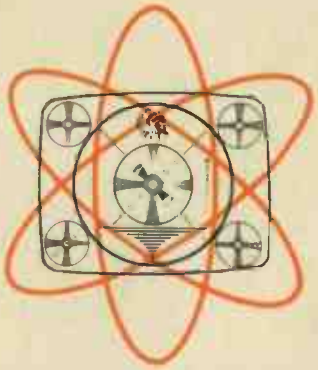
PRACTICAL TRAINING MANUAL



TELEVISION SERIES

VOLUME 1

BASIC TELEVISION

ED-21

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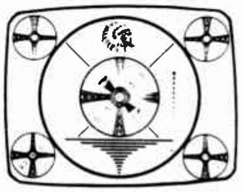

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BASIC TELEVISION

ED-21

FIRST EDITION—FIRST PRINTING—OCTOBER, 1955

RETMA
MEMBER

LITHO IN U.S.A.

PRINTED IN U.S.A.

PREFACE

The ever-increasing need for trained technicians in all phases of the electronics industry, has motivated the preparation of this Basic Television Manual.

Instructors, school authorities and students have asked for a simple, yet well-planned manual, to be used in the study of television. Fundamental training is essential, regardless of the student's plans after graduation.

This manual has been prepared from sets of lecture, shop and classroom material used successfully by one of the largest trade schools in the country for the training of thousands of students. It embodies the latest techniques of the electronics industry.

The first portion of the manual is separated into twenty-four lessons, each covering a basic phase of the study of television, permitting effective planing for a course of instruction. The second portion contains suggested projects correlated to the Lesson Section.

Differing schedules, class time and curriculum demands will result in individual application of the material. Our purpose is to provide a complete, modern work, from which can be taken the information needed to make efficient use of training time.

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TABLE OF CONTENTS

COMMERCIAL CATHODE-RAY OSCILLOSCOPES

Objective:

To study the construction and operation of the cathode-ray oscilloscope for radio and television servicing.

References:

Lesson Content

A. General

The oscilloscope is used in many fields of electronics; however, in this lesson we are primarily concerned with the instrument only as it pertains to uses in the radio-television servicing field.

It is significant that many of the circuits used in oscilloscopes are also used in television sets. Also, the controls on oscilloscopes are similar to controls on television sets. So as you study the oscilloscopes you are in reality also learning many technical facts that apply to TV sets.

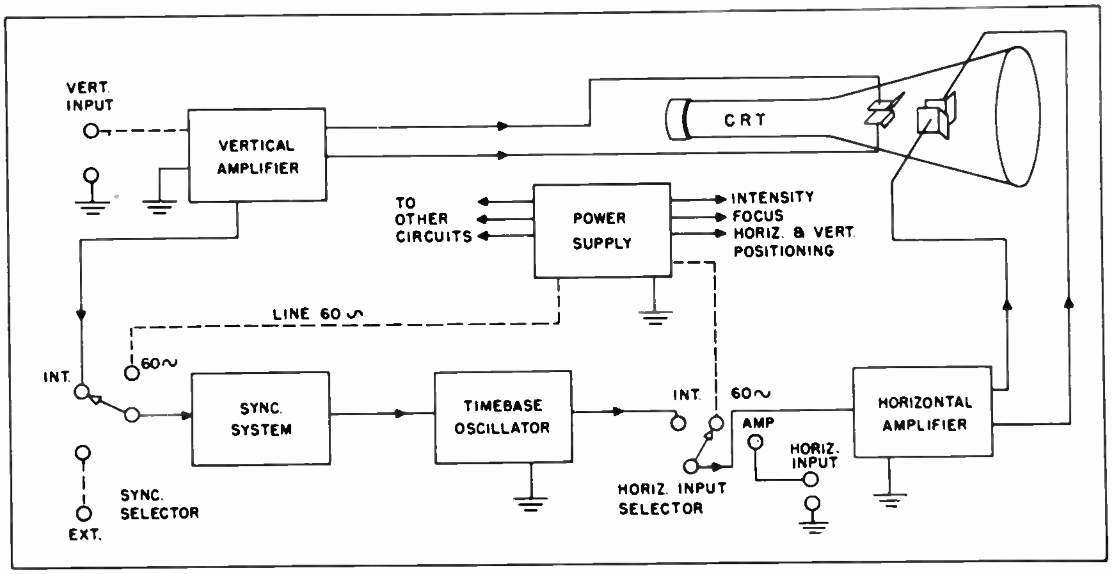


Fig. 1. Block Diagram of a Basic Oscilloscope.

The type of oscilloscope shown in the block diagram of Fig. 1, has a cathode-ray tube with its own power supply, vertical and horizontal amplifiers, vertical and horizontal deflection plates, and a linear (saw-tooth oscillator) circuit.

In addition to the above mentioned oscilloscope it is also desirable to have a sweep generator and maker for visual alignment of FM and television receivers. Separate units may be used in conjunction with the oscilloscope to accomplish the same purpose. Some of the higher priced oscilloscopes have these units built within the oscilloscope.

B. Cathode-Ray Tubes for the Oscilloscope

The cathode-ray tubes in commercial oscilloscopes differ in size of the viewing screen, sensitivity, and voltage ratings. They may be classified as low voltage types having a slight argon gas content, and having the cathode as part of the filament structure; or the high voltage type having a high vacuum, without gas, and the cathode is a separate structure. The latter type is more commonly used in oscilloscopes. Fig. 2 shows the construction of a typical cathode-ray tube.

The screen of the cathode ray tube emits light due to the bombardment of the electrons striking the screen. The screen is a fluorescent material coated on the inside of the tube. Common screen sizes are 3", 5", 7",etc. The 5" screen is commonly used in commercial oscilloscopes because it reproduces a fair size image or pattern to be studied. It is also easy on the eyes. The type of the tube screen material is indicated in the tube nomenclature (language of television) as follows:

1. The first number whether one or two digits, will represent the diameter of the screen.
2. The letter P and the number following it will indicate the type of fluorescent screen that the cathode ray tube contains.
3. Any additional letter found between the first number and letter P will distinguish between tubes that may have screens of equal size but which possess other differing characteristics.

Table I shows a list of the "P" numbers and their meanings. To illustrate tube nomemclature (language and description), let us consider a 5BP4 oscilloscope. The figure 5 indicates a 5 inch diameter screen; the P4 as in Table I is white; and the B distinguishes between this tube and other 5P4 tubes such as 5EP4 and 5FP4.

TABLE I

RETMA Designation, Substance	Activator	Fluorescent Color	Phosphorescence (seconds)
P1 — Zinc Silicate	Manganese	Green	Med. -0.03 — 0.05
P2 — Zinc Sulphide	Copper	Blue-Green	Long
P3 — Zinc Beryllium-Silicate Manganese	Manganese	Yellow-Green	Med. -0.05
P4 — P3 and Zinc Sulphite	Silver	White	Short 0.005
P5 — Calcium Tungstate		Blue	Very Short — 5 μsec
P6 — Zinc Sulphite, Zinc Cadmium Sulphite	Silver	White	
P7 — Zinc Sulphite	Silver	Blue	Med. -0.006
Zinc Cadmium Sulphite	Copper	Yellow	Long
P9 —		White	
P11 — Zinc Sulphite	Silver with a Nickel quencher	Blue	Very Short — 10μ sec

When selecting a cathode ray tube for the oscilloscope, care is taken as to the persistance of the screen. For example, the 5BP1 is commonly used because the persistance (length of time it remains lighted after bombardment) is medium and the color is green making viewing easy on the eyes.

The diameter of the oscilloscope screen is of no particular importance other than for the fact that it may be easier to observe a response or a waveform on a large screen than on a small one.

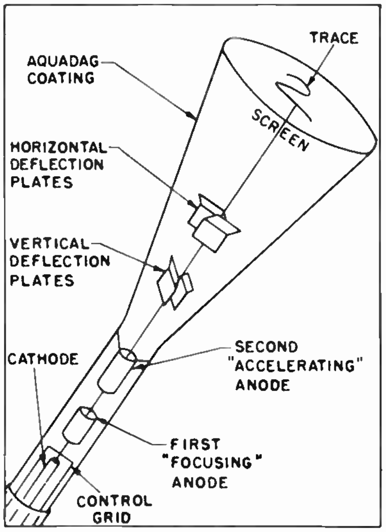


Fig. 2. A Cathode-Ray Tube.

C. Scope Applications

1. Waveform Analysis

When there is only moderate gain in whatever amplifier stages are under test, the vertical amplifier of the scope itself must have rather high sensitivity in order to produce a useful response curve. This will be the case when working through the tuner or through one or possibly two stages of the video (picture) IF amplifiers. The input from the sweep generator must be kept low in order that tubes in the amplifier will not be overloaded. For this class of work the vertical sensitivity of the scope usually has to be better than 0.1 volt per inch of deflection. If the generator signal passes through three or four stages of amplification before going to the oscilloscope, a vertical sensitivity of 0.5 volt per inch or even lower may be enough.

For measurements in parts of the receiver following the video detector a scope sensitivity of 0.5 volt per inch or even approaching 1.0 volt ordinarily will provide plenty of height on the traces. Here, however, we run into another requirement, that of frequency response in the vertical amplifier. Although the line frequency at 525 lines per frame is only 15,750 cycles per second, the square pulses of the sync signals consist electrically of combinations of many higher frequencies. To avoid extreme rounding of the corners or considerable tilting of the trace, the vertical gain should be nearly flat up to at least 500 kilocycles, and preferably up to 4 mc. Fig. 3 shows horizontal sync pulses when using the internal sweep of the scope set to half the horizontal frequency in order to show two cycles or two picture line periods.

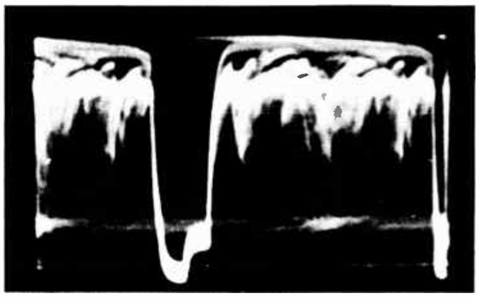


Fig. 3. Video Signal with Scope Set at 7875 Cycles.

When the oscilloscope is being used on circuits following the video detector the purpose ordinarily is to observe sync pulses (pulses which keep the television receiver in exact time with the transmitter) or various waveforms in the sync section, the sweep oscillators, and the sweep output and deflection circuits. Often there are much higher frequencies which tend to make the traces appear fuzzy and to obscure the portions which are of real interest. Fig. 3 is a photograph of the sync pulse as observed on a scope. To clear up the traces the vertical input cable should be fitted with a low-pass filter. A suitable filter circuit is shown by Fig. 4. The resistance of R may be anything between 8,000 and 15,000 ohms. Capacitance of C may be from 0.0005 to 0.002 mfd. The greater this capacitance the greater is the reduction or elemination of high frequencies, but too much capacitance will cut out some of the lower frequencies which should be observed.

Whether positive voltages are at the top or bottom of the trace depends, of course, on the polarity of the input signal, and on the number of amplifying stages through which it passes between generator and scope. The signal in the plate load of every stage is inverted with reference to the signal applied to the control grid. This polarity depends also on the number of vertical amplifying stages in the oscilloscope and on the connection from the last stage to the deflection plates of the cathode-ray tube.

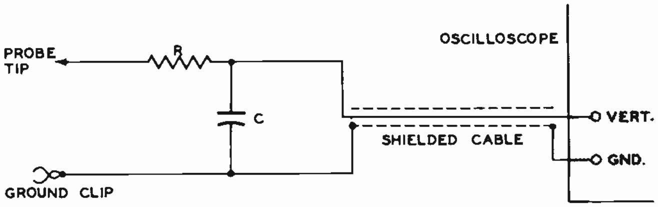


Fig. 4. A Low-Pass Filter Probe for the Vertical Input of an Oscilloscope.

When observing sync pulses or other related waveforms, the sweep generator and synchronized sweep voltages are not used. The beam of the cathode-ray tube is deflected horizontally by the internal sweep of the oscilloscope. The visible trace usually progresses from left to right with time, so that parts of a waveform occurring earlier are at the left, and those occurring later are at the right.

An unknown frequency may be determined by the use of the Lissajous figures. Electric phenomena such as phase shift, modulation, distortion, hum, and amplitude can be visually studied with an oscilloscope. Visual alignment of radio, FM, and television receivers may be accomplished when the oscilloscope is used with suitable signal generators.

Since deflection plates alone require approximately 20 volts charge to deflect the beam one inch in either direction, wide-band amplifiers are used in the oscilloscope to amplify small signals with which we are concerned in television service work. All controls and all input binding posts are located on the front panel.

2. Voltage Measurements

Fig. 5 illustrates a method of making voltage measurements. The power transformer is any small radio type whose secondary will provide 150 to 175 AC volts. Connected across the transformer is a potentiometer whose resistance must be great enough that the current through it will not exceed the transformer rating, and whose own power rating will not be exceeded by the applied voltage and current. Between either end of the potentiometer and the slider is connected a high-resistance AC voltmeter. A multi-range type of service meter is sufficient for this position. Across the voltmeter connect the ends of the vertical input the oscilloscope. It is necessary to use the cable between the scope and meter because any filter resistor or capacitor will cause some change of voltage in the cable.

