusted, the display should be
   A. a circle.
   B. an ellipse.
   C. a straight line.
   D. a triangular wave.

4. The test setup of Figure 4 is used for measuring the *capacity* of C. (In the CET test the term capacitance is sometimes used instead of capacity.) When $V_1 = V_2$,
   A. R = πfC
   B. R = 1/2πfC
   C. R = v x C
   D. R = 1/C

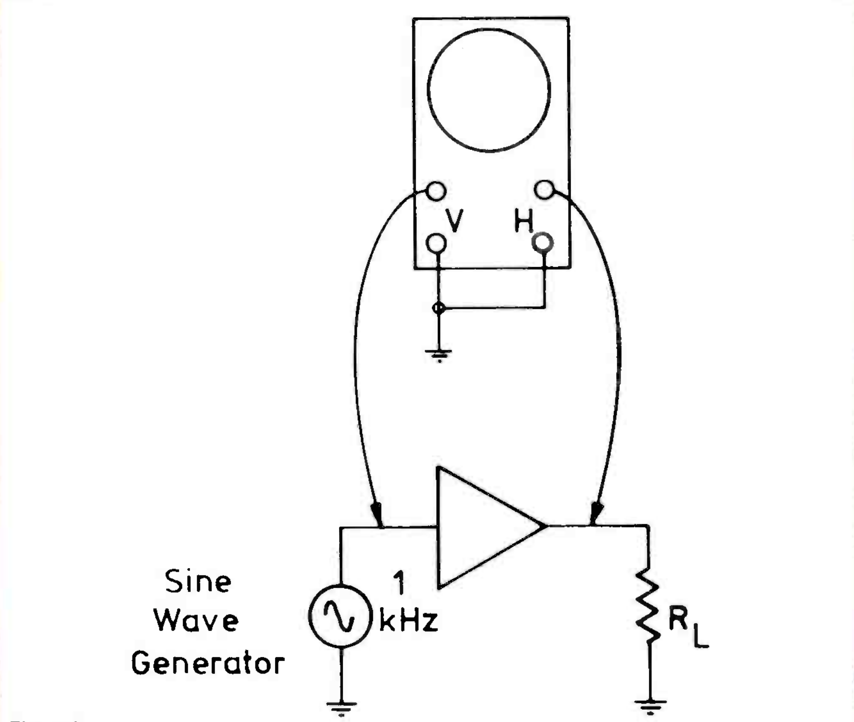


Figure 3

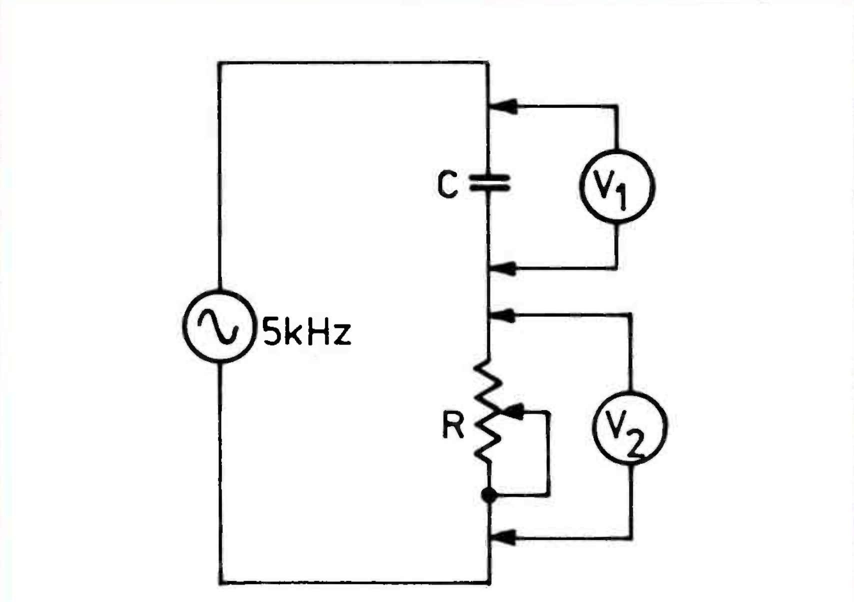


Figure 4

5. A certain capacitor has a capacity equal to (C). It is charged by connecting a DC voltage (V) across its terminals. The amount of charge can be determined by the equation:
   A. Q = C/V
   B. Q = C + V
   C. Q = C x V
   D. None of these equations is correct.
6. Two capacitors are connected in parallel. One has a voltage rating of 500V, and the other has a voltage rating of 1000V. The voltage rating of the combination is
   A. 1500V
   B. 333-1/3V
   C. 500V
   D. None of these answers is correct.
7. If a VOM is rated at 20,000Ω/V, it means that
   A. the resistance (or impedance) of the meter is 40,000Ω when the meter is measuring 2V.
   B. the meter resistance is 20,000Ω regardless of the voltage being measured.
   C. the maximum resistance that can be measured is 20,000Ω.
   D. its meter movement requires 50μA for full-scale deflection.
8. Which type of amplifier might contain all of the following circuits: low-frequency compensation, peaking compensation, R-C coupling, and degenerative feedback?
   A. AGC amplifier
   B. Video amplifier
   C. RF amplifier
   D. Audio power amplifier.
9. There is no L-C tuned circuit in
   A. an Armstrong oscillator.
   B. a Colpitts oscillator.
   C. a Hartley oscillator.
   D. a phase shift oscillator.
10. Parallax is a possible problem when making measurements with
    A. a meter having an analog display.
    B. a meter having a digital display.

How to troubleshoot VCR servos

By Robert L. Goodman

Typical of many new top-of-the-line VCRs, the General Electric IVCR4016X has still pictures, rewind and fast forward while monitoring the picture, several digital readouts and many other features.
(Photo courtesy of General Electric)

All consumer-operated VCRs place the video signal on narrow tracks recorded diagonally across the tape width. Because one complete vertical field of video is recorded on each diagonal track, the vertical-sync signal must be positioned precisely at the designated point on each track (Figure 1). Without that sync-placement requirement, the video heads could be rotated satisfactorily at constant speed by a synchronous motor, which operates at a fixed multiple of the line-voltage frequency. However, because the vertical sync must be placed accurately, a circuit must monitor the location against a standard, and then perform continuous corrections that place a vertical sync signal at the proper point on each diagonal track. Corrections are not essential for the tape speed (which is determined by the capstan and its motor) during recording, although they are needed for optimum playback.

Additional problems, such as tape stretching, arise during playback. Also, minor tape-speed and track-placement errors from recording usually add to those produced during playback, because the two types seldom cancel. For these reasons, the playback capstan speed usually is servo controlled, in addition to the usual head-rotational speed and phase. Otherwise, the playback video heads will not follow the diagonal recorded tracks precisely.

Minor speed or phase problems can produce an unstable picture, while major variations might replace the picture with out-of-sync stripes. It is impossible to overstate the importance of adequate correction for *all* types of tape-speed, head-rotation and head-phase errors. Therefore, one or more special circuits must be included to correct most speed and phase errors that originate in the mechanical components and drives. These circuits are called *servos*.

Servo basics

A servo circuit can be compared to the horizontal-phase and color-phase detectors of color-TV receivers. For example, a horizontal-phase detector compares the relative frequency and phase between two input signals and makes continuous adjustments that lock the phase of one signal to the other. Horizontal sync from the station video is the *standard* signal, while a sample of the horizontal-sweep signal is the *feedback* that reveals whether or not its phase is identical to the standard's phase. This is a simple example of a phase-locked loop (PLL) that has the same frequency and phase for both input signals. Any error of frequency or phase between the two signals produces an error-correcting dc voltage that pulls the horizontal-oscillator frequency until the two detector input signals have the same phase.

Servo circuits also require two inputs to produce an error-correcting output signal. One input signal comes from a standard, or *reference*, while the other is a feedback signal from the controlled device. (This feedback is not negative or positive, as used in audio circuits, but is a sensing signal that proves whether or not the controlled device has obeyed the servo's commands.)

In VCRs, a servo must accurately control the rotational speed and phase of the video heads or of the capstan shaft, if that is the controlled device.

Briefly stated, servo operation has two modes: recording and playback.

During recording, rotation and phase of the video heads are corrected by comparison with the vertical sync (the reference signal). These vertical intervals must be at the same desired point on all diagonal tracks, and each video track must contain one complete vertical field. The exact spacing between successive tracks is determined by the capstan speed, which must be constant. Also, a control track is recorded for use during playback.

During playback, the servo's reference is the previously recorded control-track signal that locates the beginning of each diagonal video track, while the video heads produce the TV picture, one vertical field at a time.

Figure 1a shows approximately how the two heads record alternate tracks. Notice that the heads have different azimuths (head-gap alignments) that eliminate most crosstalk between adjacent tracks, particularly during long-playing mode.

Typical servo operation

Figure 2 is the block diagram of a typical servo while it is in the recording mode. Notice the resemblance to a phase-locked loop. Filtered vertical sync triggers a monostable multivibrator (MMV or one-shot). Many variations of shaping and delay have been used. Often the one-shot's output pulse is set for a certain duration. When the next device is falling-edge triggered, this provides a delay. A shaping circuit changes the TTL-type pulse into a narrow spike, which is the standard (or reference) signal for the comparator.

The feedback signal originates with the frequency-generator (FG) winding inside the motor. This FG waveshape is sinusoidal, which also can trigger a MMV. Often the MMV in turn triggers a multivibrator that has a 50% duty-cycle, square-wave output that is partially integrated to form square waves with parabolic leading and falling edges that can be used as sawteeth. These are called *trapezoidal* waveforms that are the feedback signal at the comparator.

Many servo comparators are sample-and-hold circuits. Each reference pulse samples the edge of each trapezoidal waveform, producing and storing a dc voltage that equals the trapezoid-edge's amplitude when the reference sampling pulse arrives. These stored dc voltages (which vary as the servo operates) are filtered and power amplified before the dc voltage controls the power and speed of the motor. Of course, a higher dc voltage forces the motor to run faster with increased power, while a lower dc voltage reduces the motor's rotational speed. The servo supplies the motor with whatever voltage is required to make the heads deposit vertical sync at the correct point on each diagonal video track.

The same circuit corrects motor speed and phase during playback, except square waves from the control-track head become the standard signal. Usually, a variable delay control is provided on the front panel to allow manual adjustments that eliminate the instability from tape stretch.

Two video heads

Because the tape is wrapped half-way around the head drum, two video heads (or four in some advanced models) are provided. Each head records or plays one vertical field of 262.5 horizontal lines of video signal. If we assume the *A* head handles the odd-numbered fields, the *B* head must operate with the even-numbered fields as shown in Figure 1b. Of course, a track that has been recorded by the *A* head must be played by the same *A* head, and the *B* track must be played by the *B* head.

To accomplish this, 30Hz

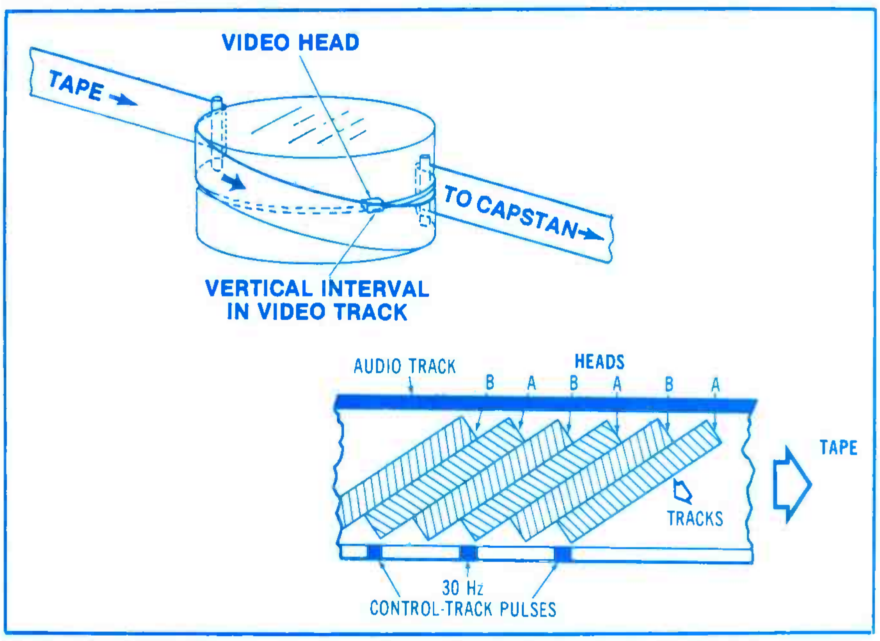


Figure 1. Guides force the tape to travel around the head drum (or cylinder) in a slanted path relative to the machine's baseplate. Therefore, the video heads (which rotate against the inside of the tape wrap) form video tracks that are diagonal to the tape's length. For clarity, the vertical-interval point has been shown at an incorrect location. Two video heads record the diagonal tracks, with each head producing alternate tracks. Slanted lines on the tracks symbolize the opposite-tilted azimuth of the heads (which minimizes pickup of crosstalk from the other head's tracks). A pulse or square wave is recorded on the control track for each *A* track. This control signal is used during playback. (The drawing is not drawn to scale.)

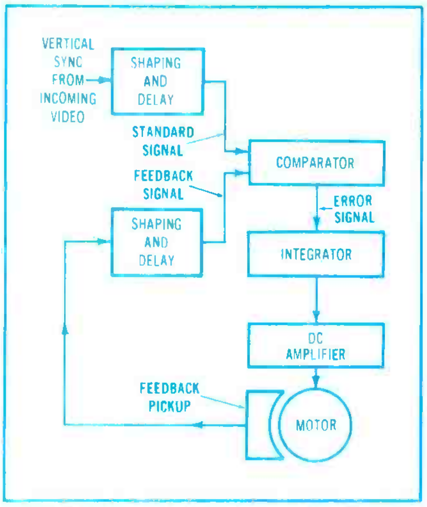


Figure 2. This block diagram demonstrates the operation of a typical VCR servo. The conditions shown are for head-cylinder speed control during recording, but a change of the standard-signal source or the feedback-signal source allows it to operate equally well during playback, or as a capstan servo. Notice the similarities to the horizontal phase detector in a color receiver, and to phase-locked loops (PLLs).

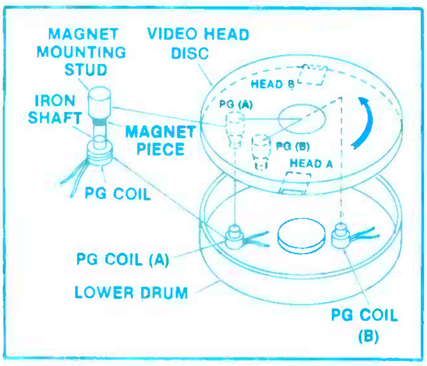


Figure 3. In the head-drum assembly, two rotating permanent magnets and two non-rotating coils produce pulse-generator (PG) pulses for Beta-type VCR servos.

repetition-rate square waves are recorded on the control track during video recording. Because 60 vertical fields are recorded each second, there is one square wave for each odd-numbered track and none for the even-numbered tracks. This in effect identifies the odd-numbered tracks.

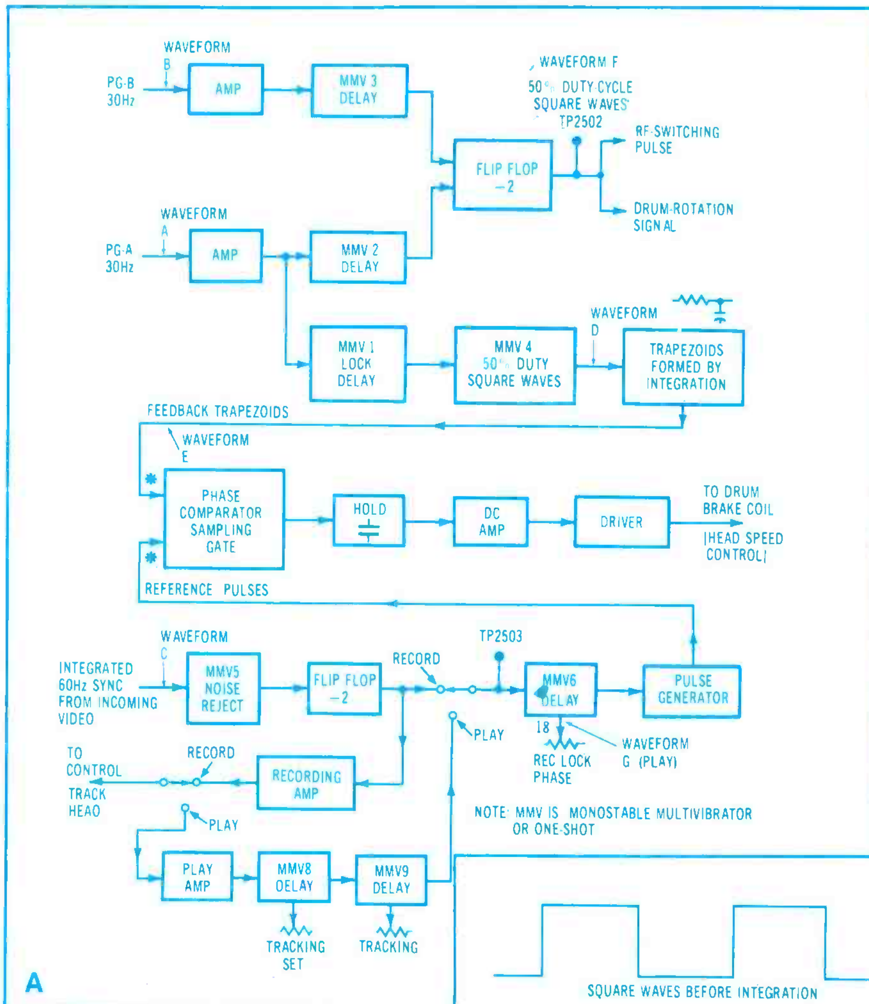
During playback, these square waves are processed and become the standard signal for the servo, and the servo forces the heads to play the correct tracks. If the heads are not positioned properly to play the assigned tracks, the servo varies the speed until a match is accomplished, and the picture is locked properly.

Dozens of basic variations and hundreds of minor differences have been used in various VCR models. However, two models will illustrate most important variations. The Zenith KR9000 (the same as Sony SL-8600) and the RCA VCT400 have been selected for study. Both are older models and should need adjustments and repairs by now.

Zenith KR9000 servo

One servo is provided in this older Zenith VCR of the Beta standard. The head-drum servo system operates a magnetic brake on the drum shaft, which is rotated by belt drive from an ac hysteresis-synchronous motor running at a multiple of the line-voltage frequency. The capstan also is rotated by the same synchronous motor. There is no capstan servo system.