Waveform voltages ordinarily are specified in peak-to-peak values, from bottom to top of the trace. Because a capacitor is always in series with the vertical input the voltage causing deflection is always alternating. Peak-to-peak voltage then is twice the usual peak voltage value, which is measured from zero to either one peak. The ordinary zero-to-peak voltage in a sine wave is 1.4 times the effective AC voltage. The voltage shown by the meter must be multiplied by 2 and then by 1.4, or multiplied by 2.8 to convert it into the equivalent peak-to-peak voltage of the scope trace. This explains why we need only 150 to 175 volts from the transformer secondary, which when multiplied by 2.8, allows measuring peak-to-peak voltages of around 400 volts.

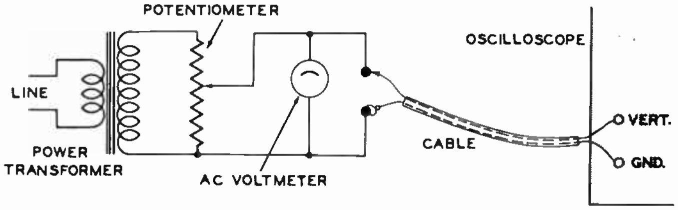


Fig. 5. A Unit for Measuring the Applied Voltage to an Oscilloscope.

Voltages measured in the manner just described are being compared with a voltage whose frequency is 60 cycles, the power line frequency. If the receiver frequencies are so high that the gain in the oscilloscope amplifier is lower than at line frequency, the computed voltage values will be lower than the actual high-frequency voltages. It should go without saying that the vertical gain control of the scope must not be changed when transferring the input cable to the voltage calibrating unit.

Whenever the input potential exceeds 400 peak volts, a divider network consisting of two resistors, in series, must be used. The values of these resistors will be determined by the value of the input potential. For example, assume that we must investigate a faulty 1000 volts DC power supply. Since the filter may be defective we must allow for considerable ripple. The positive peaks of the ripple will add to the positive DC potential of the power supply. In order to be safe we will assume that these positive ripple peaks equal 200 volts. This means that the divider network must drop the voltage applied to the oscilloscope from 1200 volts peak (1000 volts DC plus 200 volts peak AC) to 400 volts peak, a ratio of 3 to 1. Connect the ground lead of the oscilloscope input terminal to the ground side of the power supply; a 250,000 ohms 1-watt resistor across the scope input terminals; and a 500,000 ohms 1-watt resistor from the high input terminals of the scope to the high potential side of the power supply. The voltage applied to the oscillograph terminals will not exceed the maximum of 400 volts peak.

D. A Typical Commercial Oscilloscope

1. Hickok Model 670

To better understand the operation and construction of an oscilloscope, a discussion of a typical instrument is presented in the following paragraphs.

The Model 670 Hickok Oscilloscope is a general purpose instrument which permits complete visual analysis of electronic circuits. The effectiveness of a tube or circuit as an amplifier, rectifier, or source of special wave shapes may be readily determined. Using Lissajous figures, the oscilloscope provides a quick and easy method of determining unknown frequencies. (The pattern created on an oscilloscope screen when sine-wave voltages are applied to both horizontal and vertical deflection plates is called a Lissajous figure).

The Model 670 and other oscilloscopes provide an accurate and versatile means of visually studying and interpreting electrical phenomena such as modulation, phase relations, voltage amplitude, distortion, etc., Because of the design of the cathode ray tube and its associated circuit, the Model 670 will respond accurately to voltages in wide ranges of both frequencies and amplitudes.

2. How It Is Constructed

As a general rule, all oscilloscopes including the Hickok Model 670 will follow a basic method of construction although a few variations may be experienced. An oscilloscope must have the following sections.

(a) A Vertical amplifier.
(b) A horizontal amplifier.
(c) Synchronizing circuits.
(d) Sweep circuits.
(e) Cathode-ray tube and associated circuits.
(f) A power supply, both high and low voltage.

3. Description:

(a) Physical

The Model 670 shown in Fig. 6 is a portable oscilloscope. The front panel has all switches, controls, and connectors clearly marked. This panel is divided into five main controls: focus, intensity, horizontal deflection, sweep circuit oscillator, and external connections.

(b) Functional

The Model 670 will perform the following functions:

(1) Provide a means of visually studying and interpreting electric and magnetic phenomena.

(2) Permit the study and analysis of wave forms.

(3) Provide a means of measuring voltages and frequencies of AC signals.

(4) Permit visual testing and alignment of amplitude and frequency modulated receivers, and television equipment when used in conjunction with a frequency modulated oscillator or signal generators.

(5) Permits measurement of hum, gain, and distortion in audio amplifiers.

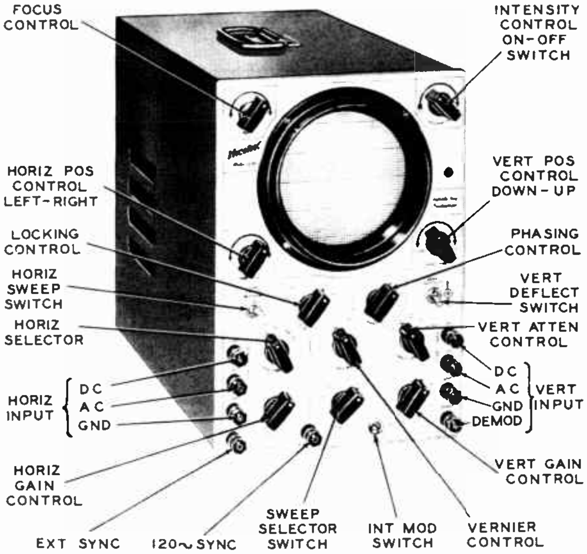


Fig. 6. The Hickok Model 670 Oscilloscope.

(c) Accessories

The AC power line cord is permanently attached. Two test leads are furnished separately. One of these is a 48 inch unshielded black test lead with an alligator clip on one end and a spade clip on the other. The second is a 48 inch shielded cable with an alligator clip on one end and two spade clips on the other.

4. Operation

The following material will serve to explain the actual functioning of all controls and connectors on the front panel of the Model 670 oscilloscope.

(a) Cathode-ray tube controls:

(1) VERT. POS., DOWN-UP. A potentiometer controls the vertical position of the cathode ray pattern.

(2) HOR. POS., LEFT - RIGHT. A potentiometer controls the horizontal position of the cathode-ray pattern.

(3) INTENSITY. The extreme counterclockwise position of this control functions as the POWER ON - OFF switch. After the power is turned on, it acts as a control of the intensity of the beam of controlling the voltage.

(4) FOCUS. A potentiometer control of the cathode-ray beam to produce a finely defined pattern.·

(b) Vertical Controls and Jacks:

(1) (VERT. ATTEN.) A control of the vertical input voltages to the cathode-ray tube. There are five (5) positions available; X1, X10, X100, X1000, and DEMOD. In the VERT. ATTENUATION positions, the selected relative percentage of signal voltage being observed is applied to the input of the vertical amplifier circuits. In the DEMOD. position the modulated RF input is fed to the demodulator where the signal is detected. The demodulated signal is then fed through the vertical amplifier to the vertical plates of the cathode-ray tube (examine the schematic in Fig. 7 to follow this electronic action).

(2) VERT. GAIN. A potentiometer control of the voltages applied to the vertical amplifier input.

(3) INPUT-GND (AC or DC). Binding post connections for an external source of vertical amplifier input.

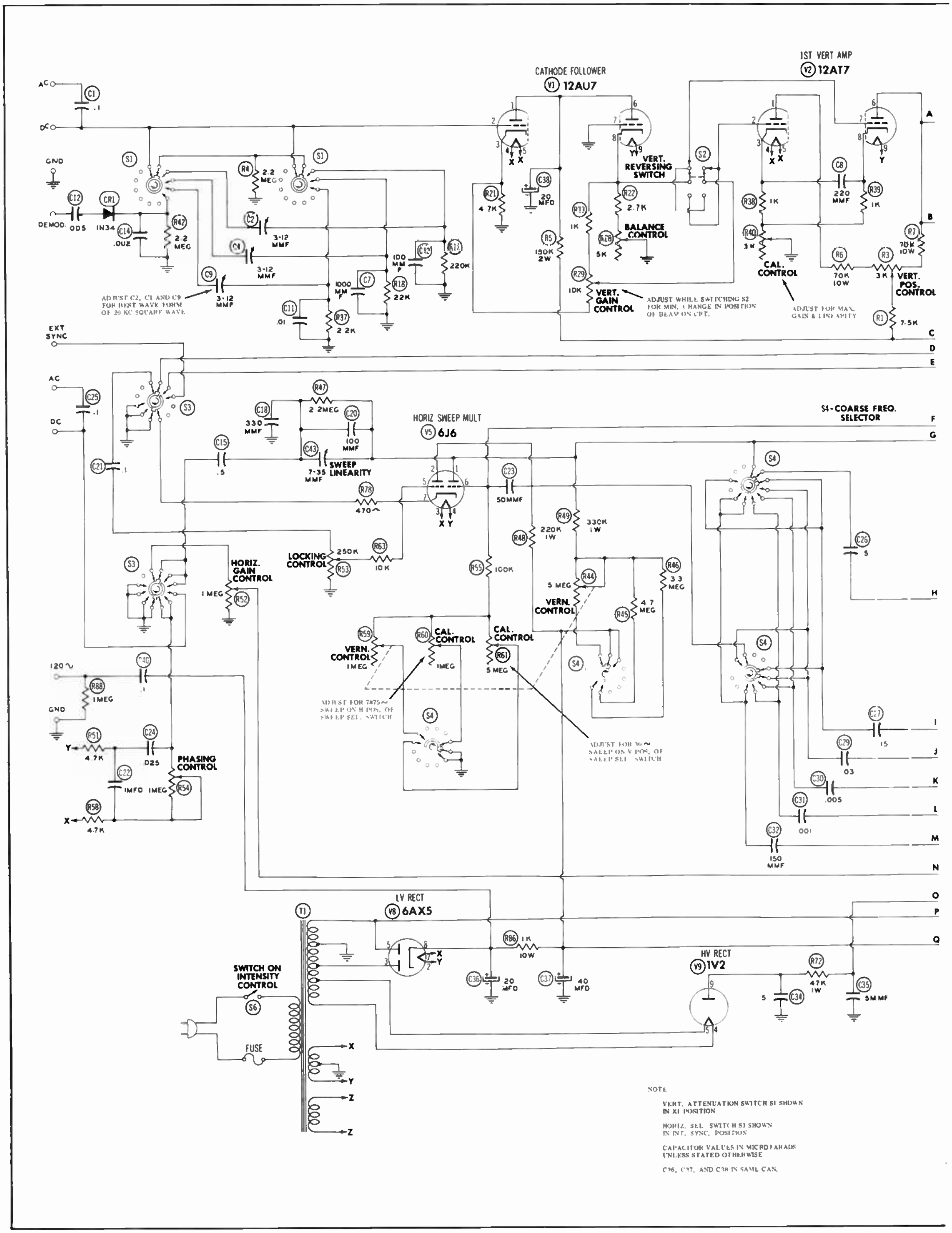
(4) Direct Connection to Vertical Plates. In the rear of the case is access to four terminals connected by jumpers. By removing the two labeled D1 - vertical amplifier, and D2 - vertical amplifier, voltage may be fed to the two deflecting plates.

(5) VERT. DEFLECT. A switch control for reversing the polarity of the display pattern in the vertical plane.

(c) Horizontal Controls:

(1) HOR. SELECTOR. A control of the horizontal sweep of the electron beam. There are five positions available: positive and negative, or external sync; horizontal amplifier; and line frequency. In the positive and negative sync positions the horizontal sweep is obtained from the internal sweep-circuit oscillator and may be of any frequency from 3 cycles to 50 kc. The output of the sweep-circuit oscillator is of a saw-tooth waveform. With such a sweep the beam progresses from left to right at a constant rate and returns to the left almost instantaneously to start the next sweep. This effectively plots time along the horizontal axis.

In the external sync position the sweep circuit oscillator may be synchronized from the external source of voltage applied at the external sync binding post. If a jumper is connected between the 120 cycle binding post and the external sync binding post, the sweep-circuit oscillator will be synchronized from an internal source of 120 cycles or two times the line frequency.



ADJUST C2, C1 AND C9 FOR BEST WAVE FORM OF 20 KC SQUARE WAVE

ADJUST WHILE SWITCHING S2 FOR MIN. CHANGE IN POSITION OF BEAM ON CRT.