Feedback signal for the servo comes from the pulse-generator (PG) coils located on the video-head disc (Figure 3). The head-drum assembly is a stacked array with a non-rotating upper drum, a rotating video-head disc containing two video heads (spaced 180° apart at the periphery) and two PG magnets, and the non-rotating lower drum. Notice that the PG magnets are not spaced 180°, and they are not the same distance from the center. Their locations vs. spacing of the PG coils in the lower head drum make possible the positive identification of both



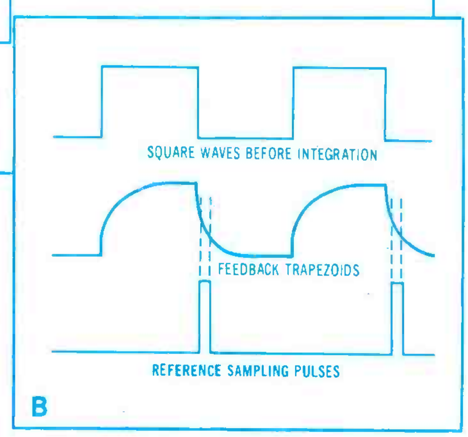
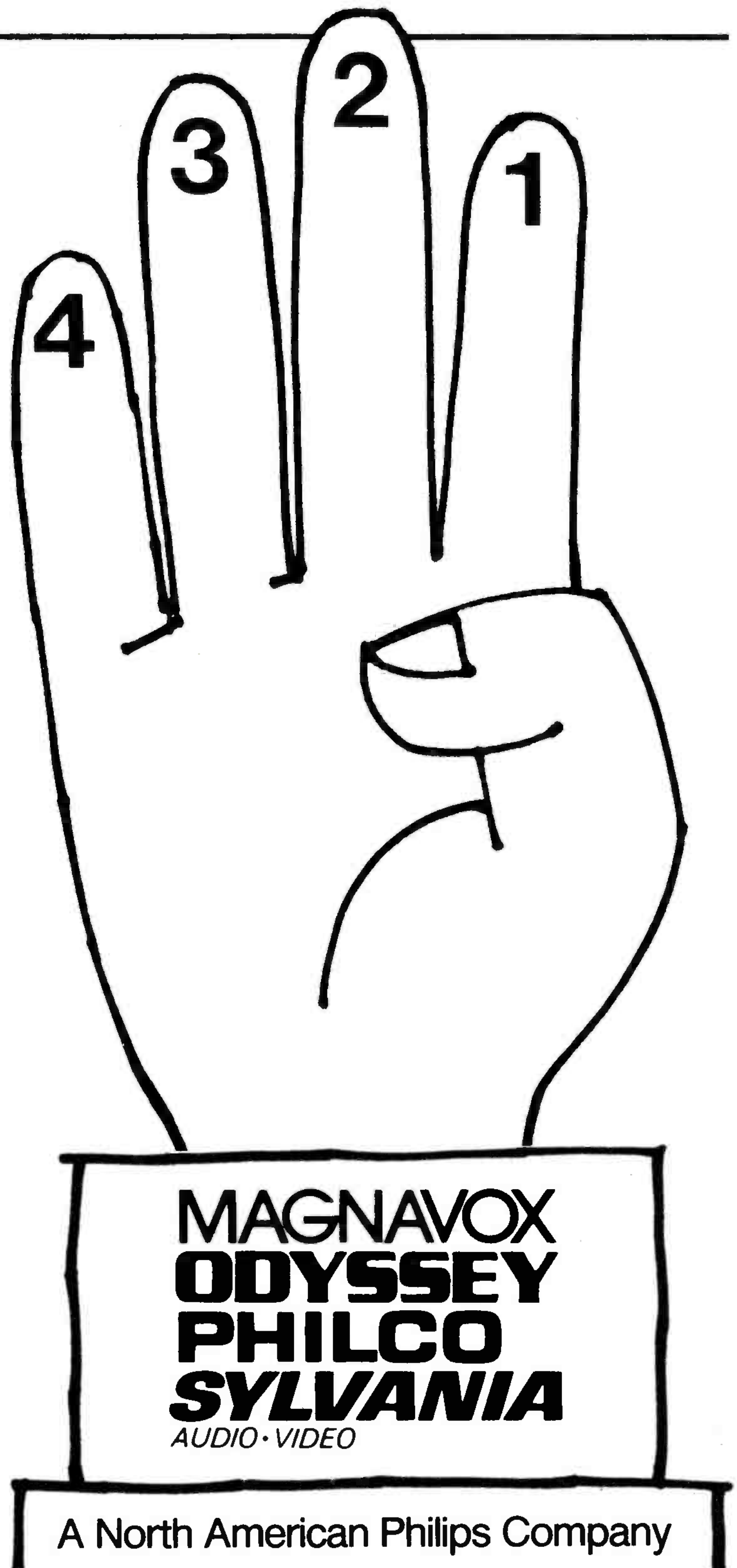


Figure 4. A block diagram of the Zenith KR9000 VCR head-drum servo is shown in part A and explained in the main text. These drawings illustrate the change when square waves are integrated into trapezoids. A rising or falling edge can be used as a sawtooth so a sampling pulse will find a different amplitude when a changing motor speed moves the trapezoid to the left or right.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1
MAGNAVOX
ODYSSEY
PHILCO
SYLVANIA
AUDIO·VIDEO
A North American Philips Company

video heads. This is important, because the same head must play the track it recorded.

Pulses are produced in these 30PG-A and 30PG-B coils when their matching magnets pass them. These two PG-coil signals are not combined, but are sent to separate stages (Figure 4a) on the ARS circuit board. Typical Zenith PG waveforms are shown in Figure 5. One of the first servo troubleshooting steps should be scoping these two PG waveforms at IC501 pin 2 and pin 24. A loss of either or both signals eliminates all picture stabilization.

After they are amplified, both PG signals trigger one-shot MMVs (Figure 4). Outputs from these MMVs trigger a divide-by-two flip flop that produces 50% duty-cycle square waves that switch the RF head signals, and also indicate head-drum rotation.

PG-A signal also triggers MMV-1, and its output signal is changed into 50% duty-cycle square waves that are integrated into approximate trapezoids. Rising and falling parabolic edges of the trapezoids can function as sawtooth ramps for the phase-comparator sampling gate. These trapezoids (Figure 4b) are the feedback input signal to the phase-comparator sampler.

Notice that the PG signals are sources of the servo feedback signal for both recording and playback modes. However, the source of sampling-gate *pulses* changes from vertical sync during recording to control-track square waves during playback (Figure 4a). Also, notice that a tracking preset and a customer-operated tracking control are included to correct any playback tracking problems.

The waveform drawings of Figure 4b show the principle of obtaining a dc voltage that varies according to the phase between the feedback and standard frequencies.

If the feedback trapezoidal signal moves to the left on a scope screen (because the motor speed is too fast), the reference pulse samples the trapezoid at a lower amplitude point. Therefore, the dc-voltage output signal from the sampling gate is lower. After it is amplified, this lower-than-average dc voltage reduces the motor speed and power, and the lower speed brings the pulse and trapezoid to the proper phase.

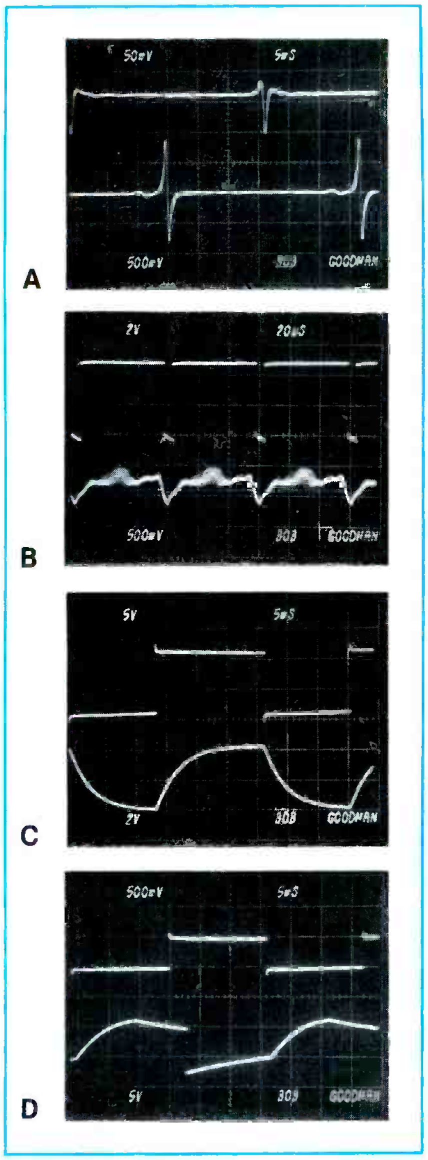


Figure 5. These waveforms were scoped from a non-defective Zenith KR9000. (A) The top trace shows the PG-B pulses called waveform B in Figure 4a schematic, and the lower trace shows waveform A pulses. (B) The top trace shows sync pulses designated waveform C, and the bottom trace is an integrated video waveform, unidentified but probably the input waveform to the sync separator. (C) Square waves (waveform D) at the input of the trapezoid integrator are shown by the top trace. The lower trace shows waveform E, the feedback trapezoids to the sampling gate. (D) The top trace shows the 50% duty cycle square waves (waveform F) at TP2502. The lower trace shows waveform G, which appears at the recording-lock phase control during playback.

If the motor and video head rotation is too slow, the trapezoid moves to the right, forcing the sampling to occur at a higher amplitude point. This provides higher voltage to the motor, increasing its speed until the head speed is correct.

Small corrections are made constantly to prevent instability of the TV picture. If the speed-correction device is a brake (for example, in this older Zenith VCR), the sampling must occur on the rising edge of the feedback signal.

Beta brake

Figure 6 shows the principle of a magnetic brake. A belt from a motor (usually the same one that rotates the capstan) rotates the head-drum about 1% too fast. Then the magnetic brake slows the shaft rotation to the speed required by the video so the vertical interval is correctly placed on each diagonal video track. Notice that the brake operates at all times with the correct speed approximately centered between maximum and minimum braking.

Magnetic braking is almost instantaneous. Direct current through the brake coil sets up a drag in the rotor (by eddy-current effect). The head-wheel inertia is small, and the motor inertia is decoupled by the belt, so the action is rapid.

In later models, magnetic brakes have been superseded by motor-controlling servos that have separate circuits for correcting speed and phase.

Troubleshooting Beta

Scoping the various waveforms (Figure 5) to identify missing, weak or distorted signals should be one of the first tests made when a servo malfunction is suspected. One method is to check the standard and feedback signals at the comparator sampling gate. If these waveforms are normal, it is not necessary to test the paths that brought them. If one waveform is incorrect, you should scope backward a stage at a time until a normal waveform is obtained. The defect will be immediately following this point.

The picture quality and appearance often can give a clue to the problem. In Figure 7, the defect was the control-track head that produced a weak and erratic signal.

Obviously, a loss of signal from a

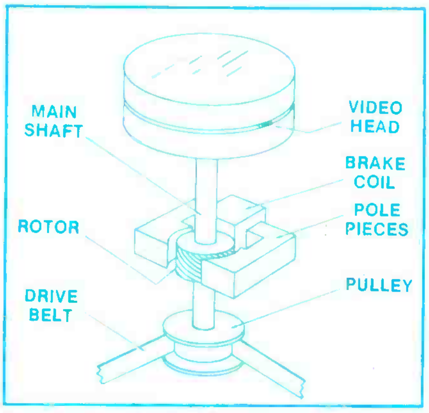


Figure 6. The basic principles of a head-servo brake are shown here. The brake applies variable electronic drag to maintain a constant speed and phase of the head drum.

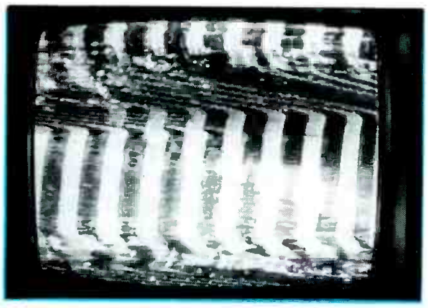


Figure 7. Horizontal pulling of the TV picture was caused by a defective control-track head.

defect in another section cannot be analyzed properly by scope waveforms. For example, some Beta machines monitor the servo signal coming from the rotating video-head drum. When this signal is missing for more than a second, shut-down is actuated automatically. Missing PG pulses might be caused by a jammed tape, a broken drive belt or a defective motor. However, a defect in the PG-pulse processing path also can produce the same symptom.

Therefore, there is no PG signal to be scoped and analyzed. You must perform signal substitution so the circuit will sense a signal and not activate the stop mode. Waveshape and repetition rate of the test signal are not very important, but the level should correspond to the normal amplitude. I have successfully used the transistor vertical-drive signal from a Sencore VA-48 after adjusting the level to 1VPP and connecting to pin 24 of IC501 on the ARS board. This stops the shut-down and allows time to find the cause of the missing PG pulses.

RCA VCT400 servos

An example of older VHS servos is found in RCA model VCT400 VCR, which has both head-cylinder and capstan servos. The video heads are rotated by a direct-drive three-phase ac motor (Figure 8). Sensing of head positions and rotational speed is made possible by a PG signal and an FG signal.

Two magnets are mounted on the head cylinder where they are rotated in turn near one stationary magnetic coil. One magnet has its north pole oriented toward the coil, while the other magnet has its south pole nearest the coil. Therefore, the PG signal from one magnet's movement will be mostly positive-going, and the other magnet's PG signal will be negative-going. These weak PG pulses are pre-amplified before reaching the servo circuit, where the positive and negative pulses are separated by selective amplification, so they can then travel in separate paths. Positive pulses indicate the position of one video head. Negative pulses prove the location of the other video head.

A winding inside the 3-phase, 4-pole motor generates 1800Hz near-sinewaves. This FG is used in the speed-control circuitry that provides 900Hz variable-width pulses for motor control.

A block diagram of the entire head-cylinder/capstan servo system is shown in Figure 9. There are interconnections between the two systems, so the operation is made more clear by including both circuits. Notice the direct-drive, 3-phase ac head-cylinder motor and the dc-operated capstan motor.

The RCA VCT400 offers a choice of standard play (SP) and long play (LP). The long-play mode allows double the recording and playing time per tape, but the head-cylinder speed is not changed. Long-play mode is initiated by reducing the capstan rotation to half the standard play speed.

During standard play, a narrow guard band of unrecorded space separates successive diagonal video tracks. The slower tape movement during long-play mode allows an overlap of adjacent tracks. Excessive crosstalk is prevented by the +6° azimuth gap tilt of one video head and the −6° azimuth of the other video head. With a FM signal of such high frequency, each head during playback almost totally ignores the signal intended for the other head.

RCA recording

During video recording, vertical sync from the incoming video is frequency-divided, delayed in time (phase delay) by a MMV one-shot, and then filtered to produce pulses. These 30Hz pulses are the reference signal for the cylinder sampling gate.

At the same time, pulses from

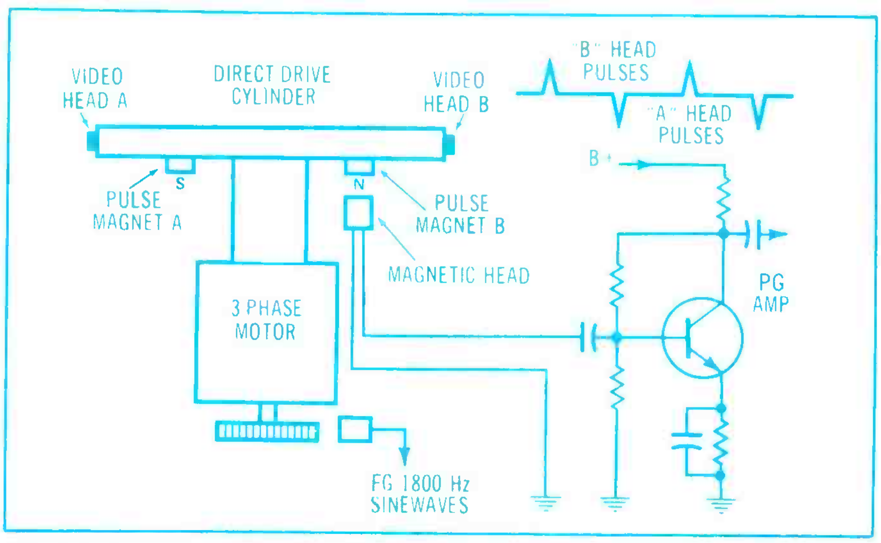


Figure 8. PG pulses in the RCA VCT400 are generated by magnet north and south poles rotated with the video heads on the direct-drive head cylinder (or drum). FG sinewaves are generated by a motor internal winding. The weak PG pulses are amplified before they are sent to the head-servo circuit.

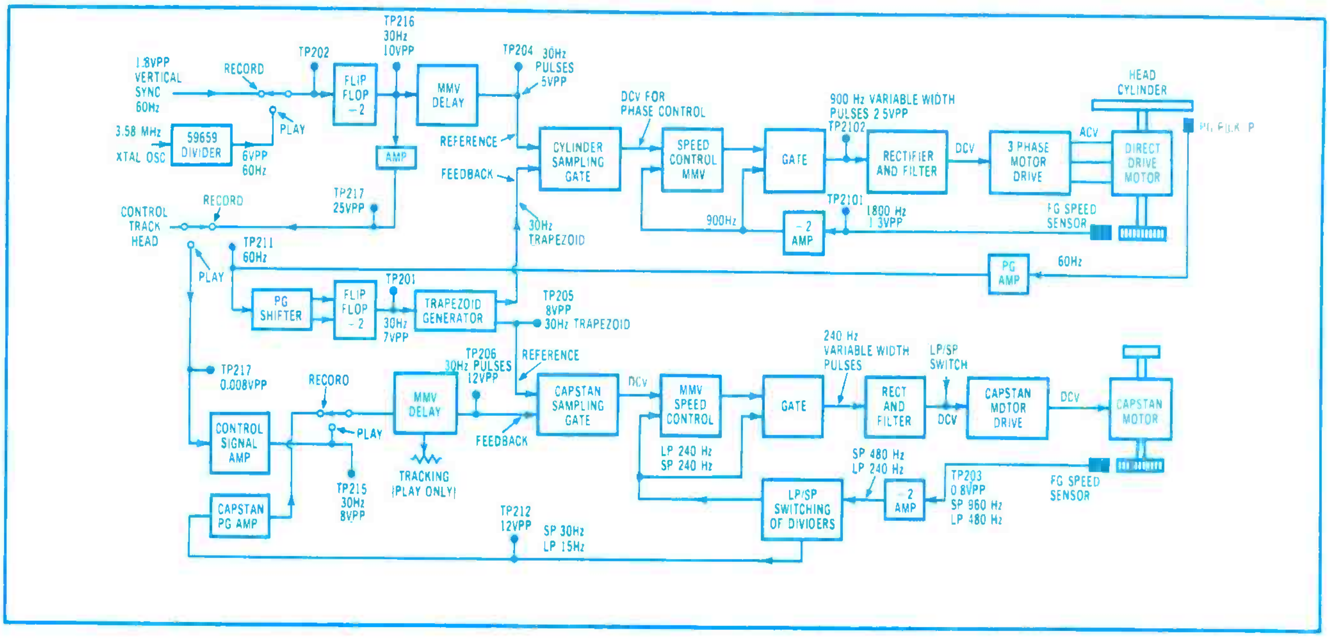


Figure 9. The complete RCA video-head and capstan servo circuits are shown in one block diagram.

the PG pickup are amplified, phase delayed and divided to produce 30Hz 50%-duty-cycle square waves, which are integrated by the trapezoid-generator circuit. These so-called trapezoids are square waves whose leading and falling edges have been changed into parabolas that serve as sawteeth. The trapezoids are the feedback 30Hz input to the cylinder sampling gate. (Also, another sample of the trapezoid signal is used as the reference signal for the capstan sampling gate described later.)