ADJUST FOR MAX. GAIN & LINEARITY

ADJUST FOR 7875 ~ SWEEP ON H POS. OF SWEEP SEL. SWITCH

ADJUST FOR 30 ~ SWEEP ON V POS. OF SWEEP SEL. SWITCH

NOTE

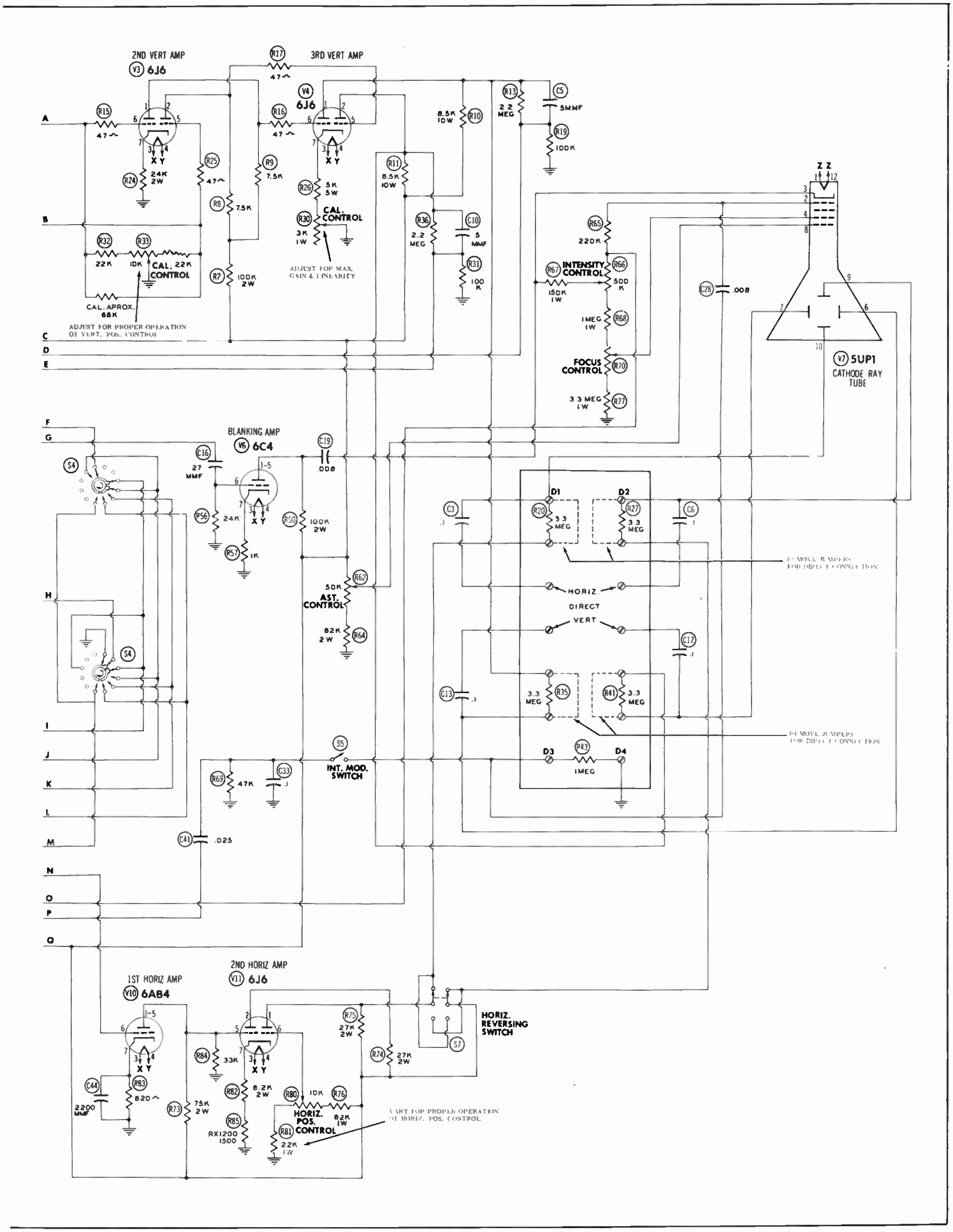
VERT. ATTENUATION SWITCH S1 SHOWN IN X1 POSITION

HORIZ. SEL. SWITCH S3 SHOWN IN INT. SYNC. POSITION

CAPACITOR VALUES IN MICROFARADS UNLESS STATED OTHERWISE

C36, C37, AND C38 IN SAME CAN.

Fig. 7. Schematic Diagram of the



Hickok Model 670 Oscilloscope.

In the horizontal amplifier position, AC or DC voltages connected to the horizontal input binding posts are connected through the horizontal amplifier to the horizontal deflecting plates. In the line frequency position, the horizontal sweep is of the waveform and frequency of the AC power supply (usually a 60-cycle sine wave).

(2) HOR. GAIN. A potentiometer control of the input voltages applied to the horizontal amplifier and subsequently, to the horizontal deflecting plates of the cathode-ray tube.

(3) HORIZ. INPUT-GND. A binding post connection where AC or DC external voltages may be applied for horizontal deflection.

(4) PHASING. This control is only effective when the horizontal-selector switch is in the LINE position. It is used to superimpose the forward and return traces when the Model 670 Oscilloscope is used for visual IF amplifier alignment of AM and FM receivers.

(5) HOR. SWEEP. A switch control for reversing the polarity of the pattern in the horizontal plane.

(d) Sweep Circuit Controls:

(1) SWEEP SELECT. A control comprising of 8 ranges, 6 of which provide coarse adjustments of the frequency of the saw-tooth sweep oscillator from 3 cycles to 50 kc. The remaining two ranges are fixed frequencies to view waveforms of TV receivers at horizontal and vertical scanning rates, being 7875 and 30 cycles, respectively.

(2) VERNIER. A variable control of the frequency of the saw-tooth sweep oscillator within the range covered by any one of the first 6 positions of the SWEEP SELECTOR control. The other two positions have calibrated potentiometers to fix the frequency of the two remaining positions of the SWEEP SELECTOR control.

(3) INT. MOD. A two-position toggle switch permitting intensity (z axis) modulation of the cathode-ray tube from either an external source when turned to the external position, or from an internal 60-cycle source, when turned to the internal position, in which case the return trace is blanked out. Internal intensity modulation should never be used except when the horizontal selector is in "Line" position. Connections for external intensity modulation are made to a connector located on the terminal board accessible through a door in the rear of the case and labeled INT. MOD.

(4) LOCKING. A variable control permitting the adjustment of the amplitude of the locking voltage used to synchronize the sweep-circuit oscillator.

5. Cautions:

(a) Never turn on the oscilloscope with the case removed as very high voltages are present.

(b) Do not leave a spot or trace on the screen in one place for a long period of time as it may burn that part of the screen. When the trace is not being observed the intensity control should be adjusted until the spot disappears.

6. Precautions

(a) Be sure that the power supply line is 105-125 volts, 50-70 cycles AC.

(b) Be sure that the beam has been properly centered before trying to interpret patterns.

(c) Set the focus intensity controls for the smallest spot with the minimum readable brilliancy in order to preserve the life of the tube.

(d) To prevent distortion use as little locking voltage as possible to cause the image to remain stationary.

E. Summary Questions

1. Define the oscilloscope — what it is — what can you do with it?
2. Name the stages of the oscilloscope.
3. What is the purpose of the cathode ray tube?
4. Name the parts of the cathode ray tube and state their purpose.
5. Name and define controls on the Hickok Model 670 Oscilloscope.

POWER SUPPLIES

Objective

To consider the operation and use of the power supplies used with the oscilloscope and television receivers.

References

Lesson Content

A. General

Television receivers and oscilloscopes employ a low voltage B power supply similar to those found in power supplies for sound systems and radio receivers. In most of the larger television receivers and oscilloscopes, the low-voltage supply system includes a power transformer, one or more full-wave tube rectifiers, and capacitor-choke filters which sometimes are supplemented with capacitor-resistor filters for circuits requiring small currents.

Many of the smaller television receivers, and some large ones, utilize transformerless or AC-DC power supplies, often with selenium rectifiers or combinations of tube and selenium rectifiers. High voltage for plates and screens may be had from voltage doublers and sometimes from voltage triplers. Another method makes use of two line-voltage rectifier systems in series, with the high positive voltage fed to plates and screens while the low negative voltage goes to cathodes of the same tubes.

The high-voltage power supply of a television receiver or an oscilloscope furnishes potentials up to 5,000 volts for plates and accelerating anodes of electrostatic deflection picture tubes, and potentials up to 16,000 or more volts for the high-voltage anode of direct-view magnetic-deflection tubes. Two principal types of high-voltage supplys are in use. In one of them, called a pulse-operated or flyback type, there is rectification of high-potential pulses caused by autotransformer action in an extension of the primary winding on the horizontal sweep output transformer. The rectified pulse voltage may be raised in a voltage multiplier before being filtered and passed to the picture tube. Flyback or pulse-operated power supplies are used with magnetic-deflection picture tubes.

The other type of high-voltage power supply employs an oscillator operating at a radio frequency to produce from the AC voltages on its elements an alternating voltage which is stepped up by a transformer. This stepped-up voltage is rectified, filtered,and delivered to the picture tube circuit. This type is normally used with electrostatic-deflection picture tubes; however, sometimes it is used with magnetic-deflection tubes.

B. Selenium Rectifiers

When the current requirements are not too high, a selenium rectifier such as the ones shown in Fig. 1 may be used. This type of rectifier replaces the vacuum-tube rectifier. The space required to house this unit is very small as compared to the tube and its socket. This rectifier has two distinct poles, positive and negative. These compare to the diode vacuum-tube rectifier plate and cathode. The positive side of the rectifier is marked with a plus sign or a red dot. The negative side is marked with a yellow dot or a minus sign. Fig. 2 shows the selenium rectifier connections for operation in a television receiver low-voltage supply.

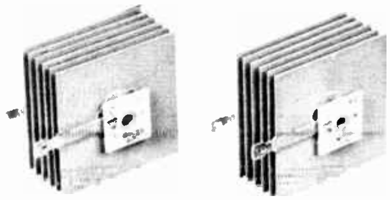


Fig. 1. Typical Selenium Rectifiers.

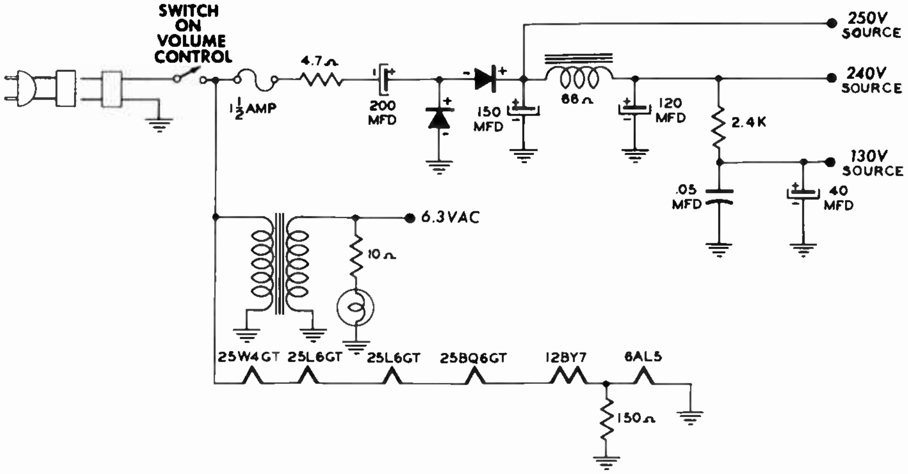


Fig. 2. A Selenium Rectifier Power Supply.

C. Low Voltage Power Supply (AC Transformer).

The power transformer and vacuum-tube rectifier power supply is illustrated in Fig. 3. When AC power is applied to the primary of the transformer, a voltage is induced into the secondary resulting in an alternately positive and negative potential on the diode plates. When the plate is positive with respect to the cathode, electrons flow from the cathode to the plate through one half the secondary to ground through the bleeder resistors back to the cathode. C1 and C2 will charge due to this electron flow. Due to the other half AC cycle causing the other half of the rectifier to conduct, the two filter capacitors cannot fully discharge; therefore, a constant DC potential will appear on the cathode of the rectifier. The bleeder resistors are arranged to make up a voltage divider, which in turn, supplies the correct operating voltages to the tubes of the oscilloscope or television receiver.

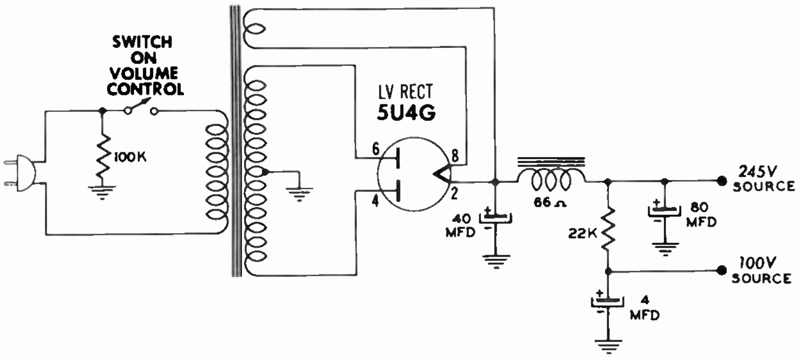


Fig. 3. A Transformer Type Power Supply.

D. Flyback Power Supply

Circuit connections for a typical flyback or pulse-operated power supply are shown by Fig. 4. This style of power supply may be connected to any of the deflection yoke circuits in general use. One such circuit is shown in the diagram.

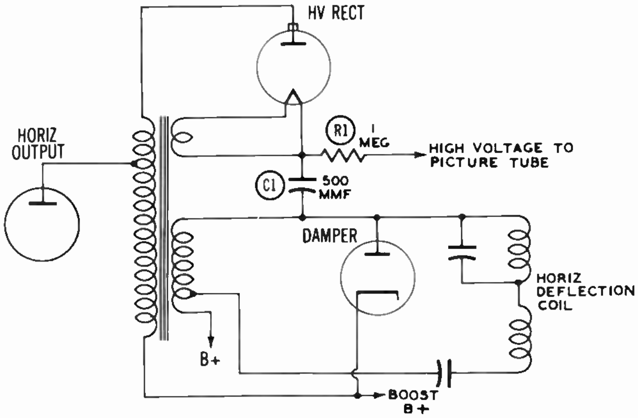


Fig. 4. A Flyback Type High-Voltage Power Supply.

At the instant of plate current cutoff in the horizontal output amplifier there is collapse of magnetic fields in the deflection yoke circuit, which includes the secondary winding of the output transformer. It is this collapse that starts retraces. The sudden change of magnetic field induces a pulse of negative potential in the secondary. Induction between secondary and primary induces a positive pulse in the primary winding. In the portion of the primary connected between the amplifier plate and damper cathode, this pulse potential reaches 4,000 volts or more. The upward extension of the primary makes this winding an autotransformer, and between top and bottom of the entire winding the pulse potential is stepped up to something on the order of 8,000 to 16,000 volts. This potential varies with operating conditions in the sweep amplifier and yoke circuits and on the strength of the negative pulse initially produced in the yoke circuit.

The high-voltage pulses are applied to the high-voltage rectifier. Rectified current charges capacitor C1. The time constant of C1 and resistor R1 is longer than intervals between pulses, so the capacitor retains a charge and delivers fairly constant voltage to the picture tube anode through R1. Filtering effect is increased by capacitance of conductive coatings and the glass of the envelope in some types of picture tubes.

Power supply voltage is affected to some extent by adjustment of the width control, the drive control, and the peaking control, since these adjustments alter the plate current of the output amplifier and currents in the yoke circuit. Any failure which prevents operation of the output amplifier stops the high-voltage supply to the picture tube. Damper failure stops the high-voltage supply when output amplifier plate voltage is furnished through the damper circuit.

E. Voltage Multipliers

A voltage doubler circuit for a flyback power supply is shown by Fig. 5. Because input to the doubler consists entirely of positive voltage pulses instead of alternating voltage the action differs from that in doublers used on line voltage in low-voltage supplies of receivers. In the doubler circuit are two high-voltage rectifier tubes, V1 and V2, also capacitors C1, C2, and C3, and resistor R1. Input is from the top of the autotransformer type of primary winding on the output transformer. Output to the picture tube anode is through resistor R2.

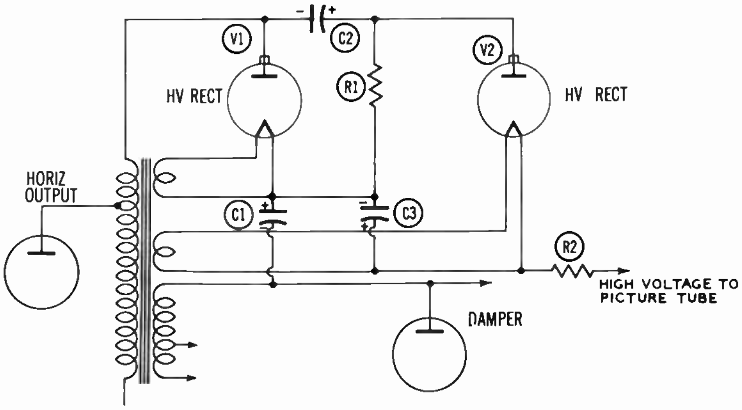


Fig. 5. A Voltage Doubler Circuit.

During each voltage pulse from the transformer the plate of V1 is made positive, and there is conduction through this tube to charge capacitor C1. Capacitor C2 previously will have been charged in the marked polarity by action to be explained. The potential on the side of C2 toward the plate of V2 is positive, so this rectifier conducts to charge capacitor C3 as marked. Capacitors C1 and C3 are thus charged simultaneously to approximately peak pulse voltage. These two capacitors are in series with each other and the connection through resistor R2 to the picture tube anode. Consequently there is applied to the anode a voltage approximately equal to twice the pulse voltage.

During intervals between pulses the plate of V1 is negative and there is current cutoff in this tube. Discharge from capacitor C1 flows through resistor R1 to charge capacitor C2 in the marked polarity. It is this charge on capacitor C2 which remains long enough to make the plate of V2 positive at the beginning of the next voltage pulse. Capacitors C1 and C3 are charged during each pulse period, and capacitor C2 is charged during intervals between pulses.

F. RF Power Supply

Connections for a typical RF type high-voltage power supply are shown by Fig. 6. The oscillator tube is furnished with plate and screen voltages from the low voltage power supply through a filter system which prevents escape of RF voltages and currents from the oscillator circuit to other parts of the receiver. The entire high-voltage power supply system is enclosed within a shield to prevent RF radiation to the remainder of the set.

The oscillator tube is biased by grid resistor R1. The tuned circuit of the oscillator consists of tuning capacitor C1 and the portion of the transformer winding across which this capacitor is connected. Capacitive feedback to the oscillator grid is here from a ring placed around the outside of the glass envelope of the high-voltage rectifier tube. This feedback ring usually is a coiled spring long enough to go around the envelope, with the ends of the spring joined so that it may be slipped onto the tube. Other styles of metallic clamps or rings may be used. There is capacitance between the metal ring and the tube elements, with the glass envelope and vacuum space as dielectric. In some power supplies of this general type the feedback is from a tickler coil coupled to the high end of the transformer winding. The oscillator frequency usually is in the neighborhood of 200 kilocycles.

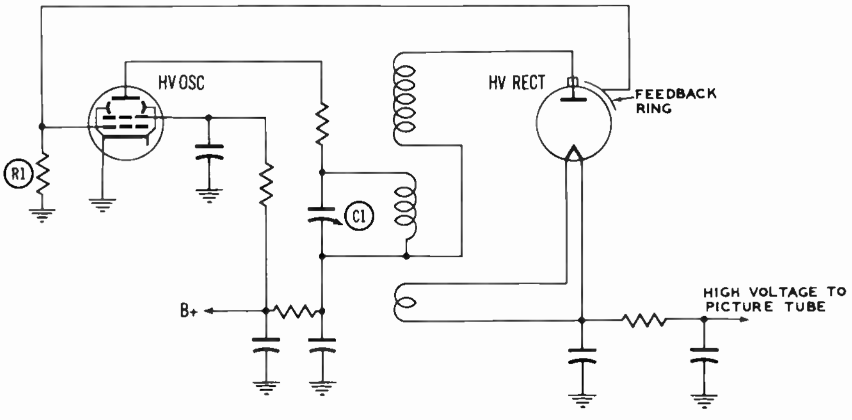


Fig. 6. A RF Type High-Voltage Power Supply.

The oscillator tube usually is a beam power type, although it may be a triode, or a pentode connected as a triode. The oscillator transformer is an air-core type of high-Q construction. The turns ratio, secondary to primary, may be as much as 35 to 1. The transformer secondary winding is tuned by its inductance and the sum of distributed capacitance in the winding, stray capacitance in connections, and internal capacitance of the rectifier tube.

Output voltage from the rectifier will be maximum when the oscillator plate winding is tuned to the natural frequency of the secondary winding, but to provide stable oscillation the plate winding is tuned to a frequency slightly higher or lower. When capacitor C1 is adjustable it is used for varying the output voltage. The method is to connect to the output a suitable voltmeter, adjust the capacitor first for maximum voltage, and then detune it to allow normal output voltage specified for the receiver. The only other adjustment is for feedback. A feedback ring or clamp should be placed, to begin with, so that it surrounds the lower edge of the tubular shield which extends up toward the top cap inside the rectifier tube, then moved slightly if necessary to have oscillation and power output. Incorrect positioning will reduce the maximum output voltage or may prevent any output at all.

The RF-type power supply is not often used in TV receivers since the flyback type supply will do the same job without using an extra tube. One other disadvantage to this type circuit (RF supply) is that any RF which reaches any part of the picture circuits will cause a pattern on the picture tube. This pattern will be either vertical or sloping bars or possibly a coarse herringbone effect.

G. Summary Questions

1. What is the purpose of a low voltage supply?
2. What is the purpose of a high voltage supply?
3. Explain briefly the operation of the flyback type high voltage supply.
4. Describe the voltage multiplier.
5. Explain the operation of the RF type of power supply.

DEFLECTION PRINCIPLES FOR THE CATHODE RAY OSCILLOSCOPE

Objective:

To determine how a sine-wave pattern is traced on the screen of the cathode-ray tube and how lissajous patterns are produced.

References

Lesson Content

A. The Deflection Plates and DC Potentials

If we could look from the big end of the cathode-ray tube through the screen and toward the cathode, the electron beam would be coming toward us passing between the deflecting plates, as in Fig. 1. The beam is composed wholly of electrons, which are negative. If, as in Fig. 1A, the left-hand plate is made negative it will repel the electrons, and if the right-hand plate is positive at the same time it will attract the electrons. The beam will be deflected to the right and the luminous spot will be formed on the right-hand side of the screen.

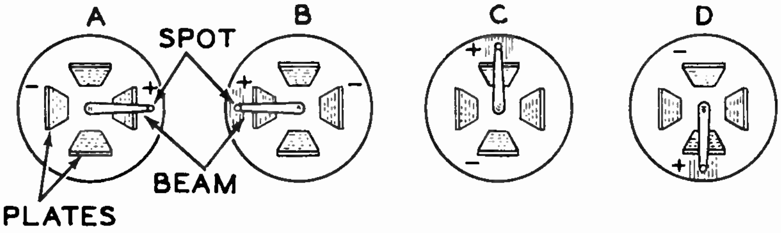


Fig. 1. How the Beam is Deflected by Potential Differences on the Deflection Plates in a Direction Correspondings to Polarities.

In Fig. 1B, the polarities of the right and left-hand plates have been reversed. The beam and the luminous spot are deflected to the left. In Fig. 1C, the upper deflecting plate is positive and the bottom one negative. The beam is repelled by the lower plate, attracted by the top plate, and the spot is formed at the top of the screen. In Fig. 1D, the polarities of top and bottom plates are reversed, and the spot is formed near the bottom of the screen.

The distance the spot is shifted sideways depends on the potential difference between the right and left-hand deflecting plates. The distance the spot is shifted up or down depends on the potential difference between the top and bottom plates. The direction in which the spot is shifted away from the center depends on the relative polarities of the deflecting plates.

The beam and spot are moved sideways, or horizontally, by the right and left-hand plates, which are called the horizontal deflection plates. Movement up and down, or vertically is controlled by the top and bottom plates, which are called the vertical deflection plates.

If there are potential differences at the same time between both the horizontal plates and the vertical plates the spot will be moved both horizontally and vertically at the same time. Consequently, the spot may move to any point on the entire surface of the screen, depending on the polarities and potential differences of the deflection plates.

B. The Deflection Plates and AC Potentials

First let us study the results obtained when only the vertical deflection plates have a signal applied. A typical wave shape for applied voltage is given to the left in Fig. 2A. If this potential, obtained from the secondary winding of a transformer, as shown in the center of the diagram, the upper terminal will be positive and the lower one negative during one half-cycle, while during the other half-cycle the upper terminal will be negative and the lower one positive. If the terminals of the transformer are connected to the vertical deflection plates of the cathode-ray tube the luminous spot will be caused to move up and down, thus forming a straight vertical line on the screen, as at the right in Fig. 2A.

The greater the amplitude, or the greater the peak voltages in the alternating potential, the greater will be the maximum difference of potential between vertical deflecting plates and the farther the luminous spot will move first upward and then downward. The vertical height of the luminous trace thus will be proportional to the peak value of the applied potential. The electron beam has no measureable weight, and has no inertia. It will follow the changes of potential on the deflecting plates, even at frequencies higher than 100 megacycles. Fig. 2B illustrates the trace when AC is applied to the horizontal deflection plates with no deflection vertically.

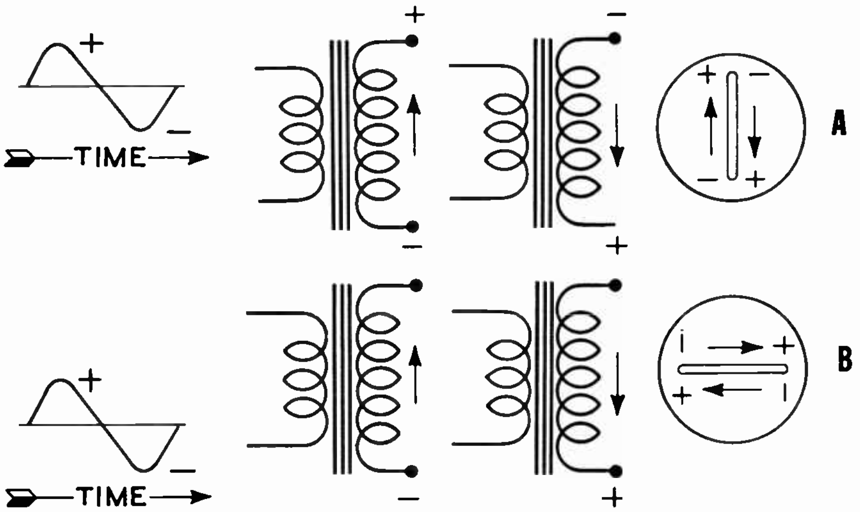


Fig. 2. How an AC Voltage May Furnish Deflection Potentials in an Oscilloscope.

C. Phase Relation

When one alternating potential is connected to the horizontal deflection plates and a second alternating potential to the vertical deflection plates of the oscilloscope, the trace will be a straight line diagonally across the screen as shown in Fig. 3A if the two potentials are in phase. The trace will be a straight line diagonally across the screen as shown on Fig. 3C if the two potentials are 180 degrees out of phase. The tilt of the line will depend on the relative amplitudes of the applied potentials and on the adjustment of the vertical and horizontal gain controls.

Fig. 3B shows the pattern which results when the applied AC potentials are 90 degrees out of phase.

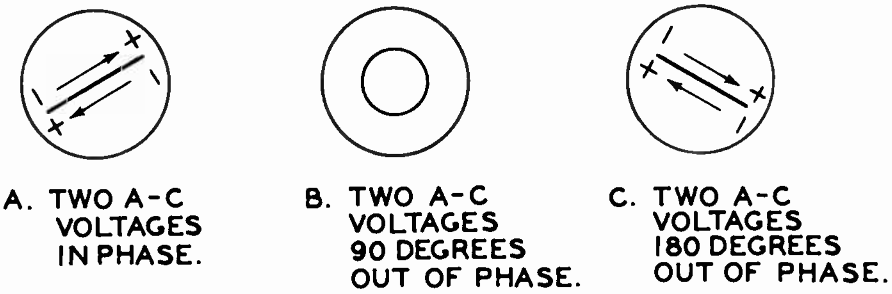


Fig. 3. Screen Traces Showing Phase Relations.