The cylinder sampling-gate output is a variable dc voltage that is one output of the speed-control MMV. The other MMV input is the frequency-divided signal from the cylinder FG winding. The output of the speed-control gate consists of 900Hz pulses rectified and filtered, becoming a varying dc voltage that controls the 3-phase motor-drive circuit. In turn, the motor-drive circuit regulates the 3-phase ac power to vary the head-cylinder motor speed.

In the capstan section of Figure 9, capstan-motor FG sinewaves are frequency divided several times (the division is different for LP mode) and have become the PG signal, because the dividers have changed the sinewaves into square waves. This PG signal passes through the capstan PG amplifier to the MMV (which allows manual tracking adjustments during playback), and the MMV output pulses are the capstan sampling gate's *feedback* signal.

The output of the capstan sampling gate is a dc voltage that varies with capstan-speed errors. This dc voltage and the 240Hz square waves from the FG/PG dividers are inputs to the MMV speed control and the gate. The output of the gate is a constant flow of variable-width pulses that are rectified and filtered to drive the capstan-motor driver circuit. A variable dc voltage from the driver circuit controls the capstan-motor speed.

RCA playback

The head-cylinder reference signal during playback is a 3.58MHz crystal oscillator followed by a divider to yield a 60Hz signal. This signal is passed through the *record/playback* switch and on to the cylinder-speed correction and the ac-power stages that drive and control the head-cylinder, 3-phase ac motor. There is no change in the feedback signal during playback.

For the capstan sampling gate's feedback signal, the previously recorded 30Hz square waves from the control-track head are switched to the MMV delay instead of the capstan PG signal used for recording. Otherwise the circuit is unchanged. The capstan sampling gate's reference signal is the same trapezoidal waveform used during recording.

Servo troubleshooting

Identification of the servo system as the cause of abnormal symptoms is the first step in troubleshooting. Although the specific symptoms take many forms, all problems affect the vertical or horizontal stability of the TV picture. Alternately, the picture might have the vertical blanking bar visible in the picture, either stationary or moving.

Next, several tests should be performed to identify whether the problem involves recording, playback or both. At this point, do not use expensive test tapes. Instead, try to play a previously recorded tape known to be normal. If this test tape plays normally, the problem has a high chance of being in the recording servo operation. However, if you make a test recording and it plays correctly, it becomes almost a certainty that the customer used a defective tape. When your test tape (previously recorded on another machine) plays normally, but a new recording plays back with the original symptom, this is proof of a recording servo problem.

The first step is to check the reference and feedback signals at the proper sampling gate (whatever it is called in that specific machine). If one is distorted, weak or missing, scope

(continued on page 56)

TELEPHONES

CHANGES ON THE HORIZON

By Mannie Horowitz

Electronic telephones are among the best-selling new products, with features such as automatic redial, memory dialing, and push-button convenience that make conventional phones seem old-fashioned. Wireless telephones have most of these advanced features plus the convenience of operation without restricting wires.

Wireless telephones consist of two basic units. The base station plugs into a telephone modular jack in the home or office, where it is powered by 120Vac. A smaller remote unit (usually with dialing push-buttons) is plugged into the base station when the remote's battery needs recharging (or for convenient storage). At other times, it can be operated at a distance from the base.

When a phone-ringing signal from the telephone line is received by the base station, the signal is changed into an audio tone that is transmitted by a radio carrier to the remote station. If the remote is in the *standby* mode, the audio tone is heard and the remote operator switches to the *talk* mode. This causes the base station to capture the phone line, allowing conversation between the person who originated the call (to the base station) and the person holding the remote unit.

Simplex telephones

Wireless telephones that employ simplex operation transmit and receive on the same radio frequency. In this case, only one person can speak at any one time. After the phone line is captured, the remote unit listens to the caller, unless its talk button is pressed. When the talk button is activated, the remote transmits, and this signal can be detected by the base station during gaps in the base station's RF output signal.

During these gaps, base-station reception of the remote carrier forces the base station into the *receive* mode, which allows remote operators to talk back to the distant caller. In other words, the person at the remote phone unit determines who is heard. The button is pressed for the remote to talk and is released so the remote can listen. Simplex phones are slightly more difficult to operate but usually cost less.

Duplex telephones

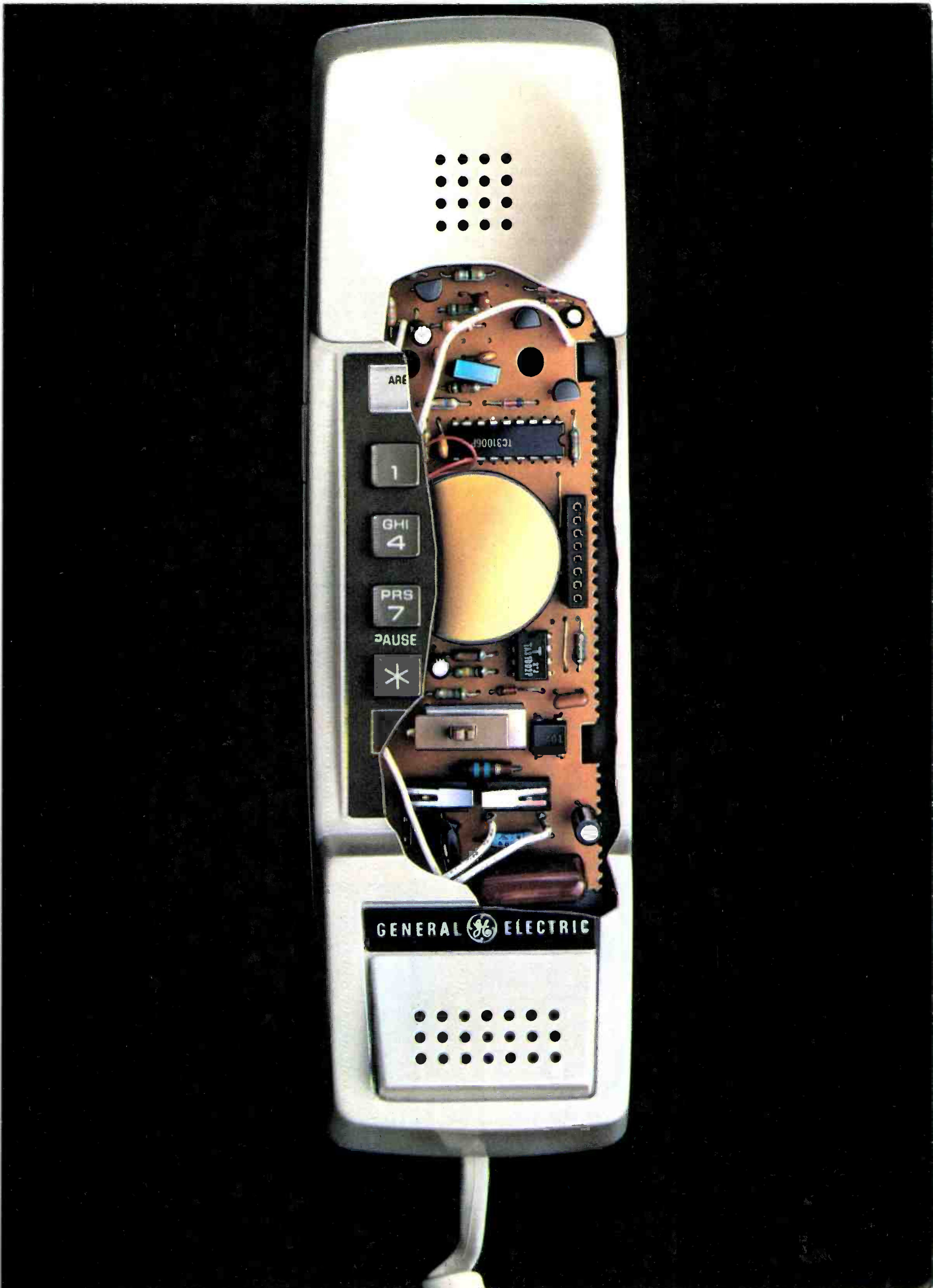
Duplex-type wireless phones are more popular because they don't require switching for talking. The base transmits on one frequency, usually about 1.7MHz, and the remote transmits in the 49.8MHz band. Because of the large separation of frequencies, both carriers can operate simultaneously without interference.

Normally the remote unit is operated in *standby,* with only the receiver powered, so that a call from the base station can be received at any time. When switched to *talk* or *converse,* the transmitter portion of the remote receives power, and both people are able to talk at any time without any switching.

Typical power supply

Line voltage powers the base unit. After rectification, the dc voltage is filtered and regulated and sent to the various base-unit circuits (Figure 1). A bridge rectifier is usually used so that the dc power can be referenced to ground even though the ac line is not grounded. Because the ac line is ungrounded, it is available for use as an antenna after isolation by RF chokes.

In Figure 1 the regulator is


1
GHI
4
PRS
7
PAUSE
GENERAL ELECTRIC

shown as an IC, represented by a triangle. However, a comparable regulator can be constructed from discrete components, as shown in Figure 2. In this circuit a specific fixed positive voltage (relative to ground) is applied to the transistor base by a resistor and a zener diode. Of course, transistor bias is measured between base and emitter. When power is applied, the B/E bias varies the C/E resistance, which in turn varies the C/E current to produce an emitter-to-ground positive voltage that is about 0.65V less positive than the base's regulated dc voltage. When varying input voltage or varying current load at the emitter changes the emitter-to-ground voltage, the transistor attempts to restore the original voltage by again varying the collector-to-emitter resistance. A voltage supply of fair (but not perfect) regulation can be produced by this circuit.

If the output from either an IC or transistor regulator is low, the first troubleshooting step should be testing the bridge-rectifier voltage, which is the input to the regulator. Another possible cause of low regulator output voltage is excessive current or a short in the RF power-output stage loading down the bridge. Excessive current drawn by circuits that are powered from the regulator is another cause of this symptom.

When no abnormal current can be found, the next suspect is the regulator itself. An IC cannot be opened for testing or repair, of course, but the discrete type of regulator can be tested. Zener diodes occasionally open or short, and power transistors are susceptible to failure.

Usually, the remote is powered by Ni-Cd batteries that are trickle-charged when the unit is plugged into the base station. Figure 3 shows the general circuit of a trickle-charger. R1, D1 and D2 apply a regulated +1.4V between base and ground. About +0.7V is needed between base and emitter as forward bias, so the emitter-to-ground voltage should be +0.7V across R2. Current through emitter resistor R2 is stable at 0.7 divided by the resistance of R2. Because the emitter and collector currents are approximately equal, the battery is trickle-charged at this current.

When the battery is not being charged properly, first test the voltage across the charger output (B+ to Q1 collector) when the battery is disconnected. This open-circuit voltage must be higher than

Figure 2

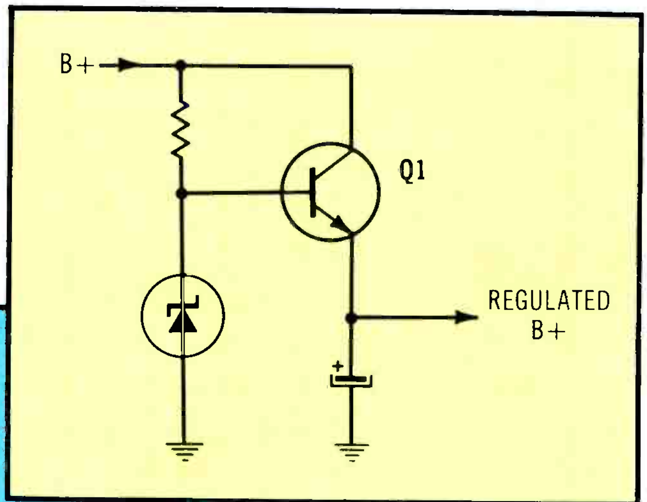


Figure 1

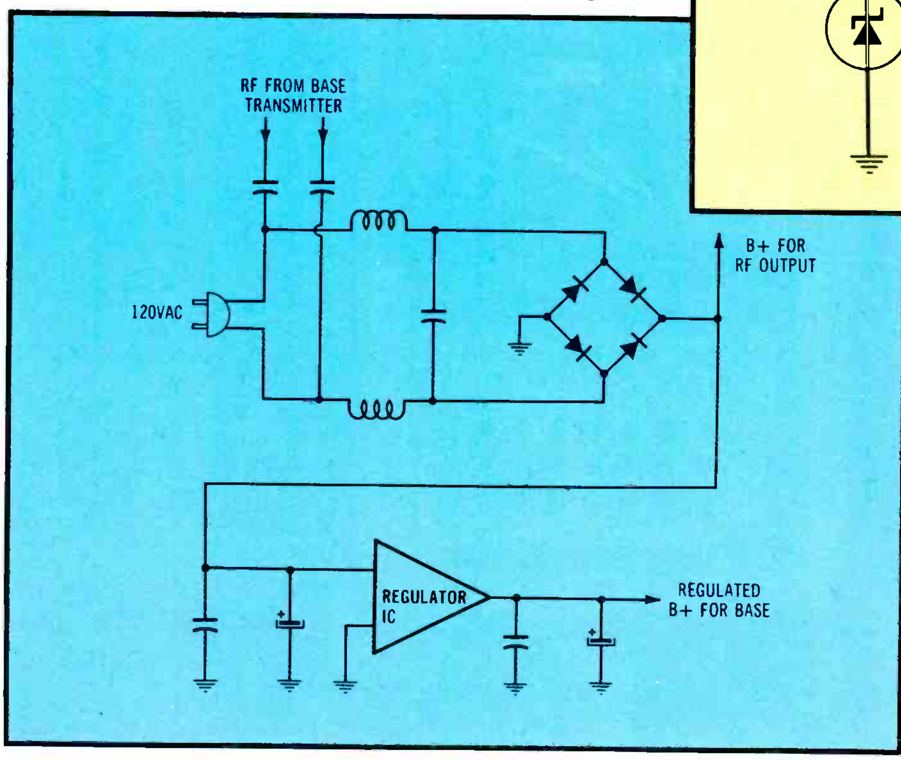


Figure 1. There is nothing unusual in most base-station power supplies, except for the RF chokes and the capacitors that feed the RF to the ac-power line. The power line is used as an untuned long-wire antenna to radiate the signal.

Figure 2. Regulation can be obtained by this circuit consisting of discrete components. The zener diode should be rated about 0.7V higher than the desired regulated B+. Any voltage variations of the regulated supply changes the bias of the transistor, which changes its C/E resistance to correct the voltage change.

Figure 3. This is one type of constant-current circuit that provides proper charging of the remote unit's NiCd battery.

Figure 4. The telephone-line ringing signal is not suitable for alerting the remote unit. Also, it is necessary for the phone line to be insulated from the base station (even the base station ground). This circuit fulfills those requirements and includes a voltage doubler for the ringing signal plus an LED in the light-tight enclosure to prevent erratic operation of the neon bulb. Q2 is a switching transistor, described in Figure 5.

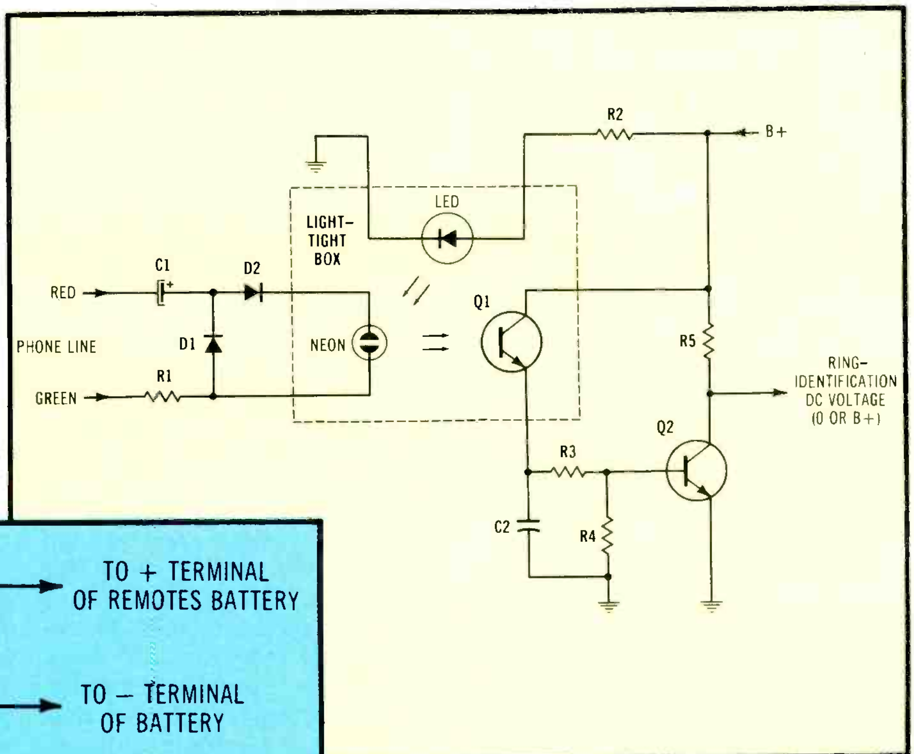


Figure 4

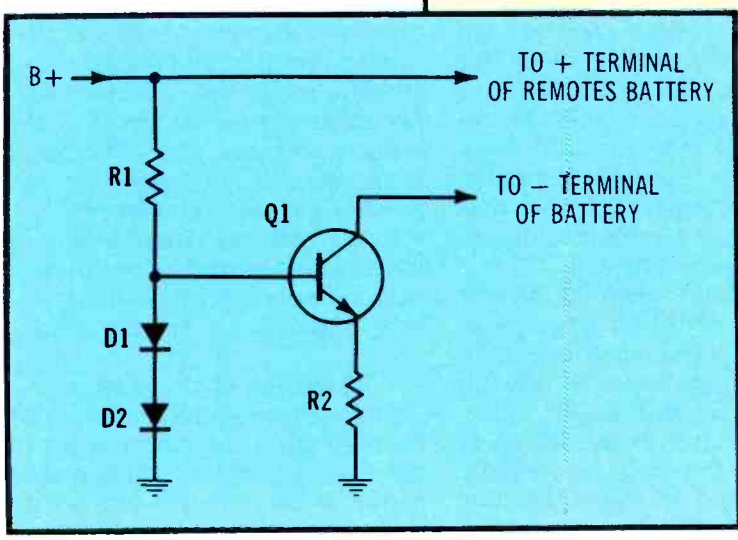


Figure 3

the battery's voltage rating. Also, measure the B+ supply to the charger circuit. Check the voltage across R2 to determine (by Ohm's Law calculation) the charging current. Check all trickle-charger components. If no circuit defects can be found, the battery may be defective.