D. The Saw-Tooth Voltage

To extend the operation of the cathode-ray tube beyond its ability to show peak amplitudes we shall apply to the horizontal deflecting plates a potential which varies as shown by Fig. 4. This potential begins at a negative value, increases uniformly with time as it passes through zero and to a positive value, then very suddenly drops back to the original negative value. We shall assume that this series of changes occurs during 1/60 second of time. The steady change from negative to positive takes an interval of time shown as A, and the sudden return takes the interval of time shown as B. The two intervals together make up 1/60 second.

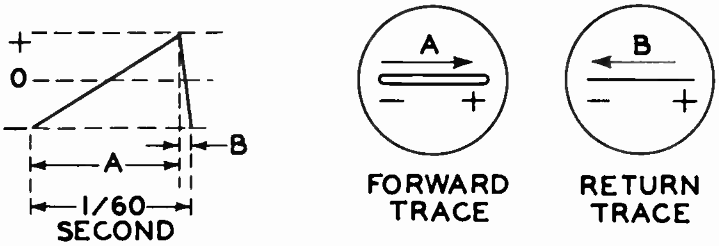


Fig. 4. This Horizontal Deflecting Potential Increases at a Uniform Rate During Most of Each Cycle.

If a potential difference of this kind is applied to the horizontal deflection plates the luminous spot will travel at a uniform speed across the screen from left to right, and will take the time interval A. This is called the forward trace. Then the spot will return to the left in the short time interval B. This is called the return trace or retrace. During the forward trace the beam moves slowly enough to make the line brightly luminous. The beam makes the return trace, however, at such high speed that the line is almost invisible.

The next step will be to apply to the vertical deflecting plates the alternating potential of Fig. 2 while applying to the horizontal deflecting plates the potential of Fig. 4. The alternating potential will be assumed to have a frequency of 60 cycles per second, so that the one cycle requires a period of 1/60 second.

What happens may be understood from Fig. 5. At instant A, the horizontal plates are holding the beam all the way to the left on the screen, the vertical potential difference is zero, leaving the spot at the center of the screen so far as vertical deflection is concerned. At instant C, the horizontal deflection has carried half way from left to right, but the vertical potential difference has dropped back to zero. At D, the beam is three-fourths of the way across, while vertical deflection has driven the beam to the bottom of its travel. At E, the spot has gotten as far to the right as possible, for here the return trace commences, and vertical deflection has allowed the spot to move almost back to the center height. Between instants E and F, while vertical deflection returns to zero, the beam is driven all the way back to the left.

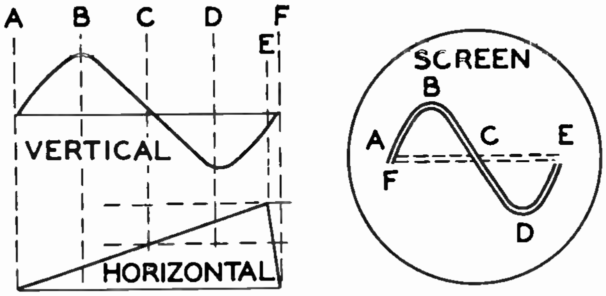


Fig. 5. Vertical and Horizontal Deflecting Potentials Trace the Waveform Screen.

A reproduction of the curve which we have learned to associate with one sine-wave cycle of alternating potential, has been traced on the screen of the tube. A little bit of the right-hand end of the curve is cut off because of the time needed for the return trace. The curve actually has been drawn or traced by the potential applied to the vertical-deflection plates.

As a general rule the cycles of alternating potential on the vertical plates would continue at the rate of 60 times a second. If we continue the rising and falling potential on the horizontal plates, as in Fig. 5, the trace of the sine-wave curve will be formed on the screen at the rate of 60 times a second. With screen coatings such as most often used, some brightness will remain all along the trace between passages of the beam and the spot, and the whole curve will be continually illuminated. But at the low frequency of 60 cycles per second most of the illussion of steady illumination of the whole trace results from the characteristic of our eyes called persistance of vision. This means that, when a bright light appears and then goes out, we seem to see the light for about 1/20 second after it should be invisible.

How the saw-tooth voltage is developed will be explained in a later lesson.

E. Frequency Comparison

Fig. 6 shows pictures of the two trace patterns. The pattern in Fig. 6A was produced with 360 cycles applied to the vertical input of the oscilloscope, and 60 cycles applied to the horizontal input. The 60-cycle potential produced the horizontal sweep frequency. The internal sweep oscillator was not being used. Note that there are six peaks or loops along the top of the pattern, and one loop on the side. The ratio of top (or bottom) loops to side loops is six to one. The ratio of vertical frequency to horizontal frequency is 360 to 60, which also is six to one.

Fig. 6B shows one loop at the top and six loops along either of the vertical sides. The ratio of loops, top to side, is one to six. This pattern was produced with 60 cycles on the vertical input and 360 cycles on the horizontal input. The ratio of vertical to horizontal frequency is 60 to 360, which is also one to six.

If unknown frequency is applied to one input, either horizontal or vertical, and an adjustable known frequency is applied to the other input, the known frequency may be adjusted to produce a nearly stationary pattern. Then the ratio of the number of loops across the top or bottom of the pattern to the number of loops on either side is the same as the ratio of the vertical to the horizontal frequency.

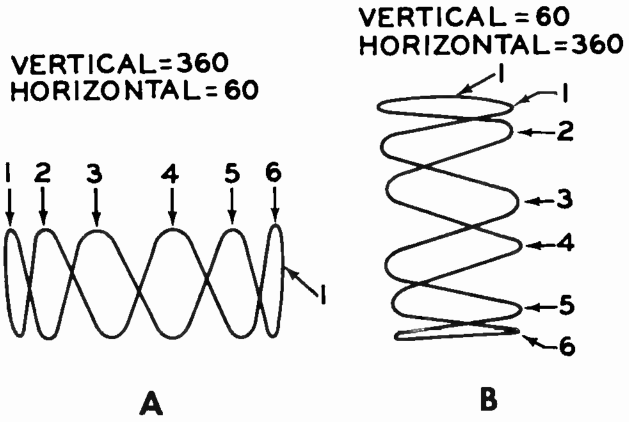


Fig. 6. How Frequencies are Compared When Their Ratio is less Than 10 or 12 to 1.

Frequency ratios as great as ten to one or even twelve to one are quite easy to count in this manner. The known adjustable frequency may be secured from an accurately calibrated audio-frequency or radio-frequency signal generator. The supply-line frequency, usually 60 cycles, may be used as the standard when the unknown frequency is a multiple or a simple fraction of the line frequency, or very nearly so.

When the two frequencies are not simple multiples or fractions of each other the pattern will rotate on the screen, with one set of "cycles" moving toward the right and the other set moving toward the left. Any one peak will go all the way from any given position back to the same position once for each cycle that the frequencies differ. For example, were you using a known frequency of 1, 000 cycles and if a peak were to make the circuit in one second, the unknown frequency would be either 999 or else 1, 001 cycles. Were the rotation to be twice per second the unknown would be either 998 or else 1, 002 cycles, and so on for any speed of rotation. The direction of travel of the peaks depends on whether the unknown frequency is lower or higher than the known one. Usually it is well to let the pattern rotate very slowly to make certain that no two loops coincide and hide each other.

If the higher frequency is of distorted waveform, with sharp peaks and kinks, the counting will be easier than with a more nearly sine-wave form because of the spots which are brighter than the remainder of the trace pattern. Also, it will be easier to distinguish between loops traveling in opposite directions.

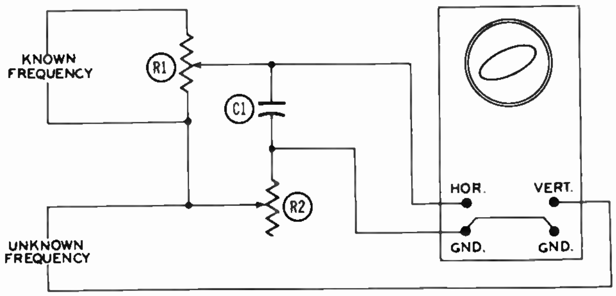


Fig. 7. A Phase-Splitting Circuit Used for Frequency Comparisons.

For ratios greater than 10 or 12 to 1 the counting is made easier by using a phase splitting circuit which will make the trace pattern into a circle or an ellipse. One phase-splitting circuit is shown by Fig. 7. Resistor R1 may be a potentiometer of the volume control type having maximum resistance of 10,000 to 20,000 ohms, R2 may be a similar type having maximum resistance of about 50,000 ohms, and capacitor C1, of the fixed type, may have capacitance of 0.1 to 1.0 mfd. Adjustment of the two potentiometers, and of the gain controls on the oscilloscope, will allow making the trace pattern of the elliptical or circular shape on the screen.

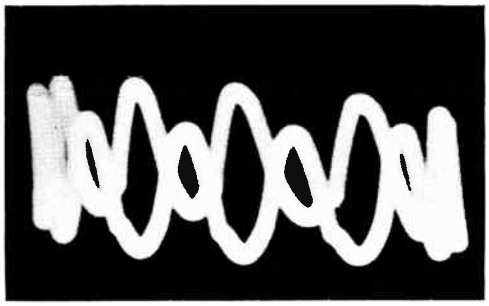


Fig. 8. Frequency ratio of 12 to 1.

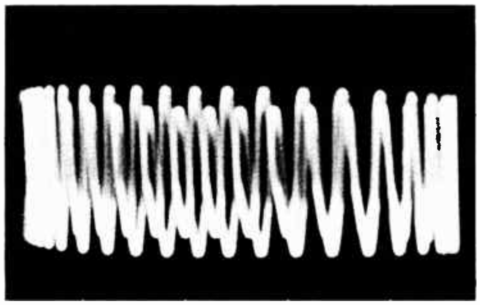


Fig. 9. Frequency ratio of 43 to 1.

Fig. 8 shows a pattern indicating a frequency ratio of 12 to 1. One showing a ratio of 43 to 1 is pictured in Fig. 9. The ellipse or circle will rotate so long as one frequency is a fractional multiple of the other, making one complete revolution per cycle of difference between the frequencies. When the multiple is a whole number, or when one frequency is divisible into the other with no fractional remainder, the pattern will remain stationary.

F. Phase Inversion

When a signal or other potential applied between grid and cathode of an amplifying tube makes the grid more negative, the potential at the plate becomes more positive as measured with reference to the cathode. This is the action known as phase inversion in an amplifier stage. The phase of the signal is inverted, which means that the tops and bottoms of the wave are interchanged.

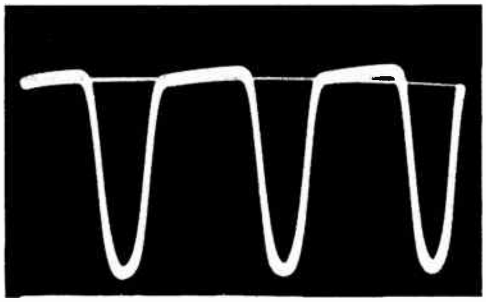


Fig. 10. Signal Observed at Control Grid of Amplifier.

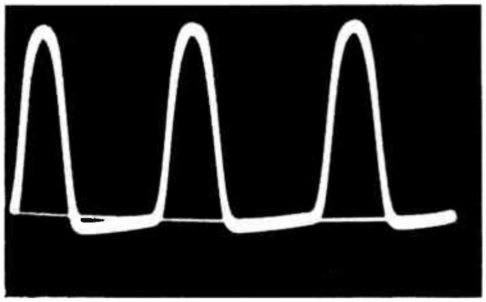


Fig. 11. Signal Observed in the Plate Circuit.

Fig. 10 shows a trace taken between control grid and cathode (or chassis ground) of an amplifier tube. The waveform is purposely distorted to allow distinguishing between top and bottom of the wave. Incidentally, this distortion was caused by insufficient plate voltage on the amplifier tube preceding the one from which traces were taken. Fig. 11 shows the signal in the plate circuit. Here the cut off side of the wave is at the bottom, while in the grid circuit of the same tube the flattened side of the wave is at the top. The phase of the signal is inverted in passing through the tube.

Grid and plate waveforms are checked by using the internal sweep adjusted to show several cycles of the signal, with the vertical input post of the oscilloscope connected through a half-megohm resistor to the tube grid and then to the plate. The vertical gain control is used to keep the vertical heights of the two traces on the screen. A check of this general type sometimes is made on the inverter tube opposite to the phase at the plate of the other push-pull amplifier. The phase at the plate of the inverter tube should be opposite to the phase at the plate of the other push-pull amplifier tube of the pair. This check shows also whether the amplitudes of the two plate signals are equal, or nearly so, as they should be.

G. Summary Questions

1. Why does the electron beam bend towards the positive deflecting plates?
2. Draw a sketch indicating the nature of the voltages applied to both sets of deflection plates that would produce a straight vertical line.
3. Draw another sketch showing voltage required to produce a straight horizontal line.
4. Why do we appear to see a spot glow for 1/20 of a second after the spot stops glowing?

APPLICATION OF THE OSCILLOSCOPE

Objective

To study various uses of the oscilloscope.

References

Lesson Content

A. General

There are numerous applications of an oscilloscope in the Radio-Television field. In this lesson we will discuss some of the more important applications. Some of these applications are as follows: (1) checking frequency response of an audio amplifier, (2) checking the waveforms of a push-pull audio amplifier, (3) checking an AC full wave rectifier power supply.

B. Preparing the Oscilloscope for Use

Each piece of equipment requires a warm up period for more accurate measurement. The oscilloscope may have been working the day before but some defect arose after the close of the previous day. It is well to find out if it is working before you need it. The following procedure may be used for preparing the scope for use:

Turn the oscilloscope on and allow a few minutes for warm up. Rotate the intensity control nearly fully on (clockwise). When a trace appears adjust the focus control for the sharpest and clearest possible trace or spot. If a trace does not appear, adjust the horizontal and vertical positioning controls until a trace appears on the screen. This procedure is necessary as the positioning controls can throw the trace outside the limits of the screen and give the impression that the scope is not operating. In order to obtain a sine-wave pattern on the screen, connect the 60-cycle test signal to the vertical input of the scope. Turn the sweep selector to the internal sweep position. Set the sync control to zero. Set the sweep range control to the position in which 60 cycles falls. Adjust the fine frequency control until a single 60-cycle sine wave appears on the screen. If unable to obtain a steady pattern rotate the sync control until the pattern becomes stationary. To keep the trace steady a small amount of the incoming signal is fed to the sweep oscillator and serves as a synchronizing pulse to lock the sawtooth generator in step with the incoming signal. When the sync control is advanced it increases the amount of synchronizing signal which is fed to the sweep oscillator. The sync control should only be advanced to the point where the trace locks in. Next set the sweep range control to the position in which 15 cycles appears, if different than the 60 cycle position, and adjust the fine frequency control so 4 cycles appear on the screen. The sweep is now operating at 15 cycles per second (15 is 1/4 of 60 cycles). The sweep is now functioning properly. The oscilloscope is now ready for use as a test instrument.

C. Inspection of Waveforms

Ordinarily the potential whose waveform is to be examined is applied to the vertical input and ground posts of the oscilloscope. The sweep frequency should be low enough to bring two or three cycles onto the screen. One of the cycles can be enlarged and centered if necessary.

It may be desirable to set the vertical and horizontal amplifiers to equal gains in order to observe the true waveform. This is done by applying any signal potential to the vertical input, setting the horizontal gain at zero and the vertical gain for the desired height of trace. This vertical height should be noted, as should also the exact position of the vertical gain control on its dial. Then apply the same signal potential to the horizontal input, set the vertical gain at zero, and adjust the horizontal gain to get the same length of trace as previously. The present setting of horizontal gain and the previously noted setting of vertical gain give equal horizontal and vertical gains.

When making waveform observations, it is assumed that the horizontal sweep moves the spot at constant speed all the way from left to right, which means that the horizontal sweep is truly linear. Otherwise some cycles will be spread more than others. Usually the later cycles will be compressed. Linearity may be checked by bringing five or six cycles onto the screen then measuring the distances between peaks. These distances will be equal for all cycles with a linear sweep. Discrepancies in the first and last cycles means nothing, since they are due chiefly to curvature of the screen end of the cathode-ray tube.

D. Waveforms, Audio Frequency

Observe the output of an audio-frequency amplifier by connecting the voice coil leads of the loud speaker to the vertical input of the oscilloscope. Another way is to disconnect one voice coil lead, connect between this lead and the other one a resistor whose resistance is very close to the voice coil impedance, and then connect the ends of this resistor to the vertical input.

An AF signal potential of good waveform, as secured from a signal generator, is connected between the "High" terminal of the volume control and B-, or is connected to the control grid of the first AF amplifier and B-, or to the control grid and B- for any following AF tube; depending on how much or how many stages of the amplifier are to be checked.

The AF signal from the generator first should be connected directly to the vertical input of the oscilloscope, and its waveform examined. Any distortion will come through the amplifier and must be allowed for in final observations. Set the signal generator amplitude rather low, to allow for amplification in the audio amplifier being checked.

Fig. 1 shows overloading of an AF amplifier tube due to a higher signal potential than can be handled with the existing plate and screen voltages and the existing control-grid bias. The fault might be due to low screen voltage, excessively negative grid bias, or too high a setting of the volume control for the signal coming from the detector.

Fig. 2 shows the waveform resulting from turning the volume control still higher with no other changes in operating conditions. The input to the volume control was of approximate sine-wave form in both of these cases.

Fig. 3 shows what happens when the control grid bias is not sufficiently negative. This particular fault was due to a cathode-bias resistor of too little resistance, reducing the bias from 7 1/2 to 5 volts negative. There was an increase of volume, and of height of the trace, due to the greater plate current.

Fig. 4 shows the result of low plate voltage, which actually was due to excessive resistance in the circuit leading from the plate through the output transformer primary to B+. The volume is noticeably down and there is severe distortion.

Fig. 5 shows the same distorted signal as illustrated by Fig. 4, but here the vertical gain of the oscilloscope is turned up. The waveform is unchanged, but the amplitude on the screen is increased.

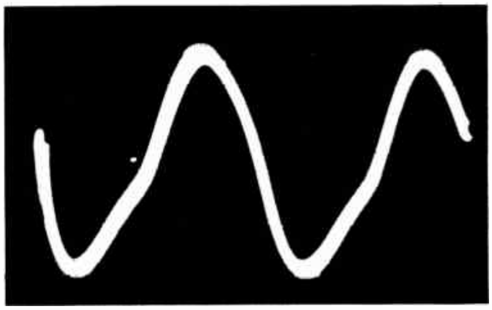


Fig. 1. Audio Distortion.

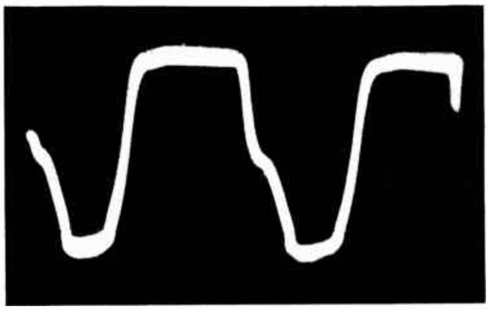


Fig. 2. The Distortion Increases.

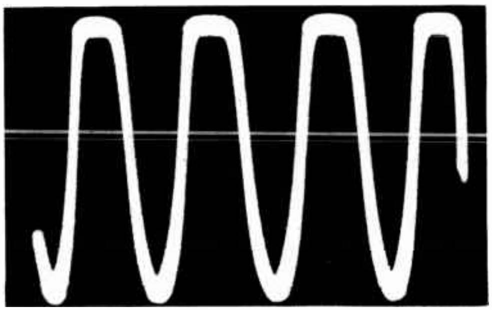


Fig. 3. Not Enough Negative Grid Bias.

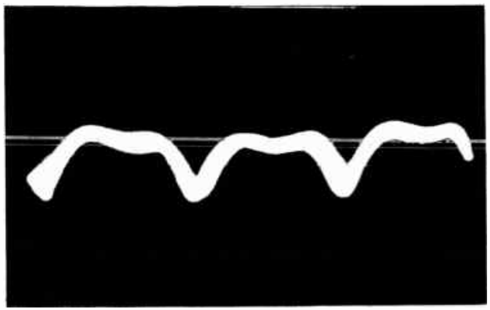


Fig. 4. Plate Voltage Too Low.

Fig. 6 shows the same signal as illustrated by Figs. 4 and 5, but here the leads to the vertical input and to ground of the oscilloscope have been reversed. The result is merely to turn the signal upside down. The same thing would happen with reversed connections to the voice coil leads or to any other points from which the amplifier output is being taken to the oscilloscope.

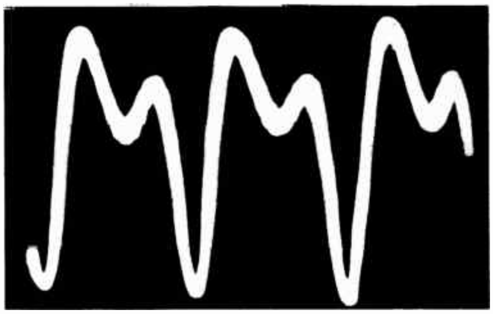


Fig. 5. Vertical Gain of Scope Increased But Plate Voltage Too Low.

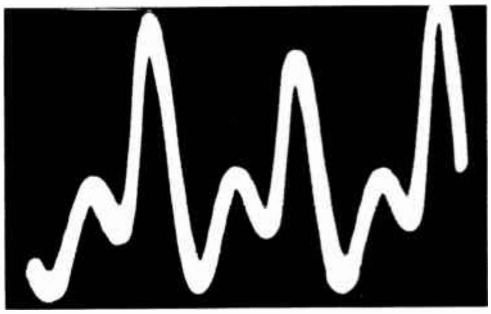


Fig. 6. Trace Inverted by Reversing Leads to Vertical Input.

With the oscilloscope connected to the voice coil leads, as at the left in Fig. 7, it is difficult or impossible to identify whether upward lines in the trace indicate increases or decreases of voltage at the plate end of the circuit, because we are working through the output coupling transformer. To make this identification the vertical input of the oscilloscope may be connected through a resistor of about a half-megohm resistance to the plate of the output tube, with the ground of the oscilloscope connected to chassis ground.

Now we are measuring or observing changes of plate voltage. We must keep in mind that plate voltage and plate current, in the tube, change oppositely. When there is an increase of plate current there must be an accompanying decrease of plate voltage, because more of the total low voltage power supply potential is used up in the plate load when there is more current, and less remains across the tube.

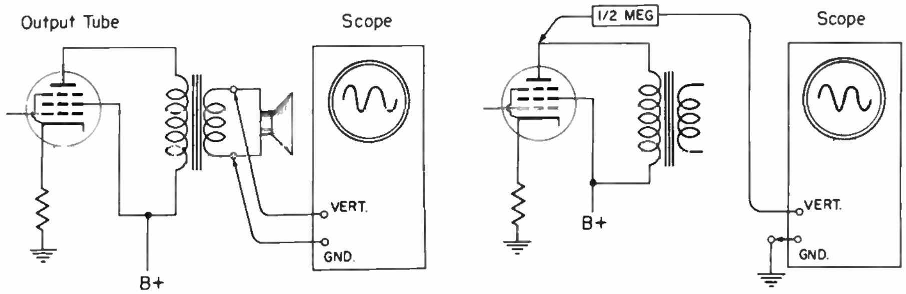


Fig. 7. (Left) Connections of Oscilloscope to Voice Coil and (Right) to the Plate of the Output Tube.

As a result of plate voltage and current being in opposite phase, when we see a trace pattern such as Fig. 8, it indicates plate current cutoff which would be due to a grid bias excessively negative for the plate and screen voltages in use. The top of the trace curves are cut off, which means that the bottoms of the plate current curves are being cut off.

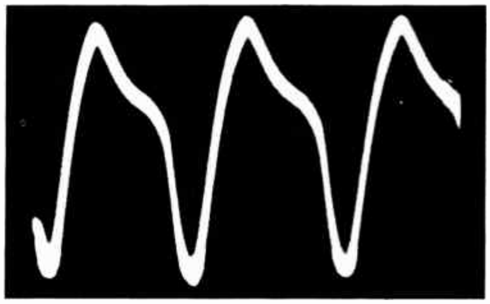


Fig. 8. Insufficient Control Grid Bias.

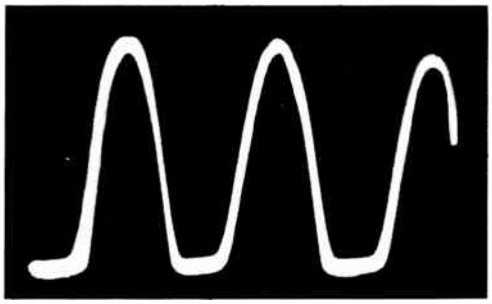


Fig. 9. Insufficient Plate Voltage.

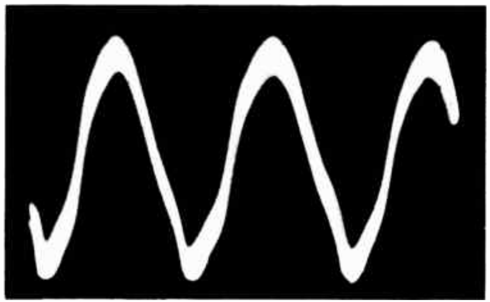


Fig. 10. Screen Voltage Too Low.

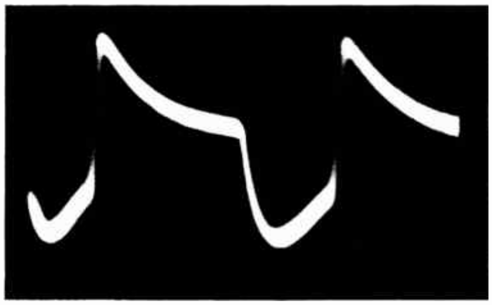


Fig. 11. Too Little Grid Bias and Low Plate or Screen Voltage.

A trace pattern such as that of Fig. 9, where the bottoms of the voltage curves are cut off, means that the tops of the current curves are being cut off in the output of the tube. When the tops of current curves or waves are cut off it indicates saturation in the tube. Saturation means that the plate current cannot follow the control grid potential all the way, as this potential becomes less negative or possibly positive. The usual reason is a plate voltage too low for the signal being applied to the tube, and for the control grid bias in use.

Assuming that the signal is no greater than should be handled by the tube, the trace of Fig. 8 then would indicate too little negative control grid bias, and the one of Fig. 9 would mean plate voltage too low.

Screen voltage too low for the plate voltage and the signal causes a trace somewhat similar to the one indicating low plate voltage, in that the bottoms of the waves are cut off. Fig. 10 shows a trace taken with screen voltage down to about half of the correct value.