Calling the remote

Conventional telephones have electrical/mechanical bells that ring when someone calls. This bell-ringing signal is not compatible with electronic telephones, particularly wireless types. Therefore, the signal must be used in another indirect way.

Most telephone systems operate from a dc voltage of 52.5V. When a phone is called, this voltage is across the two (or sometimes four) wires. In addition, a ringing signal (having an amplitude between 40Vac and 150Vac and a frequency between 20Hz and 60Hz) is superimposed on the 52.5Vdc.

Perhaps the simplest ringing-signal detector has a neon bulb that is lighted directly by the ringing signal. When the neon's light reaches a phototransistor, conduction in the transistor activates some kind of audible signal. This simple circuit has several serious drawbacks and limitations. First, the neon bulb cannot ionize unless the momentary peak voltage exceeds about 65V, while some bulbs require more voltage than is supplied by the phone line. Second, the bulb and the phototransistor must be in a light-tight enclosure, and when some neon bulbs are in total darkness, they become erratic and require starting voltages higher than 100V peak.

A circuit similar to the one in Figure 4 eliminates those drawbacks. The LED is lighted at all times when the base station is turned on (because it is powered through a current-limiting resistor from the B+ supply). Its light is sufficient to prevent the neon bulb from becoming erratic, but too dim to cause conduction in phototransistor Q1.

Reliable ionization of the neon bulb is assured by a voltage doubler. C1 blocks all steady dc voltages, while allowing the ringing ac voltage to pass. Diode D1 clamps the negative peak of the ringing signal to zero volts, so the entire signal becomes positive (not just one peak, as is true without D1) and passes readily through switching diode D2 to the neon bulb.

When the neon bulb lights to full brilliancy (during each cycle of the ringing signal) Q1 phototransistor conducts strongly, supplying a positive voltage to C2 and the R3/R4 voltage divider. C2 filters these pulses to a positive voltage with some ripple. Values of R3 and R4 are chosen so Q2 is totally saturated (high forward bias with nearly zero dcV between collector and emitter) during all ringing cycles and completely open (B+ at the collector and zero C/E current) when no ringing signal is present. Values of R3/R4 versus C2 are chosen so Q2 remains saturated until all ringing ceases. Notice that the Q2 collector voltage can be used efficiently to switch other circuits, since the voltage either is nearly zero or almost B+.

Figure 5 shows how the Q2 collector voltage activates a ringing signal in the remote unit. Two circuits are switched. First, a sample of the Q2 collector voltage goes through a limiting resistor to the Q3 base, forcing Q3 into either saturation or non-conduction in reverse of the Q2 condition (Q3 is a saturated inverting switch).

When the incoming ringing signal reaches the base station, Q2 saturates, causing Q3 to become an open circuit. In this state, the Q3 collector draws no current, so although it is connected to the Q6 base, Q6 will oscillate (usually at 1000Hz). This tone frequency modulates the varactor-diode modulator of the 1.7MHz carrier that is transmitted from the base station. When this tone signal is received by the remote, the 1000Hz tone is heard instead of bell ringing.

The FM oscillator, however, cannot operate until bias is applied to Q5. When the incoming ringing signal causes saturation of Q2 (producing a zero collector voltage) a sample is sent to the base of Q4 PNP switching transistor. This is forward bias to Q4, so it conducts positive voltage from its emitter to its collector and through resistors to the varactor diode (for reverse bias) and to the Q5 base circuit (for forward bias). Therefore, the FM reactance and oscillator stages operate normally, broadcasting the 1000Hz tone that is heard in the remote unit, indicating an incoming call.

At other times, when the 1000Hz tone is not needed for ringing, Q2 is non-conducting, and the high collector voltage biases Q3 into full conduction. Because the Q3 collector is connected to the Q6 oscillator base, the base is virtually grounded, and the Q6 transistor circuit cannot oscillate.

Broadcasting to the remote

Broadcasting either the incoming phone audio or the 1000Hz tone (for ringing) to the remote unit is accomplished by driver and RF-output transistor amplifications of the Q5 FM signal. Most driver and power-output transistors are supplied with B+ voltage at all times, but they have insufficient forward bias. Therefore, they do not draw current or amplify until the FM oscillator supplies them with RF signals.

RF power from the output transistor is tuned and sent to the ac-power line via two coupling capacitors (Figure 1). Two RF chokes prevent RF power losses in the bridge rectifier and other allied circuits, while the capacitor connected across the ac inputs of the bridge prevents the RF signal from riding in on the wiring and possibly causing interference.

In essence, the power wiring of the building is used as an untuned antenna to broadcast the base station's signal to the remote unit.

Reception at the remote

At the remote unit, calls can be received when the switch is set to the *standby* position, which applies power to the receiver but not to the transmitter. The receiver is a

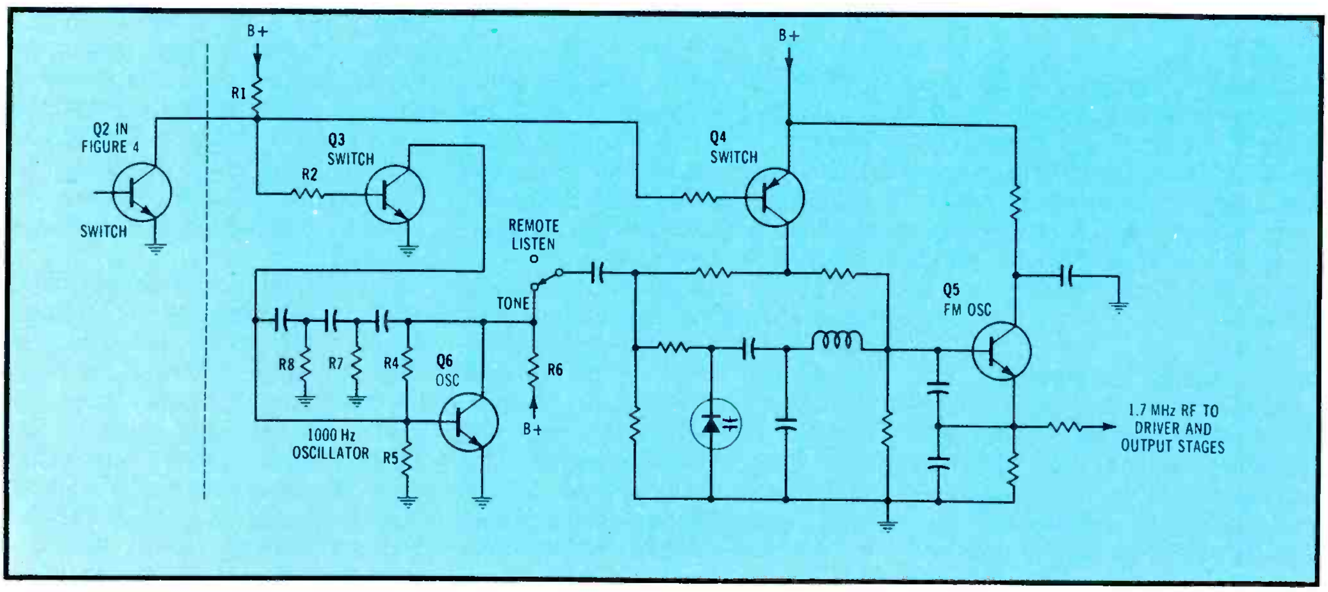


Figure 5. Two actions are necessary when a ringing signal reaches the base station: the 1000Hz oscillator is started and used to modulate the FM carrier that is broadcast to the remote unit; and the transmitter reactance and oscillator stages receive bias. See text for details.

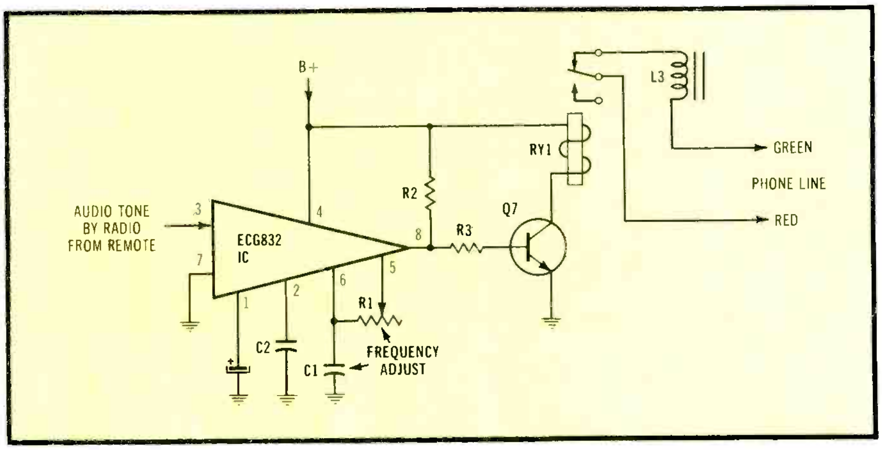


Figure 6. Capturing (locking) a phone line for an outgoing call from the remote unit requires inductance L3 to be connected across the phone line. An audio tone is transmitted from the remote unit to the base station.

simple FM superheterodyne unit.

A call is accepted by the remote unit when the switch is moved to the *talk* position. This activates a phase-shift audio oscillator (between 3500Hz and 7500Hz), which modulates a 49MHz transmitter. A collapsible rod antenna radiates the carrier.

A rod antenna at the base-station unit receives the radiated signal which is amplified and detected in the base receiver. The recovered audio tone is sent to a tone decoder (perhaps a Sylvania ECG832 IC) which produces a near-zero voltage at pin 8 (see Figure 6) when the tone is present, or B+ when the tone is missing. Without reception of the audio tone, Q7 has saturation bias through R3 from pin 8, so the Q7 collector current closes the relay contacts, disconnecting the phone line. When a tone of the proper frequency is received, the near zero pin-8 voltage stops the Q7 conduction and the relay de-energizes, producing a path for the phone line through inductance L3. (Audio for the incoming and outgoing conversations also is developed across L3.) This is capturing the phone line and allows normal operation. L3 has an impedance of about 600Ω.

C1 and the setting of R1 in Figure 6 determines the precise audio frequency that forces higher current through pin 8, thus dropping the voltage to near zero. R1 is adjusted in the following manner: after audio of the proper frequency is applied to pin 3, the pin-8 voltage is monitored while R1 is rotated. The final R1 setting should be near the center of the adjustments that reduce the pin-8 voltage to zero.

Audio from the phone line is amplified and used to modulate the varactor section of the FM 1.7MHz oscillator. This signal is then received and heard by the remote unit. Simultaneously, output from the microphone (when the remote operator speaks) is amplified and mixed with the 3.5kHz to 7.5kHz keying tone. The mixture modulates the 49.8MHz transmitter in the remote, and the signal is radiated from a rod antenna back to the base unit.

When the 49.8MHz carrier is received and demodulated in the base unit, the two audio signals are separated by a filter. The tone is sent to the tone decoder, previously explained, to maintain the phone line capture, while the audio speech signal (less the tone) is amplified and applied across L3 (in Figure 6). L3 now is across the phone line, so the caller can hear whatever the remote operator says.

After the conversation is over, the remote-unit operator switches to *standby* mode, which energizes the relay that releases the phone line. With the remote in standby, the system is ready for the next incoming phone call.

Dialing

With a conventional rotary-dial wired telephone, dialing a number is accomplished by first loading the line (with an inductance) to capture it. Then the continuity is opened one time for each dial pulse. If the number three is dialed, the line must open three times in fast succession. In wireless phones, the continuity is supplied by L3, while the open line is obtained by energizing the RY1 relay, which opens the contacts that are in series with the phone line.

Before dialing can proceed, a switch on the remote must be set to the *dial* or *talk* position. Signal then is transmitted to the base unit, the phone line is captured, and a dial tone can be heard at the remote.

Electronic information about which number is to be dialed is supplied to a specialized IC (such as an MM53190). The IC has several outputs that actually perform the dialing. One output controls the conduction of a switching transistor, which shorts the base of the microphone-amplifier transistor to ground during dialing to prevent any speech signals from interfering. A long-time-constant circuit at the switching transistor's base keeps the microphone amplifier turned off between dialing pulses.

Similarly a switching transistor is placed at the base of the input transistor of the audio power-amplifier section in the remote unit. This eliminates dialing noises that might annoy the remote operator. Again the time constant of the control-voltage filter is long to prevent any sound between dialing pulses.

A third terminal of the IC also connects to a switching transistor that is connected to the remote's tone-oscillator transistor. As explained earlier, this stops the oscillation action when capturing the phone line is not needed. Each time the switching transistor receives saturation bias, its collector shorts the oscillator base to ground. Therefore, when open-line dialing pulses are needed, no tone is transmitted to the base station. No time-delay capacitor is added to this switching transistor's base because fast response is needed. Each time the audio tone is interrupted, the base-station decoder activates the relay, opening the phone line and producing a dialing pulse. For example, three pulses in close sequence, a pause, five in sequence, a pause, and nine in sequence dials number 359.

Other phone features

Logic circuits are used in some top-of-the-line models to perform the functions described previously. Other circuits silence the remote units when no signal is received. Gain of a base station can be reduced when no signal is being received, and then restored to normal gain when a call is received. Some models can signal the remote when a button on the base unit is pressed. Models with speakers in the base unit can be used as an intercom with the remote as the other station.

With some models, ac-powered battery chargers are offered so that remote units may be charged away from the base station. In this case it is not necessary to bring the remote to the base station at any time.

A few wireless phones are limited to a 100-foot range, but most are rated for 700-foot to 1000-foot maximum distances. However, larger antennas can be added to base stations to extend the maximum range.

Other new features in some electronic phones include battery-condition indicators, end-of-range indicators, dialing-confirmation indicators, a choice of two channels, a switch to select tone or pulse dialing, a mute button for privacy, automatic last-number redial, memory dialing and security codes.

ES&T

Photofact

These Photofact folders for TV receivers and other equipment have been released by Howard W. Sams & Company since the last report in ES&T.

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HITACHI
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7P77/9X/9X2/9X72/9X77 .... 2202-2,-2-A
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List the brand, model and Photofact number followed by a narrative telling the original conditions or symptoms, the various troubleshooting steps, and the components replaced to restore the original performance. Please include a simple hand-drawn schematic of the stage that has a defect.

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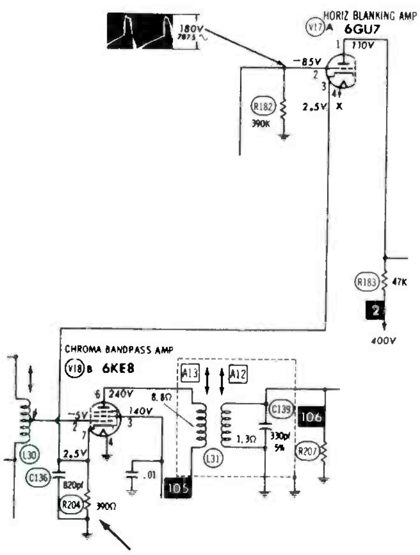
Troubleshooting Tips

Insufficient brightness
RCA CTC35A
(Photofact 925-2)

When connected to the shop test jig, the CTC35 chassis provided a dim picture. New video tubes did not help the dark picture, although they are the cause in most complaints about this condition. Voltage tests in the three –Y amplifier stages showed low plate voltages, which in turn reduced the picture-tube grid voltages. Evidently, the low CRT voltages were the basic cause of the low brightness.

Scope waveforms revealed that the horizontal-blanking-amplifier tube (V17A) had no horizontal pulses at the plate. Changing to dc-voltage checks, I soon found a small positive voltage at the blanker grid (should check about –85V) and an excessive cathode positive voltage. After more tracing of the circuit, I noticed that the blanker cathode was connected to the chroma bandpass-amplifier cathode and that they shared a 390Ω resistor to ground. This R204 cathode resistor is located next to the V18B 6KE8 bandpass tube, and it had been burned open. Because a short in either tube can burn up R204, I replaced both tubes and installed a new R204.

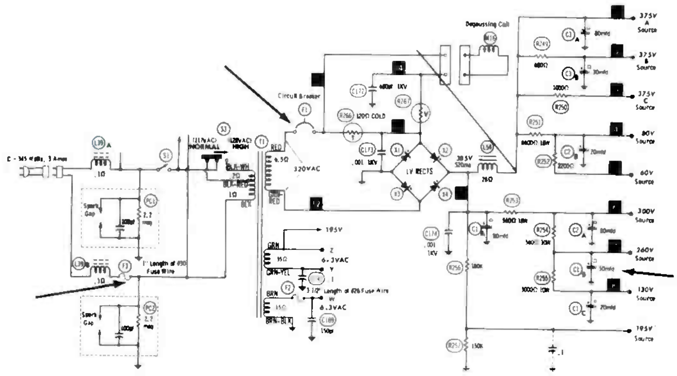


These replacements restored normal brightness, giving a good picture. Now the blanker grid measured –81V and the common cathodes reading was +2.8V. These voltages were within normal tolerance. This repair shows the importance of understanding how the horizontal-blanking pulses are applied to the –Y amplifier grids, where they are rectified to produce negative grid bias, and which affects the brightness. Also, the same grid pulses produce negative-going blanking pulses at the CRT grids.

E. V. Snider, Jr.
Little Rock, AR

No power
RCA CTC38X
(Photofact 1000-3)

According to the customer, the color receiver went dead as if switched off. No light could be seen in any tube or the dial lamp, but the B+ circuit breaker did not trip. Ohmmeter tests showed normal continuity from the input plug through the on/off switch, but F3 was open. F3 is one inch of #30 fuse wire that is connected in series with one lead of the power-transformer primary winding. I replaced F3 and applied power, but the tubes lighted and then went dark. Again F3 was open.



Evidently, an overload was loading down the power transformer. Why didn't the circuit breaker trip? Instead of installing another F3, I temporarily connected a 5A circuit breaker as a substitute. The tubes lighted and all B+ voltages were very low. In addition, R254 and R253 were operating so hot that they smoked. I disconnected the three loads at C1A and tested each leg for leakage. Resistance tests proved C1B had a leakage of about 2500Ω.

C1 and F3 were replaced and proper operation of the color receiver was restored. Although I knew the problem had been found, I was concerned about the circuit breaker not tripping. An examination of the F1 input-power circuit breaker showed it had been replaced with a 7A rated unit instead of the proper 1.2A. After the breaker was replaced with the correct type, I was satisfied with my logic. Replacing a protective fuse or breaker with a higher-current one can place the receiver in danger. Do not replace fuses or breakers with others of different ratings.