It happens that a trace pattern almost identical with that for low screen voltage may result from using a loud speaker whose voice coil impedance is much too high to match the impedance of the speaker winding of the output transformer.

If both the control grid bias and either the screen or plate voltage are incorrect there may be cutting off of both the tops and bottoms of the waves in the trace pattern, as illustrated by Fig. 11. Since there should be certain related values of all three voltages, when any one of them is incorrect to any great degree it makes the others incorrect as well. When the first voltage is brought within the design limits of the amplifier being checked the whole trouble usually disappears.

When only one of the pair of tubes in a class B push-pull amplifier is checked there normally would be some cutting off of the tops of the waves, indicating plate current cutoff. When the outputs of the two tubes are combined for the loudspeaker the apparent distortion will disappear and the output wave will follow the form of the input unless there actually is distortion in the amplifier.

There are two general methods for checking the operation of an audio amplifier stage-by-stage. One way is to connect the oscilloscope across the speaker voice coil and leave it there while connecting the input signal potential first to the control grid of the output tube, then the control grid of the preceding AF amplifier, and so on back to the volume control. The other way is to connect the input signal to the volume control or detector load resistor and leave it there while connecting the vertical input of the oscilloscope successively to the control grid of the first AF tube, then to the plate of this tube, and so on to the control grid then plate of each following tube in the amplifier. With either method any indicated distortion is caused by faults located between the input and the oscilloscope so long as the distortion is shown by the trace patterns.

E. Modulated RF and IF Waves

The oscilloscope will show an amplitude-modulated high-frequency wave when the wave frequency is in the radio-frequency or intermediate-frequency ranges.

Connections which may be used for observing modulated waveforms are shown in Fig. 12. The RF (or IF) high-side output of the signal generator is connected through a dummy antenna (D) either to the antenna post of the receiver for checking operation of both the RF and IF amplifiers with this one connection, or else is connected to the signal grid of the converter tube for checking only the IF amplifier. The signal generator ground is connected to the receiver chassis ground in an AC receiver or through the usual blocking capacitor to B- in an AC/DC receiver.

The vertical amplifier of the less expensive oscilloscopes usually will not give distortionless amplification at frequencies in the RF and IF bands (some modern professional oscilloscopes will handle frequencies to 4 mc). Therefore, instead of making a connection to the vertical input posts of the oscilloscope a connection should be made from the plate of the last IF amplifier tube of the receiver through a capacitor directly to the vertical deflection plate of the oscilloscope. The capacitor need be of no more than 0.0001 mfd capacitance, but must have a voltage rating high enough for the amplifier plate voltage. The ground of the oscilloscope is connected to the receiver chassis through a blocking capacitor which may be of almost any capacitance value greater than 0.001 mfd.

The sweep frequency is adjusted for the modulating frequency of the generator, which often is about 400 cycles. The sweep may be synchronized for a stationary pattern by using the regular sync amplitude control. Connect the external sync post of the oscilloscope to the AF output, at modulating frequency, of the signal generator. Then set the sync selector switch of the oscilloscope for external synchronization.

Fig. 13 shows the trace pattern, as made with the setup of Fig. 12, with an intermediate frequency of 456 kilocycles amplitude-modulated at 400 cycles and applied to the converter signal grid.

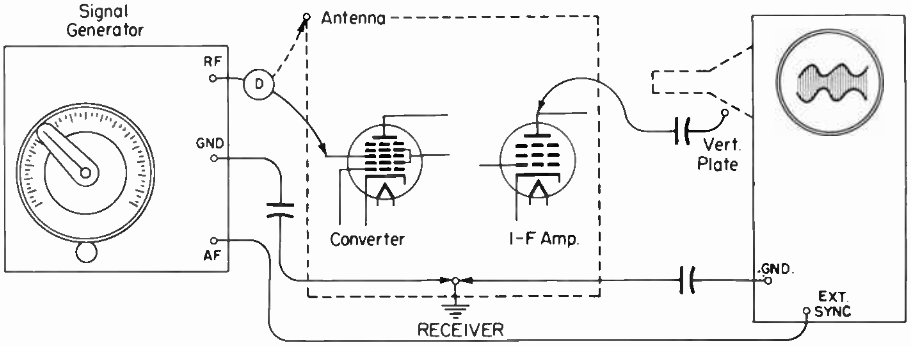


Fig. 12. Connections for Observation of RF or IF Envelopes, Either Modulated or Unmodulated.

The audio-frequency wave, which provides the upper and lower envelopes in Fig. 13, now may be observed by taking the oscilloscope lead off the plate of the IF amplifier tube and connecting it to the detector load resistor or to the high side of the volume control. This connects the vertical deflecting plate of the oscilloscope to the detector output. No other connection changes are required, nor should they be made, and the output of the signal generator should not be altered. A picture of the demodulated wave made in this manner is shown by Fig. 14. Note that the waveform of this AF signal is the same as the upper envelope of the modulated wave of Fig. 13, which indicates that there is no distortion in the detector stage. Were there any alternation of the waveform it would result from overload or from some incorrect operating condition in the detector stage.

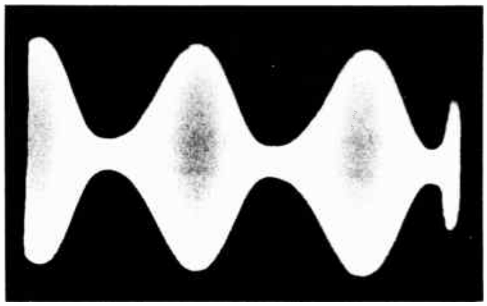


Fig. 13. High Frequency Wave.

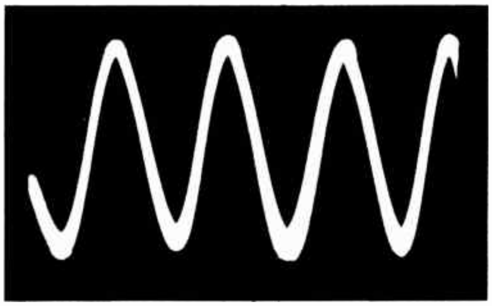


Fig. 14. The Demodulated Audio-Wave from the Detector.

Now the input from the signal generator may be shifted to the antenna post of the receiver, with the oscilloscope vertical deflecting plate connected to the plate of the last IF amplifier tube. The generator and the receiver tuning dial must be tuned to the same frequency. The trace pattern should appear like the one shown by Fig. 13 if there is no trouble in the antenna and RF stages of the receiver. The same radio frequency from the generator and in the receiver tuning will be indicated when the loops of the modulation envelope reach maximum height as either the generator tuning or receiver tuning is varied.

Fig. 13 shows modulation of about 60 per cent. Percentage modulation, as a fraction, may be determined by first measuring the vertical distance between envelope peaks where they are farthest apart, calling this the maximum amplitude, and then measuring the vertical distance between depressions where they are closest together, calling this the minimum amplitude. The next step is to subtract the minimum from the maximum amplitude, calling this the difference, and then to add the maximum and minimum, calling this the sum. Finally, dividing the difference by the sum gives the modulation fraction, which may be multiplied by 100 to determine percentage of modulation.

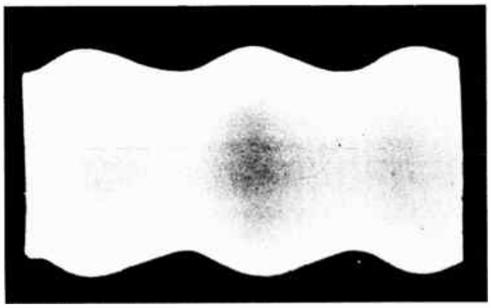


Fig. 15. Smaller Percentage Modulation.

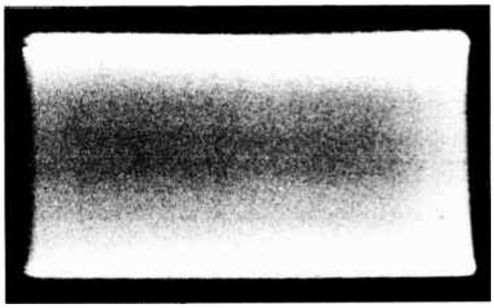


Fig. 16. Unmodulated High-Frequency Wave.

Fig. 15 shows audio-frequency modulation of about 26 per cent, with the same high-frequency, either radio or intermediate, as before. Fig. 16 shows the high-frequency wave, either radio or intermediate frequency, with no modulation at all. Since the sweep frequency here is set for the frequency of the audio modulation, the separate alternations of the high-frequency wave are far too close together to be distinguished; they form merely a blur on the screen, with separation between top and bottom proportional to the high-frequency peak amplitude.

If there is distortion in the RF or IF system, which would cause irregularities in the waveform were the unmodulated RF or IF wave to be observed, there will be horizontal streaks of lighter area intervening with darker bands on the unmodulated trace. That is, instead of having a trace like that of Fig. 16 where the only bright lines are at the top and bottom, there will be a pattern on the general order of the one shown by Fig. 17, with intermediate light streaks. The trouble in the case of Fig. 17 was due to harmonic frequencies.

It is apparent that connection of the signal generator and the oscilloscope to various places in the receiver will show where faults are originating. Faults which cause incorrect patterns must be somewhere between the connections of generator and oscilloscope, and by bringing the two closer and closer together the trouble may be located as existing in some one stage or in a small section of the receiver.

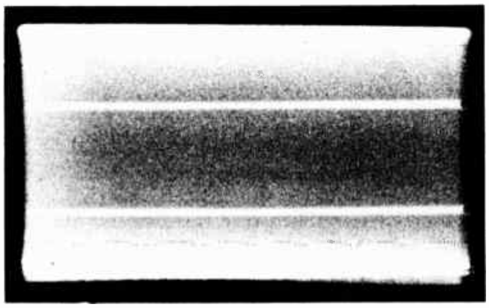


Fig. 17. Distortion in RF or IF Systems Cause Streaks in the Unmodulated Wave.

F. Voltage Measurements With a Scope

If the horizontal gain control is set at zero and an alternating potential applied to the vertical input of the oscilloscope, the height of the vertical trace line will be proportional to the applied potential. The height corresponding to a certain voltage may be determined by applying a known voltage and measuring the trace. If the vertical gain control is readjusted the voltage proportion to height of trace will be affected because the amplifier does not respond uniformly with control settings. With the gain control at maximum most amplifiers are "flat" for all frequencies up to some certain limit, which may be anything from about 50 kilocycles to several megacycles, depending on the type of instrument and amplifier. At higher frequencies the gain falls off rapidly. If the measured potential is applied directly to the vertical deflection plates the frequency response will be uniform all the way from direct current up to a hundred megacycles or more, but then a considerable potential is required to get measurable deflection.

In practice the oscilloscope is limited to measurement of frequencies not much higher than the audio range when voltages are low, and is limited to fairly high potentials at all higher frequencies where potential measurements are to be made.

G. Hum Tracing

The oscilloscope may be used for checking the existence and magnitude of hum voltage or ripple voltage at various points in the filter and voltage divider or voltage-dropping systems on radio apparatus. Start with the sweep frequency adjusted to the frequency of the power supply line by applying a low potential at line frequency to the vertical input. Then the ground of the oscilloscope is connected to the receiver chassis ground (or floating ground). To the vertical input post of the oscilloscope is connected a test lead with a prod on the free end. In series with this prod lead should be a capacitor of at least 0. 25 mfd and of a working voltage as high as the maximum peak potential which may come from the rectifier tube. This potential should be assumed as equal to at least double the highest plate voltage for any tube in the receiver or other apparatus.

With the vertical gain control turned low touch the prod to the rectifier cathode lead or to the input of the filter system and adjust the vertical gain to allow observing the pattern of the rectifier output. With half-wave rectification there will be one peak per cycle, and with full-wave rectification there will be two peaks per cycle. Then move the prod successively to following points in the filter system, proceeding toward the filter output, and then along the voltage divider or voltage-dropping resistors toward the connections for plates and screen grids of the various tubes.

The ripple voltage should lose its sharp peaks and become smaller and smaller, requiring higher and higher setting of the vertical gain to observe it at all. Since the DC output of the filtering system never becomes pure direct current it always will be possible to observe some ripple at line frequency or double this frequency by turning the vertical gain high enough, but when high gain is needed the ripple voltage no longer will cause objectionable hum.

H. Summary Questions

1. Which waveforms shown in this lesson indicates overloading?
2. By diagrams show how you would connect the equipment for audio-amplifier waveform analysis.
3. Why are the capacitors used in the ground leads of the oscilloscope and signal generator?
4. What is one method of measuring an AC voltage with the oscilloscope?
5. List the steps for Hum tracing.

COMPARISON OF AM AND FM CARRIER WAVES

Objective:

To learn the general principles of frequency-modulation transmission.

References

Lesson Content

A. Introduction

Radio engineers were searching for a method of eliminating noise from the AM type of transmission and reception, when the idea of changing the frequency of the carrier wave at an audio rate was developed. This development has proven better under adverse conditions as to noise free reception and easier to eliminate interference from other nearby stations operating on the same frequency.

FM transmitter circuits are so arranged that it is more economical to produce a given wattage signal with this equipment than to produce the same wave with amplitude modulation. The large difference in cost however, lies in the audio power required to produce a certain signal strength signal. With AM the audio power is generally 50 percent of the average carrier power, which may require many thousands of watts for a powerful station. In FM the audio required represents only a fraction of the output power and can be generated more easily.

FM and AM fidelity could be equal if it were not for the 10kc band width in AM. FM will prove better fidelity under the present FCC regulations.

B. Definitions

1. Modulated Carriers

Radio waves whose amplitude, frequency, or phase has been changed at an audio rate.