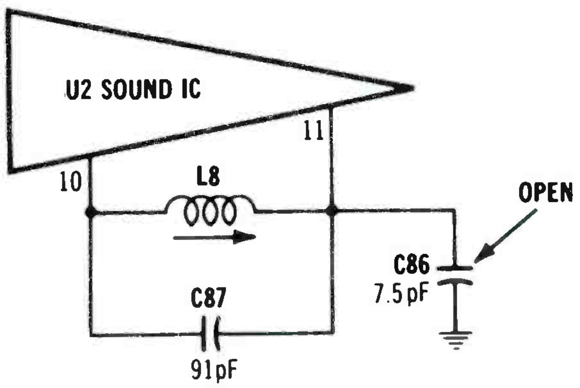
William P. DeRita
Providence, RI

Distortion and low sound volume
RCA CTC97
(Photofact 1862-1)

Symcure #1 of the August 1982 issue of **Electronic Servicing and Technology** suggested that C86 was causing weak and distorted audio. There is no doubt that an open 7.5pF C86 will produce audio distortion. Several months later, Frank Fligel (Berwyn, IL) submitted the same tip, but he also stated that a 20pF value could be used if L8 is readjusted for loudest, clearest sound.

Also, I strongly suggest that nothing except the specified temperature coefficient rating be used. Most sound demodulation capacitors are NPO (zero temperature coefficient) type. If the parts list specifies an NPO, do NOT use an ordinary ceramic type. Drift is almost a certainty when incorrect replacements are used.

Later, George Starr (Sebring, FL) wrote about an RCA with the same symptoms, but C86 was not the cause. A defective L8 tunable detector coil produced weak and distorted sound on-channel, but loud noise off-channel. Starr said to remove the L8 shield and notice if the sound becomes normal. In that event, replace L8, install the shield, and adjust the core for the loudest undistorted sound.



These cases illustrate some limitations and helps that can come from symcures. Theoretically, symcures should cover failures that have happened more than one time (ideally, a common failure in that model). Such a knowledge of repetitive failures can save many hours of diagnostic time. However, all experienced technicians know that other component failures often produce the same symptoms. Therefore, if the component failure suggested in a symcure is not helpful in a specific case, check other components of the same stage or circuit. The symcure will be of value if it directs our attention even to the offending stage. Another potential help from symcures can come from similar circuits in different model numbers. Sometimes a manufacturer will retain a certain component configuration for a series of chassis, or over a period of a few years. Therefore, look for similarity of circuits and symptoms, using the suggested defect as a starting point for troubleshooting.

Carl Babcoke, CET
ES&T Consumer Servicing Consultant

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Positive thinking about negative feedback

By Bernard Daien

Negative feedback (inverse feedback) is an essential part of audio high fidelity amplifiers, instrumentation amplifiers, control systems and automation. Nevertheless, negative feedback itself is usually ignored in the textbooks and manuals for such equipment. When negative feedback *is* discussed, the treatment includes numerous mathematical expressions, which are not easy to comprehend or to apply directly to practical circuits.

Actually, negative feedback is not difficult. This article covers inverse feedback in a direct way, with very little math. What math is included is no more difficult than that already used by the average technician.

This coverage of negative feedback would be incomplete without including some reference to operational amplifiers, so they are noted. Finally, the effect of negative feedback on input and output impedances is also considered; a practical matter that is usually glossed over, and one that every technician realizes is quite important. This article is basic to the understanding of modern industrial circuits in the control and automation fields, as well as much of the newer home entertainment equipment.

In past years, with simple radio receivers, a drop in gain or signal level was taken care of by manually readjusting the volume control. In an instrumentation amplifier, a drop in amplifier gain results in an error in the readout, which is not acceptable. Negative feedback is useful in both cases. In the receiver, automatic gain control (a form of negative feedback) takes care of signal level variations. In instrumentation circuitry, various forms of negative feedback provide stability despite variations in the gain of the amplifier.

It is widely known that inverse feedback reduces distortion, increases bandwidth, maintains constant gain in spite of changes in supply voltage, aging of components, etc. However, there are many misconceptions about inverse feedback, too. For example, many operational amplifier texts state, "Due to inverse feedback, the operational amplifier is an ideal amplifier...with very high input impedance, and very low output impedance." This is not at all true. Inverse feedback can alter input impedance, making it high or low, and it can also alter output impedance, making it high or low.

A few preliminaries

An understanding of inverse feedback requires getting a few concepts straight. First, look at what is commonly called a *voltage-regulated source*. Such a source does not change its output voltage when the current drain upon it changes (load change). In Figure 1, the constant-voltage source has low internal resistance. If the internal resistance were appreciable, the output voltage would change as the load current changed. Thus, *a constant-voltage supply has a low source (generator) impedance.*

Now look at a constant-current supply, approximated in Figure 2. Note that it consists of a high-voltage source with a high internal resistance deliberately placed in series with it. Because practical loads are much smaller than the high internal impedance, the current is determined by the limiting effect of the internal resistance, so variations in the load resistance have little effect on the output current. In other words, if the load varies from 0Ω (a short circuit) to 1000Ω, the output current will change less than 1 percent. Thus, *a constant-current supply has a high internal impedance.*

The above is called the "Black Box" approach, because what matters is not what is actually inside the "box," but how it responds to external circuitry. In this case, the little black boxes are constant current, or constant-voltage generators. It is important to understand this in order to see how this interrelates with the application of inverse feedback, which will be covered later. Using inverse feedback to hold either a current or a voltage constant forms either a constant current or a constant-voltage source, which in turn, is either a high, or a low impedance circuit. Feedback can be applied to make any desired input or output impedance.

Figure 3 is the block diagram of a simple audio amplifier in which the output is 180 degrees out of phase with the input. It is sampling the output *voltage* by means of a divider, and feeding a percentage of the output voltage back into the input as negative-voltage feedback; in this case, 10 percent feedback because it is feeding one tenth of the output back into the input via a ten-to-one voltage divider. (Expressing 10 percent as a decimal: it is 0.1). Although it is common to talk about feedback as a certain percent, it is simpler to write it as a decimal when doing calculations, so Table 1, percentage vs. the decimal equivalent, is included for your convenience.

Note: the ratios in the table show the ratio of the divider required to produce the desired percentage of feedback in a practical circuit. A one-tenth divider would consist of the circuit in Figure 3. The ratio of voltage output to voltage input of the divider is one-tenth, even though the ratio of the resistors is 9:1. That's because the *total* resistance of the divider is 10,000Ω, and the feedback circuit is tapped down at only 1000Ω, which is one-tenth of the total.

Table 1

Percent	Decimal	Ratio
10	0.1	1/10
5	0.05	1/20
1	0.01	1/100
1/10	0.001	1/1000

The voltage gain of the amplifier in Figure 3 will be shown to be 10 with the feedback switch closed. This is known as the *closed-loop gain.* With the switch open, the feedback loop is opened, and the gain rises to the gain of the audio amplifier itself (no feedback). This is known as the *open-loop gain.* Closing the switch reduces the gain of the circuit. This gain reduction is the "trade-off" for the benefits of negative feedback. A simple math formula is used to predict the closed-loop gain, if the open-loop gain and the percent of inverse feedback are known.

$$A_{CL} = A_{OL}/[1 + (H \times A_{OL})]$$

where A_{CL} is closed-loop gain, A_{OL} is open-loop gain and H is feedback expressed as a decimal.

Do this equation for the amplifier in Figure 3. The percent of feedback is known, but a figure must be chosen for the open-loop gain, which leads to an important practical point. *This equation works perfectly when the open-loop gain is much higher than the closed-loop gain, but is in error when the*

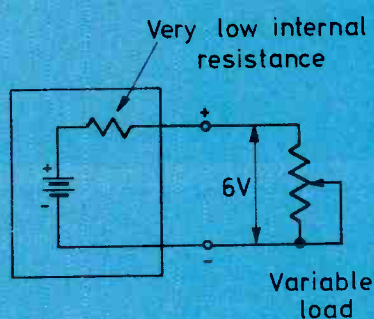


Figure 1. A constant-voltage source exhibits low internal impedance.

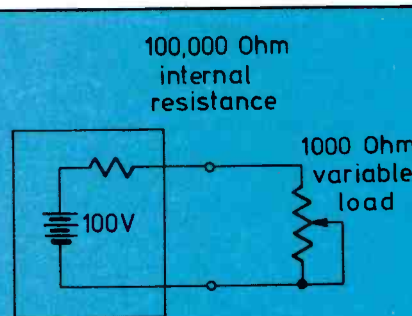


Figure 2. A constant-current source consists of a high-voltage source with high internal resistance.

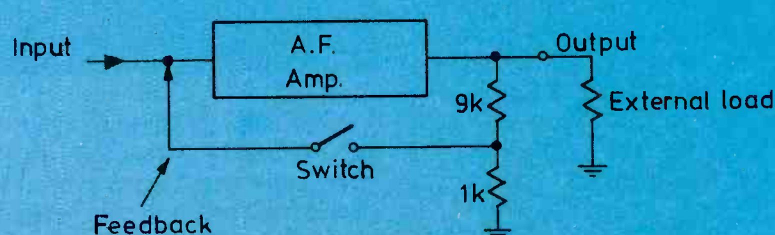


Figure 3. The voltage divider arrangement feeds back 10 percent of the output signal to the input, out of phase, when the switch is closed.

open-loop gain approaches the closed-loop gain. This tells you that you must use an amplifier with a high open-loop gain if you intend to wind up with a reasonably high closed-loop gain.

If you start out with an amplifier that does not have a high open-loop gain, then you can only use the formula with accuracy if you are content to have a low closed-loop gain. In other words, the error increases as the closed-loop gain approaches the open-loop gain. As a practical rule, you would want a ratio of 100:1, which would give you an error of only 1 percent in your calculations. (Because most resistors have a tolerance of more than 1 percent in many practical circuits, this is acceptable. Of course, in an instrumentation amplifier or other precise application, you might want to increase the ratio, and the resulting accuracy of calculation. This is why most operational amplifiers have an open-loop gain in the hundreds of thousands.

Another important point is that the gain will depend on the ratio of the resistors used in the feedback loop, and they must be precision resistors if you expect an accurate result. You cannot simply "select" the precise value of resistor you need out of cheap composition types, because they will not have the long-term stability required. If they drift, the gain will drift, and so will the other characteristics of the closed-loop circuit. The characteristics of the circuit are no longer dependent on the characteristics of the amplifier but are now dependent on the feedback network.

To demonstrate this, here are some calculations based upon the feedback equation, and a table of results. Using the circuit of Figure 3, and assuming an open-loop gain of 10,000, put the values into the equation as shown:

$$A_{CL} = 10{,}000/[1-(-0.1\text{x}10{,}000)]$$

Notice the minus sign in front of the 0.1, which indicates that the 10 percent inverse feedback (expressed as a decimal) is a *negative number*. This indicates a *phase reversal*. Of course, when you multiply a negative by a negative, the result is a positive so look at the next step as the calculations unfold, step by step.

$$A_{CL} = 10.00/[1+(0.1\text{x}10{,}000)]$$

which leads to

$$A_{CL} = 10{,}000/(1+1000)$$

which equals 10,000/100 = 9.99 (10 with an error of one-tenth of 1 percent). Remember, it was stated earlier that the gain would be 10. How was it possible to know that? By a simple short-cut. Look at the promised tabulation of results.

Table 2
Amplifier with ten percent inverse feedback.

Open-Loop Gain	Closed-Loop Gain
10,000	9.99
1,000	9.90
100	9.09

Table 3
Amplifier with constant open-loop gain of 10,000.

Feed–back percent	Closed–Loop Gain	Divider Ratio
20	4.998	1/5
10	9.990	1/10
5	19.96	1/20
2	49.75	1/50

Table 2 demonstrates what happens if the 10 percent feedback is kept constant, but the open-loop gain of the amplifier is changed.

Ideally, with 10 percent feedback, this amplifier should have a closed-loop gain of precisely 10. It is within one-tenth of 1 percent of that ideal when the open-loop gain is 10,000. It is within 1 percent when the open-loop gain is 1000; still quite acceptable for most uses. However, when the open-loop gain drops to 100, the closed-loop gain is only 9; a significant 10 percent error from expectations. This demonstrates what we previously noted: the open-loop gain *must* be much higher than the closed-loop gain for the system to work effectively.

There is another important lesson to be learned from Table 2. Notice that if the open-loop gain drops from 10,000 to 1000, a drop in gain of 90 percent, the closed-loop gain drops less than 1 percent. This proves that the closed-loop gain is independent of gain variations in the amplifier because of time, temperature, voltage changes, etc.

Now look at Table 3, which keeps the open-loop gain constant at 10,000 but changes the percent of feedback.

Notice that when the feedback percentage is 20 percent, or one-fifth of the output, the closed-loop gain is five, and the feedback-divider ratio is 1/5. It is no coincidence that when the feedback percent is 10, the gain is 10, and the divider ratio is 1/10. When the feedback is 5 percent, or 1/20 of the output, the gain is 20, and the feedback-divider ratio is 1/20. The feedback divider ratio tells you the closed-loop gain. *Just invert the divider ratio and you have the circuit gain.*

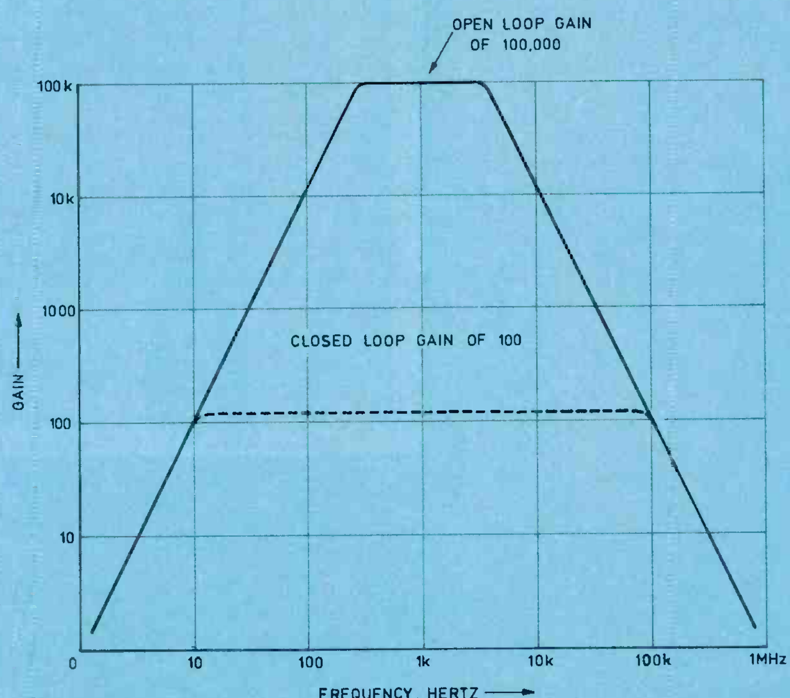
Of course, this indicates another important fact. The circuit gain may be independent of the amplifier open-loop gain drift, but it is directly dependent on the ratio of the feedback divider, so you had better use precision, high-stability resistors in your feedback networks when you repair, modify, or build feedback amplifiers.

In addition to adjusting the gain, negative feedback affects a number of other circuit parameters: frequency response, distortion, input impedance, and output impedance.

Frequency response

The graph shows a typical gain-vs.-frequency-response curve for a high-gain amplifier. Superimposed on the figure is a dotted line at some reduced gain (as might be produced by the use of inverse feedback). Notice that at reduced gain the bandwidth will increase markedly.

If you look at the data sheet for a typical operational amplifier (integrated circuit), you will find that the bandwidth with open loop is poor, but because op-amps are used with inverse feedback, the closed-loop frequency response is very good. The amount of improvement depends on how much the gain is reduced when going from open loop to closed loop. This reduction in gain is called the *Gain Reduction Factor.* If the open-loop gain is 100,000 and the closed-loop gain is 100, the gain reduction factor is 1000. This gain reduction factor is the key to the improvement in stability, bandwidth and the reduction in distortion. *The greater the gain reduction factor, the greater the improvement in performance.* (This was stated in another way earlier in the article, when it was noted that the error in calculations became significant as the open-loop gain approached the closed-loop gain; i.e. as the gain reduction factor was reduced.)



Negative feedback reduces the gain of an amplifer, but increases the bandwidth.

Input impedance

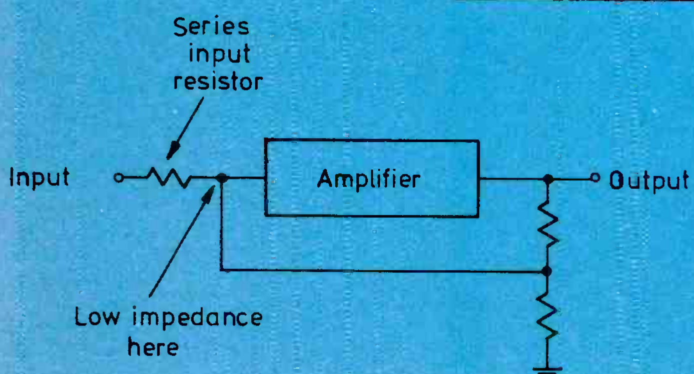
Many texts give the impression that somehow the gain of the amplifier is reduced by negative feedback. This is obviously not true. An op-amp is an IC, and nothing changes inside the IC when the loop is closed, so the gain of the IC itself does not change.

What happens is that the output signal is out of phase with the input signal. When some of the output signal is fed back into the input, *it cancels out some of the input signal.* Because the output signal is much larger than the input signal, feeding back even a small portion of it into the input is enough to almost completely cancel out the entire input signal.

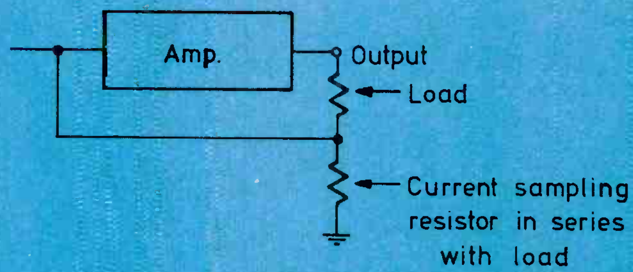
As a result, if you use an instrument to look at the input to the amplifier with the loop closed, you will see only a small signal, which approaches zero amplitude. If you have never serviced such a feedback amplifier, you could easily assume that there was no input signal and that the previous stage was defective. Not so. The system is operating properly.

Because the input to the amplifier is close to zero with the feedback loop closed, the input to the amplifier resembles a short circuit to ground, or close to zero input impedance. The previous stage is putting out a normal signal, but at the input to the amplifier, the signal appears to be "shorted" to ground. This means that the previous stage would be operating into a short circuited load, a condition that cannot be allowed.

One way to get around this problem of very low input impedance is to use a series limiting resistor between the previous stage and the amplifier, as shown here. The previous stage looks into the resistance of the series input resistor; thus the current is limited, and a short circuit input condition is avoided. This problem can be avoided in the true op-amp by having two inputs, one being used for the signal, and the other for the feedback.)



Deriving negative feedback for an amplifier using a feedback resistor in parallel with the load causes the system to appear to have low input and output impedance.



Placing the feedback resistance in series with the load makes the output appear like a constant current source and thus exhibit high output impedance.

Distortion

Distortion is reduced by approximately the same factor as the gain reduction factor. If the gain reduction factor is 100, then the distortion with open loop is reduced by about 100 times when the loop is closed. An op-amp with 10 percent distortion at a gain of 100,000 open loop would approach about 1/100 of 1 percent distortion at a closed-loop gain of 100. (Actually, because of other limiting factors, it is not possible to achieve the full reduction in distortion, but it can be approached.

Again, the gain reduction factor is the key to improvement. Negative feedback is only effective when you can use a large gain reduction factor, which in turn implies that you had better start off with an amplifier with a high open-loop gain. Because most op-amps have a high open-loop gain this is no problem, but if you entertain thoughts of improving the performance of an existing amplifier by adding (or increasing) inverse feedback, you had better be prepared for a drastic reduction gain. Sometimes this can be offset by adding a preamp stage; sometimes it is simply not practical.

Output impedance

Referring back to Figure 3, notice that the *output voltage* is sampled by means of a voltage divider. The voltage divider is in parallel with the load, and therefore has the same voltage applied to it as does the load. If it is assumed that a constant input signal is applied to the amplifier, and that the feedback does what it is supposed to do, then the output voltage will also remain constant despite variations in the load. This occurs because as variations in the load cause changes in the output voltage, these changes will be applied to the voltage divider, and the negative voltage fed back into the input of the amplifier will vary accordingly, causing the output to remain constant.

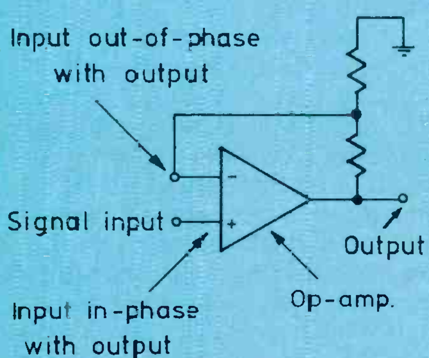
If you sample the output voltage for the inverse feedback, you will cause the output voltage to be a constant-voltage source, and you already have learned that such a constant-voltage source is a very low impedance. Thus, this method of feedback results in a very low output impedance.

What if you do not want a low output impedance? Then you can try the circuit shown here, which samples the *current* through the load. A small resistor is placed in series with the load. The load current also flows through this resistor, causing a voltage drop across the resistor *that is proportional to the load current.* In this case, the feedback tends to make the load current constant, and you have already learned that a constant-current source is a high impedance. Thus, the output of the amplifier is now a high impedance.

As pointed out earlier, feedback can be used to raise or lower the input and output impedances. It should be pointed out that sometimes it is necessary to use a high-impedance circuit to prevent loading a high-impedance source. At other times, it is necessary to use a low-impedance circuit, to be inserted in series with a low-impedance generator, in order to avoid adding impedance and upsetting the operation of the series circuit. In instrumentation there is good use for these high and low impedance amplifier circuits.

The op-amp

An op-amp is nothing but a high-gain amplifier with two inputs out of phase with each other, and a single output. This is accomplished by using a differential amplifier as the input stage. A differential amplifier has high *common mode rejection*, which makes it immune to power supply variations and power supply ripple. Now add to that the advantage of having two inputs, one for the signal, and the other for the negative feedback, and you have a versatile amplifier. By adding a few resistors as shown, you have a practical amplifier for less than a dollar and that circuit is stable, has good common mode rejection, low distortion, with any input or output impedance you desire, and any gain you desire.



An op-amp is a low cost versatile amplifier with the advantage that the input and the feedback may be isolated from one another.

Until now it has only been mentioned that you can make the frequency response of the feedback amplifier flat over a wide range (good frequency response). By putting a reactive element, such as a capacitor or inductor in the feedback network, however, the feedback loop becomes frequency sensitive and you can make a highpass, or lowpass circuit (active filter circuit). You can also combine these to form band pass and band reject filters. This emphasizes why the op-amp is considered a *universal building block* for modern electronics. Just remember, the op-amp by itself is virtually useless, only when you add the negative feedback loop does the op-amp become useful. It is the concept of negative feedback that makes the op-amp so universal. **ES&T**

Part 2

Using linear ICs

By Joseph J. Carr, CET

The first installment of this 2-part series discussed how to set the gain of inverting- and non-inverting-follower op-amp configurations. It also covered how to deal with dc offset voltages as well as how to provide frequency compensation. This installment will cover differential amplifiers and ac coupling.

Differential amplifiers

A differential amplifier produces an output voltage that is proportional to the *difference* between two input voltages, shown as V1 and V2 in Figure 1. An operational amplifier, which has inverting and non-inverting inputs, is inherently a differential amplifier. The output voltage will be A_{vd} $(V_1\text{-}V_2)$, where A_{vd} is the differential voltage gain.

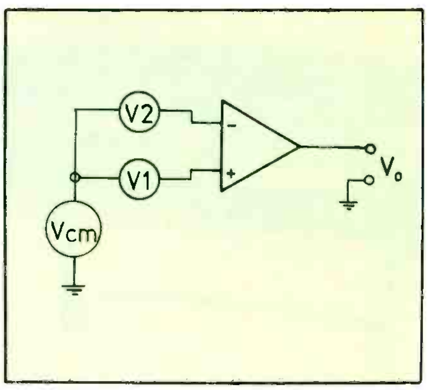
An implication of the differential amplifier is that applying equal voltages to the two inputs will cause zero output voltage. In other words, if V1 = V2, then the quantity (V1-V2) is zero. This characteristic of differential amplifiers is used to suppress interference signals. Electrical interference of 60Hz, for example, will be picked up by both input lines equally, so the net effect is zero 60Hz output signal. If the desired signal is differential in nature, then it will be amplified, while the interfering signal, which is applied equally to both inputs, is suppressed. A signal that affects both inputs equally is known as a *common-mode* signal, and is assigned the symbol V_{cm} in Figure 1. Because this common-mode signal is not amplified and does not appear at the output, it is said to be *rejected.*

The simplest form of op-amp dc differential amplifier is shown in Figure 2. This circuit uses a single operational amplifier device. The gain of this circuit is given by either R3/R1, or by R4/R2, provided that R1 = R2 and R3 = R4. The equality of those resistors, incidentally, is essential to ensure that the common-mode signal is rejected. The degree to which the circuit is successful in rejecting common-mode signals is measured by a quantity called the common-mode rejection ratio (CMRR). This value is determined by dividing the voltage gain of the amplifier for differential signals by its voltage gain for common-mode signals. CMRR = A_{vdiff}/A_{vcomm}. The higher the figure the better the rejection.

Both the practical gain and the input impedance of Figure 2 are limited for the same reasons as apply to the inverting follower circuit (A detailed explanation of this was presented in Part I, **ES&T,** November 1983). The solution to the problem is the instrumentation amplifier (IA) circuit of Figure 3. This circuit uses three operational amplifiers. Amplifier A3 is in the standard dc differential amplifier configuration per Figure 2. Amplifiers A1 and A2 are connected in the non-inverting follower configuration in order to take advantage of the extremely high input impedance. The differential voltage gain of Figure 3 is given by the product of the gains of A3 and the pair A1/A2:

$$A_{vd} = [(2R2/R1) + 1][R6/R4]$$

Figure 1. A differential amplifier produces an output voltage proportional to the difference between the two input voltages.



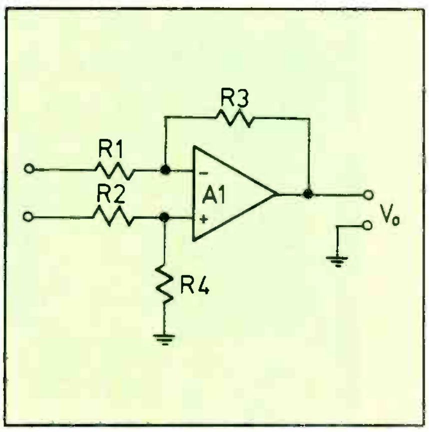
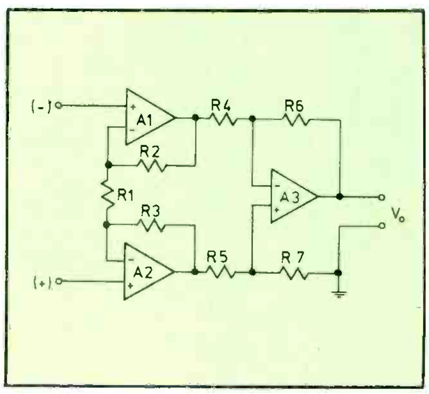


Figure 2. Simple differential amplifier is based on a single operational amplifier.

Figure 3. Instrumentation amplifier based on three op-amps overcomes gain and impedance limitations of single op-amp differential amplifier.



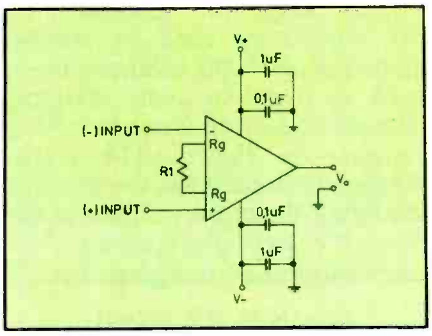
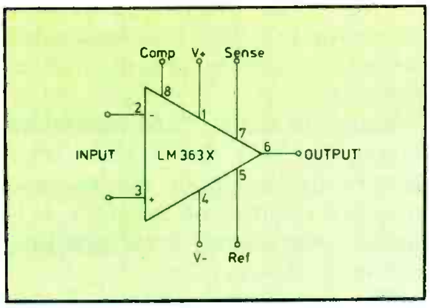


Figure 4. An ICIA contains almost all IA circuitry in a single IC package.

Figure 5. ICIAs can be obtained with a number of desired gains. This device is available with gains of 10, 100 and 500.



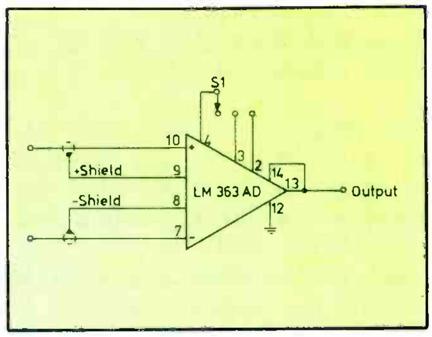


Figure 6. This ICIA has switch selectable gains of 10, 100 and 1000.

provided that R2 = R3, R4 = R5 and R6 = R7. The common mode rejection ratio depends on resistor equality. In some cases, R7 in Figure 3 (or R4 in Figure 2) is replaced with a potentiometer or a series combination of a fixed resistor and a potentiometer. These arrangements permit adjustment of the CMRR to optimize the circuit. Adjustment is as follows:

1. Short the two inputs together and connect the junction to the output of a 1kHz signal generator that produces 1V of output.
2. Monitor V_0 on an ac-coupled oscilloscope or ac voltmeter.
3. Adjust R7 for minimum output signal. Use successively more sensitive input positions on the instrument until no further improvement is possible.

For ordinary application, the resistors used can be 5 percent types, but for precise applications, 1 percent or better is required.

Resistor R1 is sometimes used for gain control. It is common practice to replace R1 with a series combination of a fixed resistor and a potentiometer. The fixed resistor is used to limit the maximum gain. If R1 goes to zero, then the gain goes to maximum.

Figure 4 shows a new form of instrumentation amplifier – the *integrated circuit instrumentation amplifier of ICIA*. Such an IC contains all of the circuitry of Figure 3, except R1. Resistor R1 is mounted externally, and is used to set the gain of the device. In almost all cases, the gain will be given by an equation of the form $(K/R_1 + 1)$, where "K" is a constant. The Burr-Brown INA-101, for example, provides a gain of

$$A_{vd} = (40/R_1) + 1$$

where A_{vd} is the differential voltage gain, and R1 is expressed in Kilohms.. The ICIA device provides a high input impedance and gains of greater than 1000 in a small IC package.

Another form of ICIA is shown in Figure 5. This device is the National Semiconductor LM-363-X. The metal-can IC provides fixed gains of 10, or 100 or 500 depending on the specific model. The gain is given in the part number: LM-363-10 provides 10, LM-363-100 provides 100 and LM-363-500 provides 500. These devices provide all of the advantages of an IA, at popular gains, in a small metal IC can.

The LM-363 is also available in a 16-pin DIP (dual-inline package) version that permits three switch-selectable differential voltage gains: 10, 100 and 1000. Figure 6 shows the LM-363AD with a switch used to select one of the three possible gains. When all three pins are open, the gain is 10. A gain of 100 is set by shorting pins 3 and 4, while a gain of 1000 is set by shorting pins 2 & 4.

The LM363AD has an interesting feature that makes it useful for many low-signal-level applications, including biomedical applications: guard-shield connections. By summing the two input signals, and applying the result to the shields of the input wiring, you can cancel problems due to differences in input capacitances. Such problems can severely affect low-level signals by causing certain common-mode signals (for example, 60Hz hum) to become differential signals. The use of the + SHIELD and – SHIELD terminals, as shown in Figure 6 overcomes this problem.

AC Coupling

The basic operational amplifier is a dc differential amplifier. This means that the amplifier will amplify signals from dc to some upper frequency limit (usually a few kilohertz to dozens of kilohertz). There are times, however, when ac coupling is needed. In the biopotentials amplifiers used in medical electronics, the signal (for example, an electrocardiogram, or ECG) may contain frequency components near dc, while at the same time producing a dc offset voltage. That dc potential, which is caused by the contact potential resulting from connecting a metal electrode to human skin, can be 2000 times larger than the peak signal amplitude. Obviously, ac coupling is needed to block that dc offset potential. For an ECG amplifier, the appropriate frequency response is 0.05Hz to 100Hz.

Figure 7 shows a method for ac coupling the instrumentation amplifier. In this case, identical capacitors are connected in series with each input. Because the bias currents normally existing on operational amplifiers will tend to charge the capacitors (thereby blocking the amplifier), we must find a way to keep them discharged. This function is accomplished by resistors R1 and R2. The lower end – 3dB point in the frequency response curve of these RC circuits is given by:

$$F = 1/2\pi RC$$

where
F = frequency in hertz
R = resistance of R1 and R2
C = value of C1 and C2.

Normally, you will know the minimum frequency and will select a value for R from input impedance and other practical considerations (10MΩ is a common choice). You will thus want to rewrite the equation as below to find C for a fixed R and selected F:

$$C = 1/2\pi FR$$

Example

Select capacitor values for C1 and C2 in Figure 7 for an ECG or EEG (electroencephalogram) amplifier with a frequency response of 0.05Hz to 100Hz.

$$C = 1/2(3.14)(0.05\text{Hz})(10^7\Omega)$$
$$C = 1/3.14\text{x}10^6$$
$$C = 0.32\mu\text{F}$$

The next larger standard capacitor is 0.33μF, so that value would be used in practical situations.

Some modern instrumentation amplifiers have field effect transistors in the input stages, and may not require the resistors. It is usually considered good practice, however, to use them.

The amplifier in Figure 7 also has output ac coupling. This is rare, but is used in some cases. The purpose of R3 is 2-fold. First, it keeps dc offsets from charging C3, and second, it provides a load for the operational amplifier.

Figure 8 shows transformer-coupling to the input of an operational amplifier. Transformers are sometimes used to receive signals from 600Ω balanced lines, such as found in audio systems. The connection to a non-inverting follower is shown. The transformer turns ratio has the effect of changing the *apparent* gain of the stage. For example, the gain of the circuit in Figure 8 is given by:

$$A_v = [N_s N_p][(R_2/R_1) + 1)$$

Be careful when selecting transformer T1. A high turns ratio will place too high a signal level on the operational amplifier input and can saturate the amplifier.

The audio characteristics of the transformer are also important. Both frequency response and phase-shift problems can occur, and the cures are costly.

You can drive a 600Ω balanced audio line with either a special output transformer or a circuit such as shown in Figure 9. Again, cost forces the use of the operational amplifier where transformers would otherwise be used. The circuit in Figure 9 uses two operational amplifiers, both of which are in the inverting follower configuration. These amplifiers are connected in cascade, so their respective output signals are 180 degrees out of phase. At normal audio frequencies, the phase delay at the output of A2 does not pose any great problem.

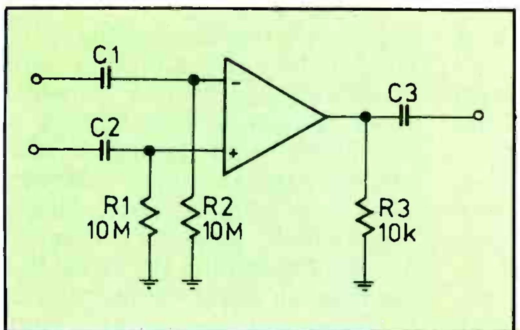


Figure 7. AC coupling blocks the dc potential input to an ECG amplifier by the human skin, which may be as high as 2000 times the peak signal amplitude.

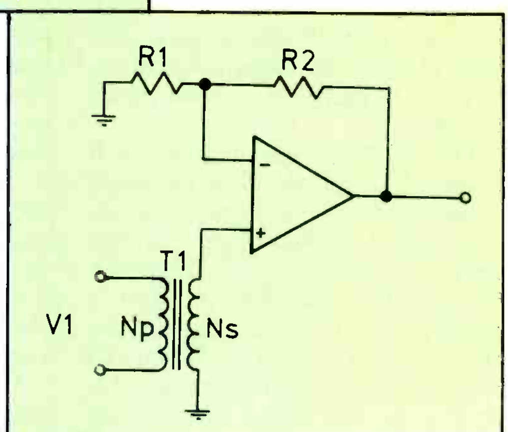


Figure 8. Transformer coupling allows op-amp to be connected to 600Ω balanced line.

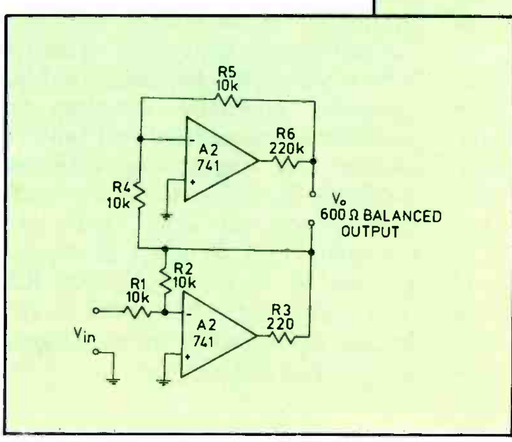


Figure 9. Another method of connecting an op-amp to a 600Ω balanced line is with a circuit such as this.

Troubleshooting op-amp circuits

Operational and IC instrumentation amplifiers have been appearing in a wide range of equipment from consumer electronics to high-priced medical/scientific instrumentation. Even in supposedly computerized instruments, there is inevitably an analog subsection at the front-end. The analog circuitry generally contains either an op-amp or an IA. Technicians in most areas of electronic servicing will at least occasionally encounter linear IC amplifiers of one sort or another.

There are several defects that can be attributed to any linear IC amplifier: It won't pass signal; it passes an attenuated or erroneous signal; it passes too much signal; and it produces a noisy output. These are the same defects that might be expected with any linear amplifier, regardless of whether or not ICs are used.

Once a defect is isolated to a particular stage by normal signal tracing methods, the next logical step will be checking the dc voltages. In most cases, there will be V+ and V− power supply voltages; typically +4.5Vdc to +18Vdc. These voltages must be present. If one is missing (or extremely low), the result will be a high output-offset potential of the opposite polarity. For example, if the V-power supply voltage is missing, then the output terminal will be at a potential close to V+. Similarly, if the V+ is missing, the output terminal will be at a voltage close to V−.

Whenever the op-amp (and most IAs) fail to produce a proper output, the principal question is whether the input terminals are *capable of controlling the output signal.* For most circuits, the main test will be to set the input potential to zero and observe whether the output voltage goes to zero. You can do this by shorting the (+) and (−) inputs together. If the operational amplifier is working properly, and if both V+ and V− power supply potentials are normal, then shorting the input terminals together should make $V_O = 0$. If not, then you can assume that the device is bad.

Be careful when using the above dc troubleshooting protocol, however. First, you must evaluate the circuit to determine that no harm will result from shorting the input pins together. Of particular interest are preceding outputs that may not tolerate grounding, and succeeding cascade circuits (for example, certain power transistor circuits) that require some normal dc offset to remain in control. Second, be certain that you are dealing with either an operational amplifier or an IA. There are some special purpose IC linear amplifiers that are neither op-amps nor IA. Some of those will not tolerate input shorts. Also a caution, but one that should not need mention, is that you should be *sure* that it is the input pins that are being shorted together. Shorting other combinations can result in destruction of the IC.

Noise can be a particularly difficult troubleshooting problem. Only in a few cases will noise within the IC produce changes in the dc potentials on the pins. Sometimes, noise within the device will produce output offset voltage shifts (which can be viewed on an oscilloscope), but the noise problem often is transparent with respect to the dc terminal voltages.

Fortunately, most causes of internal noise in any linear IC are sensitive to temperature changes. The use of both freeze mist spray and heat can work wonders in locating the defective IC. Although linear IC devices provide immense amounts of circuitry in a small space, they hold only a few surprises for the skilled troubleshooter. ES&T

Readers' Exchange

For sale: B&K model 1077B TV analyst, $395; B&K model 2040 CB signal generator and B&K model 1040 CB service master, $299 for both. All equipment with leads and factory operation manual, schematics and parts lists. *Goetsch Electronic Servicing, 12698 Shorewood Drive S.W., Seattle, WA 98146; 206-241-0507.*

For sale: Model 460 Eico scope, barely used, with probes, $130 plus freight. *R. Faircloth, 7801 S.W. 129th Terrace, Miami, FL 33156; 305-251-2856.*

Needed: Schematic and manual for Knight R-100A receiver. *Leroy F. Jones, 1600 W. 3rd, Lee's Summit, MO 64063.*

For sale: B&K 1076 TV analyst with book and cables, $200; B&K 415 sweep marker generator for TV/FM with book and cables, $300; Beltron I CRT restorer/rejuvenator with extra adapters, books, etc., $200. *John Rysso, 1057 Big Pine Drive, Santa Maria, CA 93454; 805-925-8773.*

Wanted: VA48 analyzer, including cables and manual. Will pay $625 C.O.D. if in excellent condition. *Walt Sattler, 512 S. Lynch, Flint, MI 48503; 313-238-3538.*

For sale: B&K model 470 picture tube tester with adapters, $200; Tektronix model 281 dual trace oscilloscope, $800; Astar desoldering station model DS707, $200. *W. A. Frederickson, 3103 W. 12th Ave. Court, Broomfield, CO 80020.*

Needed: Cassette motor and pulley for an Audiotronics cassette player/recorder model 148B, or manufacturer's address. *Ray Welborn, Welborn Radio & TV Service, 522 Ellisville Blvd., Laurel, MS 39440.*

Needed: Sears technical manual/schematic for model 800.20210400 AM/FM clock radio. Will buy or copy and return. *Charles E. Norris, TV-Radio Service, Box 105, Airedele Road, Ridge, MD 20680.*

Needed: Service manual for Spectro Acoustics Amp model 200 SR. Will pay expenses or reasonable cost. *Mr. Dujaric, 661 W. 180th St., New York, NY 10033.*

Needed: Schematics for Lectrotech Inc. vectorscope, model V-7; and Sanyo color television, model 90C33U. Will pay expenses or reasonable cost. *Leslie O. Robensin, 4662 Esther St., San Diego, CA 92115.*

For sale: Howard W. Sams Photofacts 1-1000, including two file cabinets, $900. *Carl Cowan, 566 Rife St., Chambersburg, PA 17201; 717-264-2043.*

Needed: Self-study courses, books, projects, etc. Must be complete and in good condition. Please send full details in first letter. *Ewing A. Allmon, P.O. Box 2421, Lawton, OK 73501.*

For sale: 1072 new radio-TV tubes, all types and hard-to-find. SASE for list. Complete lot, $600 prepaid. *F. Keylor, 821 Court St., Auburn, ME 04210.*

For sale: Sencore CB 41 and CB 42 test equipment, like-new condition, including all leads and manuals, $525 plus UPS. *Martin Major, 15810 Sapwood St., Tampa, FL 33624.*

For sale: TV and stereo test equipment and service data; B&K 1077B analyst, $230; Sylvania CK 3030 color jig with 40 "D" adapters, $350; send SASE for list. *John D. Badovinac, 6894 Elmhurst Drive, San Diego, CA 92120; 619-582-1820.*

For sale: Heath IT5235 yoke/flyback tester with H.V. probe and all manuals, excellent condition, $75; Heath IM5218 V.T.V.M. in excellent condition, $50; Hitachi V-209 portable dual trace 20MHz scope. Like new with probes and tech and operating manuals, $600. *Neil Sherwood, 2352 Danby Road, Willseyville, NY 13864; 607-256-4951.*

Needed: New or good used 370AUB22, also Philco IC E.C.G. 782. *Jerome Rosenblatt, 2063 E. 56th St., Brooklyn, NY 11234.*

Needed: Schematic for a Code-a-phone, Diplomat-2, serial number 001912, KWF Industries, Portland, OR. *Daniel E. Barlow Sr., 3327 La Junta Ave., San Diego, CA 92117.*

Needed: Schematic for stereo receiver Sansui model G-4500. *Jesús Rivera, Muñoz Rivera #49, Barranquitas, Puerto Rico 00618.*

For sale: B&K sweep marker generator model 415; B&K TV analyst model 1077-B. Both used only once, new condition. Make offer. *William J. Maida, 341 Isabella Drive, Longwood, FL 32750.*

For sale: Hewlett Packard oscillator 200CD and 202C, $35 each; Hewlett Packard function generator 202A, $39; Esterline Angus Speed Servo chart recorder, $42. *Frederick Jones, 407 Morningbird Court, Niceville, FL 32578.*

For sale: B&K scope model 1461, 10MHz, solid state, triggered sweep, like new with manual and extra new probe, $225 includes UPS prepaid; Dage CM-6 digital capacitor meter with manual, $45. *Robert L. Soyars, 711 W. Walnut St., Johnson City, TN 37601; 615-928-8224.*

For sale: Lampkin 107C communications service monitor, excellent condition. Best offer. *John Sannino, 62 Holly Hills Drive, Somers Point, NJ 08244.*

For sale: B&K 415 sweep marker generator with all probes and books, never used, $107.50; used Cal-Rad autotransformer, 0-130V output, 115V, 5amp input. *Peter Daley, Daley's TV & Communications, 305 North St., Rt. 2, Box 34, Preston, MN 55965; 507-765-2572.*

For sale: Test equipment, latest from Sencore. Like new condition, retiring from business. *Dells, 192 Magothy Beach Road, Pasadena, MD 21122.*

Needed: Construction manual for Electronics Measurements Corporation model 801 resistance capacitance bridge and in circuit capacitance checker. Will pay $5 for manual. *Max Emerson, 1923 N. Texas, Weslaco, TX 78596; 512-968-3913.*

For sale: Sencore FC51 frequency counter with WBA 52, like new, $650. *Steve Hamilton, 3746 S. Peoria, Tulsa, OK 74105.*

For sale: Sencore FE20 F.E.T. multimeter (portable); Sencore FE160 F.E.T. multimeter (bench type); or Sencore FS134 fieldstrength meter, $50 each. *Ken Stoll, 119½* W. Pacific, Branson, MO 65616; 417-334-0027.

Needed: Schematic, service manual and operating instructions for Bliley electric crystal controlled oscillator model IA. Will buy or copy and return. *Robert J. Blackwell, 2925 Riggs Ave., Baltimore, MD 21216; 212-362-6678.*

For sale: R.C.A. Junior volt Ohmyst manual and probes, $25; Eico sine and square generator model 377 and manual, $25; Panasonic FM stereo pack model CV951VA, $10. *Al Crispo, 3225 Chipmunk Drive, New Port Richey, FL 33552.*

For sale: Sencore VA48 model TV-VTR-MATV and video analyzer, one year old, $1000; Sencore SC61 waveform analyzer, used four months, $2400. *Beals TV Repair, Rt. 1, Box 43, Mason, IL 62443; 618-483-5295.*

Needed: Schematic for Sears model 132.91931800 AM/FM radio-phono and tape player. Will buy or send copy and I will pay for copy plus postage. *M. W. Smith, 400 Brandon Road, Richmond, VA 23224.*

Needed: Schematic or address for ECG med-scope model CS-25 made by Burdick Corporation, Milton, WI. *Patrick Wells C.E.T., 449 S. Canyon Drive, Redmond, OR 97756.*

Needed: Service manual and schematic for Pilot AM/FM stereo receiver model 5000. Will buy or copy and return. *Jerome Kennedy, 4217 S. 16th Road, Arlington, VA 22204.*

Wanted: Any early radio-TV literature or ads, etc. by high school student making study of radio. Originals or copies appreciated. *D. Mark Maurer, 2352 Grace Ave., Lebanon, PA 17042.*

For sale: B&K capacitor checker, $75; Eico flyback/yoke tester, $50. *Stan Hayman, 19707 Turnberry Way, Miami Beach, FL 33180; 305-944-5674.*

Needed: Owner's manual for a Conar model 250 scope. *Joseph Farkas, 283 Avenue B, Palmerton, PA 18071; 215-826-2698.*

Needed: Service manual for Pioneer AM/FM tuner amplifier combination, model SX-600T. Will copy and return. *John L. Wingfield, P.O. Box 685, Cedaredge, CO 81413; 303-856-6341.*

For sale: Sencore VA-48 analyzer, excellent condition, $800; Sencore CG 169 deluxe color generator, $60; Heathkit sweep generator 1G-5257, $60; 170 Sams 793-1931; $150. *Henry Price, 640 Cambrian Court, Sacramento, CA 95825; 916-481-2418.*

Needed: Heath model SM-2420, or SM-4130 frequency counter or similar model, EMC model 802 signal tracer/generator. *Caswell Davis Jr., 601 Delmar, Apt. 2, San Antonio, TX 78210; 512-532-9378.*

For sale: Dentron model MLH-2500 linear amplifier, $475; Kenwood model TR-9000 2-meter FM all mode transceiver, $300; Kenwood model PS-20 regulator power supply, 4.5A, $50. *William D. Shevtchuk, One Lois Ave., Clifton, NJ 07014; 201-471-3798.*

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Circle (21) on Reply Card

More about π in electronics equations

By Sam Wilson, ISCET test director

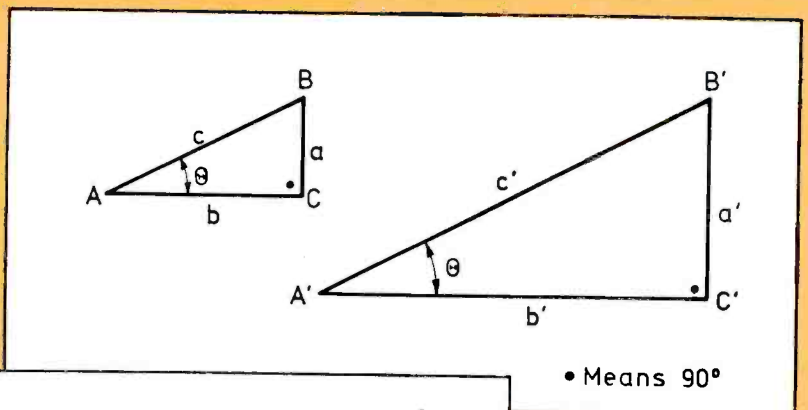

Figure 1

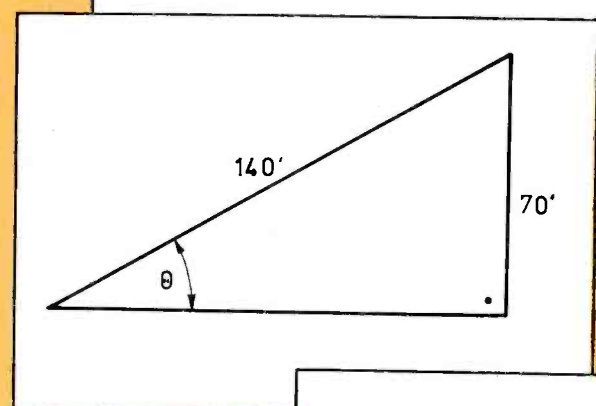

Figure 2

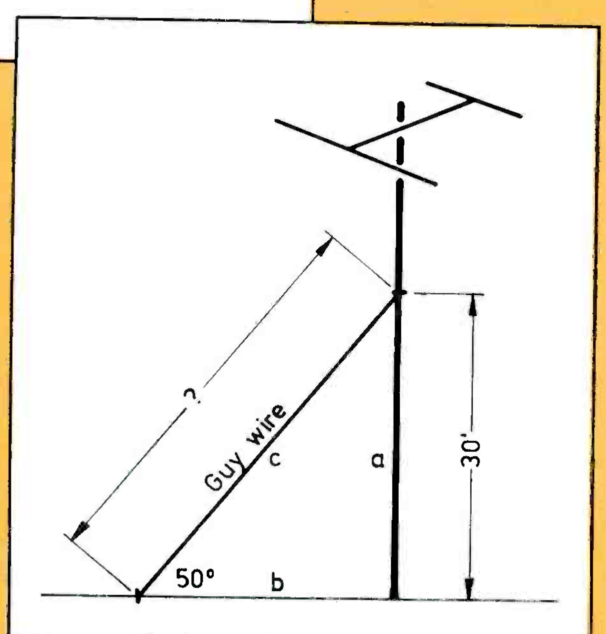

Figure 3

In his book, *The History of π*, author Petr Beckmann traces the development of the mathematical concepts of π from 2000 B.C. up to recent times. He shows that the development of mathematics coincides closely with the accuracy to which π can be stated.

In the earliest days, the value of π was given as being about 3¼. Great mathematicians later calculated π with greater accuracy. You should know that π is an irrational number, meaning that it can never be expressed as a ratio of two integers. Other examples of irrational numbers are the square root of 2 and epsilon.

The book leaves off at a point where the value of π had been calculated to 500,000 decimal places. However, since the book was written, a Japanese computer expert has calculated the value to *4 million places.* It's hard to imagine that in 4 million places the number never comes out even, and worse yet, there is no pattern of repetition for the numbers in the decimal places.

The area of a circle is calculated by the equation:

$$A = \pi r^2$$

where
A = area
r = radius of the circle

It follows that the area can never be known exactly because the value of π is not known exactly. You could use the value of π to 4 million decimal places, and that would certainly satisfy most people, but there is always another decimal to follow and one more after that, and after that, etc.

People who study irrational numbers for the first time are sometimes put off by the fact that the values don't come out exactly even. This is especially true in electronics because π is used in so many equations. However, keep in mind that values of equations with π can be *calculated* more precisely than they can be *measured* with present day equipment. For example, there would be little use in calculating the inductive reactance of a circuit using π to 4 million decimal places because we have no equipment that could measure it to that accuracy.

Microcourse in trigonometry

I believe that mathematical concepts are best introduced when they are *needed* for solving problems. It is necessary now to define the sine – usually written sin – of an angle before proceeding with the understanding of how π gets into so many electronic equations.

Figure 1 shows two right triangles that are defined as being *similar*. (A right triangle is one that has a "right" or 90-degree angle as one of its angles.) Similar triangles have identical angles but not necessarily identical lengths of sides. (When the lengths of the sides as well as the angles are identical, then the triangles are said to be *congruent*.)

When triangles are similar, the ratios of the sides are constant and equal. Of specific interest in Figure 1, a/c is defined as the ratio of those two sides. Because the triangles are similar:

$$a/c = a'/c'$$

In fact, no matter how many different sizes of right triangles you draw with the angles being equal, the ratio of sides marked a/c would be the same. That is an important point to remember because that ratio – a/c – *is called the sine of angle* Θ (the Greek letter, theta).

Equation 1. $\sin\Theta = a/c$

In the early days of mathematics, you could consult a table to find the sine of an angle. In such a table, you would find, for example, the sin 30° = 0.5. That is not surprising because in a right triangle the side opposite the 30° angle is always equal to one-half the hypotenuse. (The hypotenuse is the longest side of the right triangle, the side opposite the right angle.) The ratio of the side opposite the 30° angle to the hypotenuse is 0.5 in a right triangle that has an angle (Θ) of 30°.

The table of sines includes the ratios for every possible angle that you would ever want to know. Today, the math tables have been replaced by a scientific calculator. All you have to do is punch in the numbers for the angle, then punch the sin button. The calculator will tell you the sine of the angle.

If you punch in the number 59 (for 59°), then punch sin for the sine of that angle, you will find that sin 59° = 0.857 to three decimal places. Your calculator will no doubt carry the value much further. If you divide the side opposite the 59° angle by the hypotenuse you will find that the ratio is 0.857+.

Two other forms of Equation 1 are:

Equation 2. $c = a/\sin\Theta$
Equation 3. $a = c\sin\Theta$

Two simple problems will be used to show how the sine of an angle can be used in making calculations.

Sample problem #1

Figure 2 shows a right triangle with an angle Θ. The side opposite Θ is 70-feet long and the hypotenuse is 140-feet long. What is the value of the angle marked Θ?

Solution

$$\sin\Theta = 70/140 = 0.5$$

What you have shown by working with Equation 1 is that the sine of the angle is 0.5. What you really want to know, though, is the angle, not the sine of the angle. To obtain the angle, you use the arc sign, or inv sin (for inverse sin) on your calculator (or look up the value in a table). This is sometimes written with the symbol $\sin^{-1}$.

Equation 4. $\Theta = \sin^{-1} a/b$

In the problem you just worked, you would have to use the equation:

$$\Theta = \sin^{-1} 70/140 = \sin^{-1} 0.5 = 30°$$

Sample problem #2

The problem just worked shows that you can find the angle if you know two sides in a right triangle. Now look at a second problem using the sine of an angle. Figure 3 shows an antenna that you are mounting on a roof. You wish to have the guy wire mounted at 30 feet, and you want it to make an angle of 50° with the roof. How long should you cut the guy wire? (Do not allow extra length for fastening the guy wire in this problem.)

Solution

Use Equation 2 to find the value of the hypotenuse (the length of the guy wire). You should know the length of "a" is 30 feet. Also, you know the angle of Θ is 50°. So, you can write (from Equation 2)

$$c = a/\sin\Theta = 30\text{ feet}/\sin 50° = 30\text{ feet}/0.766 = 39+\text{ feet}$$

Now that you have had this microcourse in trigonometry it is possible to return to the problem of why π appears in so many equations.

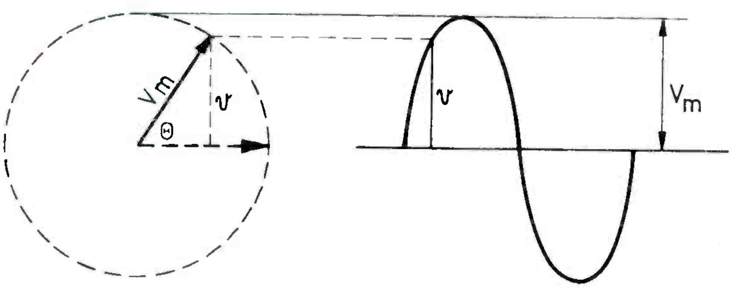

Figure 4

Sample Problem #3

The general equation for a certain sine wave voltage is

$$v = 75 \sin 377t$$

Using this equation calculate the following:

- Maximum (or peak) voltage
- Frequency of the sine wave
- Average value of the sine wave
- rms value of the sine wave

Solution

The maximum value of the sine wave is given by the equation itself.

$$v = V_m \sin 2\pi ft$$
$$v = 75 \sin 377t$$

Look at the original equation, and look at the equation for this problem. You will see that 75 must be the value of V_m because it is the coefficient of the sine of 377t.

To calculate the frequency, look again at the equations. Note that the value of omega is 377.

$$\omega = 2\pi f = 377$$

Divide both sides of the equation by 2π.

$$377/2\pi$$

so,

$$f = 377/2\pi = 60\text{Hz}$$

Equating the voltage at any instant for a pure sine wave

In the last issue of **ES&T**, we showed how a sine wave voltage can be represented by a rotating phasor. In Figure 4 the phasor marked V_m is rotated counterclockwise to produce the sine wave. The maximum or peak voltage of the sine wave is V_m. Also, the radius of the circle described by the phasor is V_m. Note that Θ shows the angle to which the phasor has moved and v shows the value of the projected voltage at any instant. Standard symbols are used here. The capital letters are used for constant values and lower-case letters are used for variable values.

An equation for the voltage at any instant is:

Equation 5. $v = V_m \sin\Theta$

Note that this is simply another way of writing Equation 3.

Equation 5 shows a general equation for a sine wave voltage, and a method of calculating that voltage at any instant. However, you are unlikely to know the angle theta in degrees. If theta is expressed in radians, you can write the angle as ωt, or, $2\pi ft$. Remember that ω (omega) is the angular velocity of the phasor. The angle at any time is equal to the angular velocity times the time:

$$\Theta = 2\pi ft$$

Substituting ωt in Equation 5, the general equation for a sine wave voltage becomes:

$$v = V_m \sin 2\pi ft \text{ or}$$

Equation 6. $v = V_m \sin \omega t$

The term ωt is actually the angle in radians, and you must use the radian notation on your calculator. If you don't have radians on your calculator, you can always convert degrees into radians or radians into degrees using these basic equations:

Degrees = Radians x 57.3

or

Radians = Degrees/57.3

You can get a lot of information out of Equation 6. The following example will show a few ways in which the equation will reveal characteristics of a given sine wave.

The average value and the rms values are calculated from the fact that the peak value is known. There some tricks for getting greater accuracy for these values.

Usually the average value is calculated from the equation:

$$V_{avg} = 0.636V_m$$

If you have a scientific calculator, you can get a more accurate average value by using the equation:

$$V_{avg} = 2/\pi\ V_m$$

For this problem

$$V_{avg} = 2/\pi \times 75 = 47.746V$$

the usual method of calculating the rms value is to use the equation:

$$V = 0.707\ V_m$$

With a scientific calculator, you can get greater accuracy by using the equation:

$$V = V_m/\sqrt{2} \text{ or } V = 1/\sqrt{2}V_m$$

Theory "purists" will object to the radical in the denominator and insist the equation be written:

$$V = (\sqrt{2}/2)V_m$$

For this problem

$$V = V_m/\sqrt{2} = 75/\sqrt{2} = 53.033V$$

(continued from page 20)

the path from the sampling gate back toward the original signal source. Either the source is incorrect, or a defect in a stage between the source and the gate is removing or degrading the signal.

After the approximate area of suspicion is identified, a series of power-off tests should be made in-circuit. These should include resistance checks, diode and transistor junction tests (Figure 10), and visual inspections.

Because of danger to transistors and ICs, power-on tests should not be made unless all others fail. If you are forced to perform power-on tests, use the insulated-hook type of probe, turning off the power before the connection is made, turning on the power only long enough to make the tests, and then turning off the power before disconnecting the test probe.

After repairs are made, repeat the playback test using an expendable tape, and then attempt to record and play back another work tape. Do not insert a new cassette or an expensive test tape until after you have *proved* the machine does not ruin tapes.

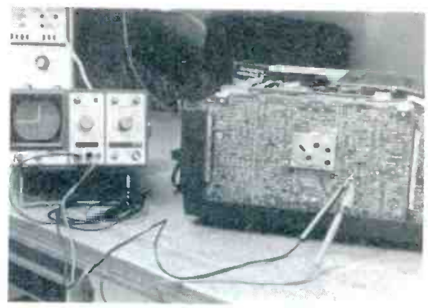

Figure 10. A scope or other instrument that tests capacitors and diodes by the current-versus-voltage method can be used for rapid in-circuit tests to find defective components. A Hameg scope is shown.

It is likely the machine needs head cleaning and routine lubrication, which should be done before the final tests. When the VCR is considered finished, carefully examine the picture quality and stability of your expensive standard test tape when viewed on a well-adjusted color receiver. Observing this sequence can minimize damage to your work tapes and prevent all damage to the expensive standard tapes, while reducing the number of unprofitable callbacks. ES&T

Literature

A 36-page 2-color catalog from *Hamtronics, Inc.* features many new products, including an expanded line of FM repeaters and accessories such as power amplifiers, DTMF tone decoder/controllers, and autopatches. FM and AM receivers, FM transmitters, VHF and UHF transmitting and receiving converters, space shuttle receivers, 800MHz scanner converters and preamps are also included.

Circle (60) on Reply Card

A wide range of connector products, designed to help customers meet EMI/RFI requirements, including FCC Docket 20780, are detailed in a 16-page catalog published by *ITT Cannon.* Catalog FCC-1 provides product descriptions, performance characteristics, electrical data, contact arrangements, mounting and terminations, assembly data and tips on how to select and order the proper connector and "black box" for your EMI/RFI requirements.

Circle (61) on Reply Card

A 12-page bulletin from *Superior Electric Company* gives complete specifications and ratings on the company's 5-way binding posts, supercon electrical connectors and 5-way test probes. Bulletin EC779-1 contains a detailed description of the new limited opening binding posts that are recognized components per UL Standard 1244 and are designed to prevent accidental contact with current carrying parts. Standard hex and fluted nut, miniature fluted nut and double assembly types are offered.

The Supercon Electrical Connector section describes panel board plugs and receptacles having 25, 50, 100 and 250A capacities. The plugs have a positive grip design, and all are available in nylon plastic in six colors. Also described are 5-way test probes for making fast, positive connections to PC boards and components. Their design permits plug-in, hook-on or touch contact connections.

Circle (62) on Reply Card

Answers to quiz

(from page 8)

1. *A* The output of the AND gate will always be logic 0. The inverter changes that output to logic 1. Due to the propagation delay of the inverter at the AND input there may be a glitch in the output.
2. *A* In hexadecimal numbers, 1110 is E and 1101 is D.
3. *C* When the input signal is a sine wave, the output signal should also be a sine wave. The two signals are 180 degrees out of phase. The lissajous pattern should be a straight line. This test is used to determine if the amplifier is distorting the signal.
4. *B* When the voltage drops are equal, $R = X_C$. Because $X_C = 1/2\pi fC$, it follows that $R = 1/2\pi fC$.
5. *C* The equation Q = CV is important for understanding basic capacitor theory.
6. *C*
7. *D* The Ω/V rating is the reciprocal of the full-scale deflection.
8. *B*
9. *D*
10. *A*

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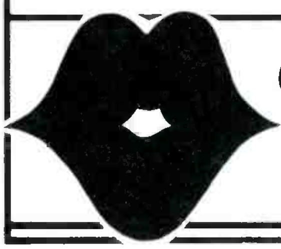

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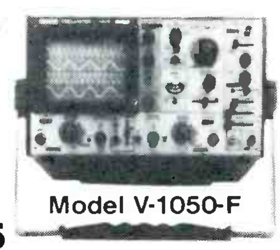

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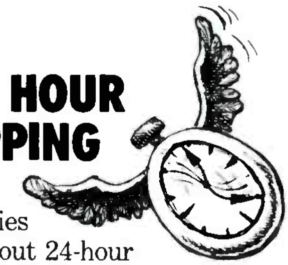

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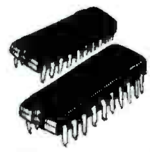

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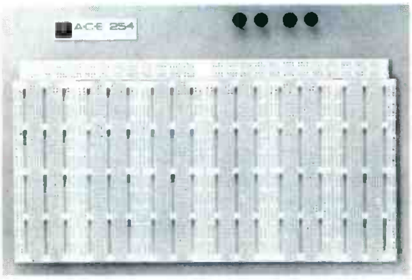
Circle (25) on Reply Card

Products

All-circuit evaluators

AP Products has expanded its line of all circuit evaluators in response to requests for breadboards that can accommodate larger testing and prototyping projects.



The ACE 245 features a universal matrix of 4488 solderless plug-in tie-points, and is composed of 640 separate 5-tie-point terminals, 40 vertical distribution buses, and 4 horizontal buses.

For larger projects, the ACE 254 combines the plug-in ease of a 0.1" x 0.1" solderless matrix with the convenience of 768 separate distribution buses of 5-tie-points each, plus 4 horizontal buses.

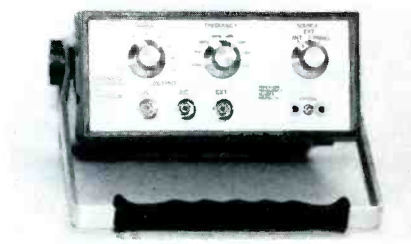
Circle (70) on Reply Card

Frequency source

A low-cost, portable precision frequency source that is battery powered for absolute line isolation is available from *Technical Novations*. The model 130 has high stability and accuracy with a total of 58 discrete frequencies between 4MHz and 0.008Hz and provides both decade and binary division of its 4MHz crystal oscillator. Provisions are included to use an external crystal or use the decade/binary dividers only with an external signal input. Calibration is traceable to the National Bureau of Standards.

The instrument requires no warm-up to reach rated accuracy. It is powered by rechargeable ni-cd batteries. A wall-plug-type transformer is included for recharging.

Calibration applications include oscilloscope time base, plotter and X/Y recorders, radio receiving equipment and frequency to voltage converting equipment. Testing and measuring applications include pulse rate converter

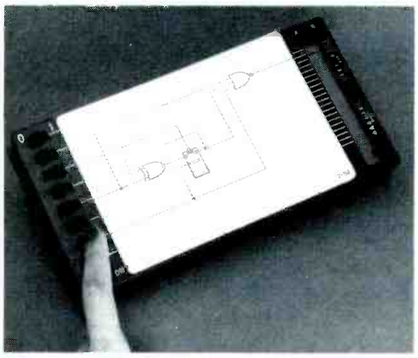


systems, frequency counting and measuring equipment, filter response evaluation and as a variable clock for use with microcomputer and microprocessor systems.

Circle (71) on Reply Card

Logic trainer

The Logic Trainer Model 100 from *L. J. Broder Enterprises* is a device for fast, straightforward learning of digital circuits. No prior training is required. Read the self-paced manual and become familiar with several digital components. Solve the applicable trainer problems for retention and understanding. Then repeat this process with additional devices. No IC or wire manipulation is required. Boolean algebra (a design aid) is not part of the basic course. The logic trainer may be used for



testing, training, and upgrading the performance of troubleshooters.

Solving the trainer problems requires manipulating the input logic states to produce a logic "1" at the output (a bar will appear on the LCD). The portable unit covers gates, flip-flops, transistors, relay logic and commonly used circuits.

Circle (72) on Reply Card

Test prods and patch cords

A line of test prods and patch cords featuring solderless crimp-on connections for strain relief and long life has been introduced by *E. F. Johnson Company.* The line is comprised of 154 different combinations of interconnects, colors and lengths that conform to the latest UL and ANSI safety standards.

The test prods have molded flanges for protection against electrical shock, anti-slip ribs for better grip, and tips that are threaded to accept spade lugs or alligator clips. The meter input end of the test prods have shrouded standard banana plugs for maximum protection, and tapered back ends and anti-slip ribs for a good gripping surface. They are insert-molded to provide a reliable integrated unit.

The patch cords are available hook-to-hook, hook-to-standard banana plug, hook-to-miniature banana plug, hook-to-bare wire, standard banana plug-to-standard banana plug, or alligator clip-to-alligator clip. The hooks have plunger-type action with stainless steel springs and contacts of beryllium copper and gold plate for low resistance. They hook securely to lead sizes up to .040-inch diameter and slide onto the .025-inch square posts.

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Troubleshooting course

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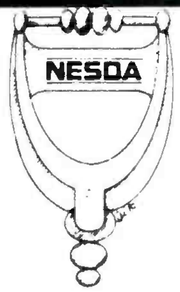

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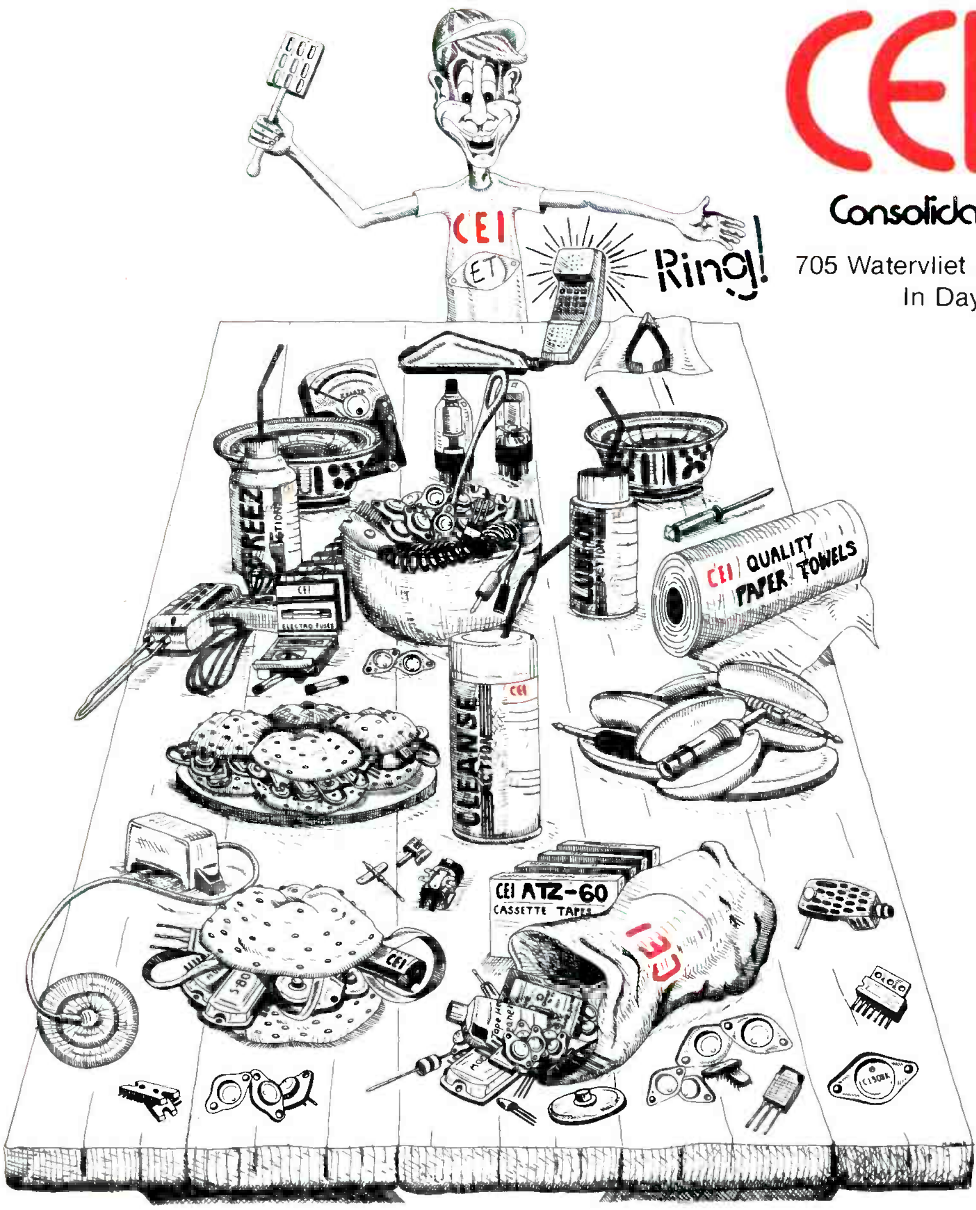

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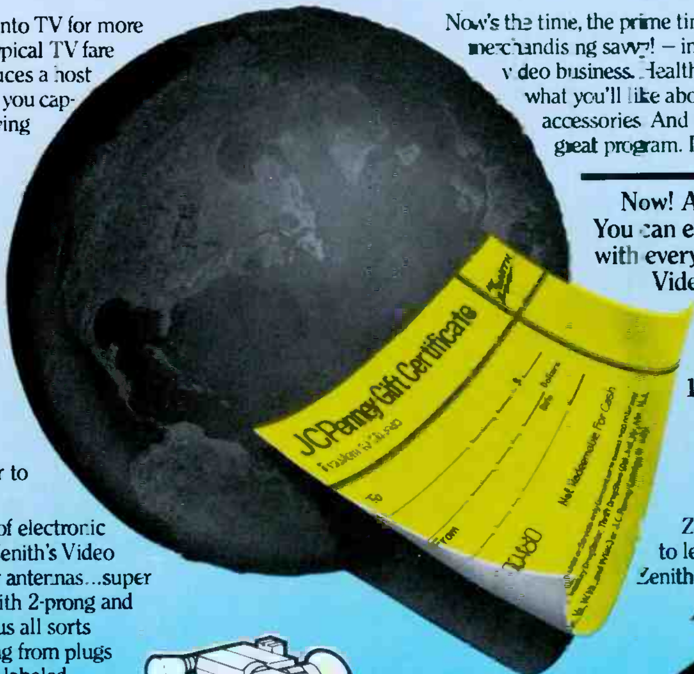

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