2. Amplitude modulation (AM)

The result of superimposing the audio onto the RF carrier by changing the carrier amplitude at an audio frequency rate.

3. Frequency modulation (FM)

The result of superimposing the audio onto the RF carrier by changing the carrier frequency at an audio frequency rate.

4. Sidebands

The RF frequencies other than the carrier frequency produced as a result of combining the RF and the AF signals.

C. Carrier Waves

Carrier waves may be described by specifying frequency in kilocycles or megacycles per second; or by amplitude in terms of the field strength, which usually is expressed in millivolts or microvolts per meter of antenna height. If either the amplitude or the frequency is varied in a manner that corresponds to changes in an audio-frequency voltage, it becomes possible to transmit through space the audio-frequency signals and to reproduce the original sounds at the speaker of the receiver. Such variation of the carrier characteristics is called modulation. If the amplitude of the carrier is varied while the frequency remains constant we have AMPLITUDE MODULATION. If the frequency is varied while the amplitude remains constant we have FREQUENCY MODULATION.

Radio waves (also the potentials and currents induced in receiver circuits) are represented as in Fig. 1. Variations of amplitude may be shown, as at the top, by differences between relative heights of the curves in the graphs. Variations of frequency may be shown, as at the bottom, by placing successive alternations closer together for higher frequency and farther apart for lower frequency; assuming that a given horizontal distance represents the same period of time in all cases. The carrier waves, before modulation, are identical with the possible exception of their fundamental frequency.

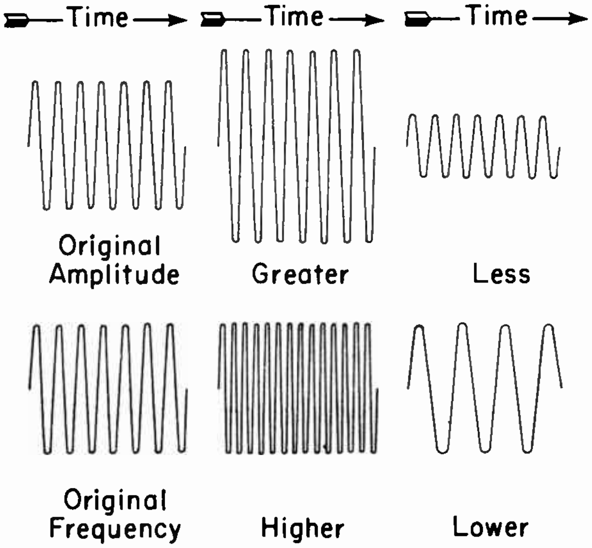


Fig. 1. How Variations of Amplitude (Top) and of Frequency (Bottom) May be Shown by Curves or Waves.

D. Amplitude Modulation

Fig. 2 shows the principle of amplitude modulation. At the top of Fig. 2, is a curve representing the rise and fall of amplitude in a low-frequency or audio-frequency signal which is to be transmitted. The carrier amplitudes are shown at the bottom of Fig. 2. At the left the carrier is unmodulated, meaning that its amplitude does not vary. At the right the carrier is modulated with the low-frequency signal. In effect, the instantaneous amplitudes of the signal are combined with the instantaneous amplitudes in the carrier. When the modulating signal rises above its average value, the amplitude of the carrier is proportionately increased at every instant, and when the signal amplitude falls below its average the carrier amplitude is proportionately decreased. The modulated carrier then is transmitted at constant frequency and with varying amplitude. In the case of amplitude modulation we are transmitting the characteristics of the AF signal; its frequency and its intensity or loudness.

The frequency of the AF signal is represented in the modulated carrier by the time intervals between successive maximum or minimum carrier amplitudes, and by the number of such intervals per second, which corresponds to the signal frequency in cycles per second. The strength or intensity of the AF signal is represented by the difference between maximum amplitudes in the carrier. A loud sound causes greater amplitude differences than does a weak sound. The carrier frequency remains unchanged.

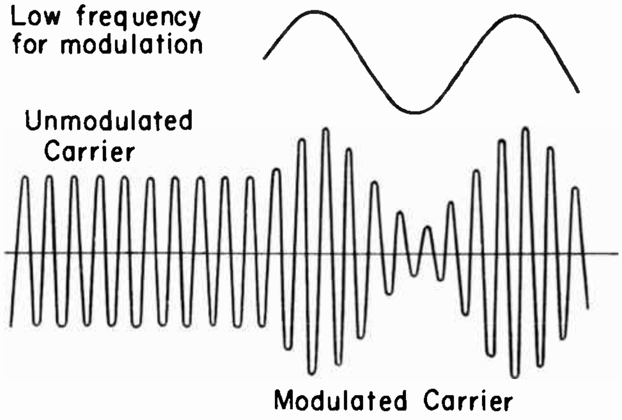


Fig. 2. Amplitude Modulation of a Carrier Wave.

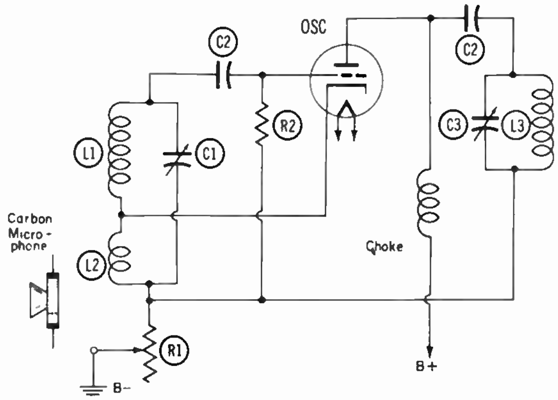


Fig. 3 A Simple Method of Amplitude Modulating the RF Oscillator.

A simplified explanation of amplitude modulation is as follows:

The variable resistor, R1, shown connected in series with the tank circuit (Fig. 3), represents a carbon microphone similar to the familiar telephone transmitter unit. As speech is imposed onto the microphone, the current in the tank circuit varies at the audio rate. This change in current will cause the total circuit current to "pulse" at the audio rate and result in amplitude modulation.

E. Frequency Modulation

Fig. 4 shows the principle of frequency modulation. At the top are represented variations of amplitude in an AF modulating signal, below are shown the corresponding variations of frequency produced in the carrier while the carrier amplitude remains unchanged.

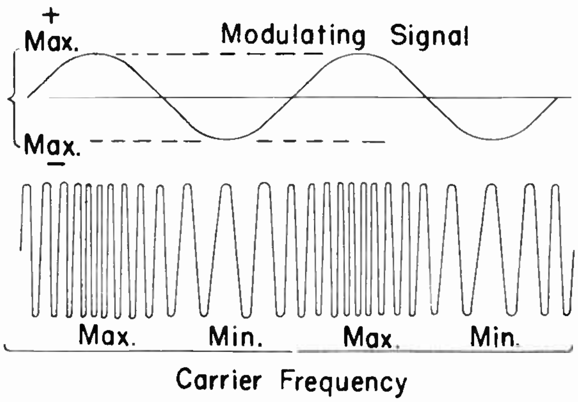


Fig. 4. Frequency Modulation of a Carrier Wave.

At the left, where the modulating signal has zero amplitude, the carrier frequency has its unmodulated value shown as "Original Frequency" in Fig. 1. The carrier frequency increases as the signal amplitude becomes more positive. The amount the carrier frequency increases depends on the amplitude of the modulating signal; the louder the sound and the greater the AF amplitude, the greater will be the carrier frequency. As the signal amplitude returns to its zero value the carrier frequency returns to its unmodulated value, which we may call the center frequency. As the audio signal amplitude then goes negative in the second part of its first cycle, the carrier frequency decreases from the center frequency. When the signal amplitude reaches its maximum negative value the carrier frequency will have reached its minimum value. Then, as the signal amplitude returns to zero the carrier frequency will return to the center value.

In frequency modulation we transmit the same two characteristics of the AF signal as with amplitude modulation; we transmit sound frequency and sound intensity or loudness. Sound frequency corresponds to the time intervals between successive instants of maximum carrier frequency, or of minimum carrier frequency. Two complete cycles of modulating signals are shown in Fig. 4. During each cycle the carrier frequency starts from its center value, goes to maximum, then to minimum, and back to the center value. The number of times per second that the carrier frequency goes through these changes is the same as the cycles per second of the modulating sound frequency.

The extent of change in carrier frequency above and below the center frequency corresponds to the loudness or intensity of the sounds represented by the modulating signal. It is important to keep in mind that sound intensity is represented by the extent to which the carrier frequency changes, and that sound frequency is represented by the number of changes per second in the carrier frequency.

A simplified explanation of frequency modulation is as follows:

A variable capacitor across the tank circuit shown in Fig. 5, represents a capacitor microphone. As speech is imposed onto the microphone, the capacity of the capacitor microphone will change at the audio rate. This change in capacity will deviate the resonant frequency of the tank circuit at the audio rate, and result in frequency modulation.

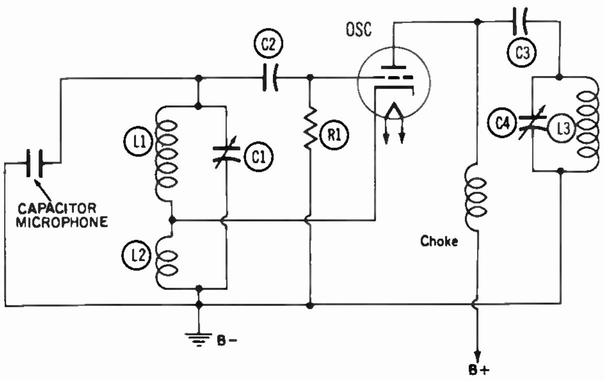


Fig. 5. A Simple Method of Frequency Modulating the RF Oscillator.

F. Deviation

The number of kilocycles by which the FM carrier frequency varies above and below the center frequency is called the deviation, or the frequency deviation (frequency shift). In a transmitter and receiver the deviation might be made almost any number of kilocycles, but it has been agreed that the maximum sound loudness (amplitude) of the modulating signal which is to be transmitted shall be represented by a deviation of not more than 75 kilocycles above and below the center frequency of the carrier. This means that the total maximum change of carrier frequency will be twice this deviation, or will be 150 kilocycles as shown in Fig. 6. On this basis each FM transmitted signal will occupy a frequency band width of 150 kc.

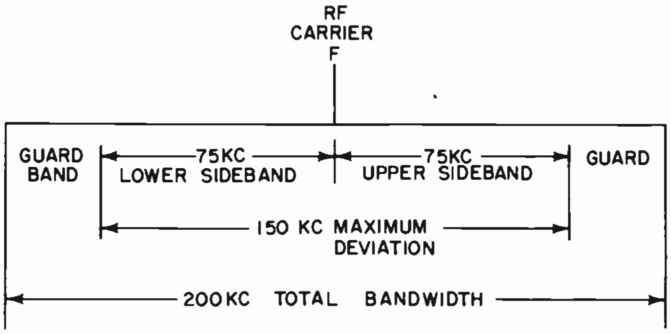


Fig. 6. FM Station Channel Allotment.

1. Modulation Index = $\frac{\Delta F}{f}$

The ratio of the maximum deviation to the maximum sound frequency transmitted is called the deviation ratio. With maximum deviation of 75 kilocycles (75,000 cycles) and the highest audio frequency transmitted 15,000 cycles, the deviation ratio would be 75,000/15,000; this equals a modulation index of 5. Modulation Index can be expressed in the form of a formula: Delta F divided by f equals modulation index. Where delta F means the amount of frequency shift or deviation and f means the audio frequency causing this shift in the carrier frequency.

2. Bessel Function Chart, Fig. 7

Refer to the Bessel Function chart and find the modulation index of 5. Follow to the right and in the second and third columns you will find the number of sidebands created by this modulation index. The total number of sidebands times the audio frequency (f) equals the total bandwidth required to transmit the signal using the deviation ratio. Divide the total bandwidth by 2 and this will determine the bandwidth on either side of the carrier.

3. Sidebands

In FM, we have seen, the carrier frequency is shifted back and forth from its central resting point. Now in the process of frequency-modulating a wave, sidebands are formed. It will be remembered that the same thing happened when a carrier was amplitude-modulated. In FM, however, we obtained more than a pair of sidebands for each modulating frequency. In fact, the number of sidebands produced will depend largely upon the strength of the audio-modulating voltage. A strong voltage will produce many sidebands; a weak voltage will produce few sidebands. This is illustrated by the value F/f. With no modulating voltage, there will be no sidebands. Fig. 8B illustrates the sidebands and their placement above and below the carrier for a typical case. Fig. 8A represents the carrier before modulation is applied.

In Fig. 8B, we can count seven sideband frequencies above and below the carrier. All of these are due to a single modulating note. Each sideband is separated from its neighbor by an amount equal to the frequency of the mdoulating signal itself. If we whistle a 1,000-cycle note into the microphone, a series of cycles apart, the strength of the sidebands decrease until the very end ones shown contain so little power as to be of no practical importance in the formation of the signal at the receiver.

To review, then, we find the following situation prevailing. As the carrier frequency is shifted by the audio-modulating voltage, sidebands are formed which stretch away in both directions from the carrier resting frequency. When the audio-modulating voltage is strong, there will be many sidebands containing appreciable power and the signal will occupy a greater bandwidth. On the other hand, when the modulating voltage is weak, only a few significant sidebands will be formed.

Each carrier can be shifted plus-minus 75 kc from its center frequency. With sufficient power, the sidebands formed by this shifting can extend beyond the plus-minus 75 kc limits. Hence, to minimize interference to other stations, the 25 kc guard band (at each band end) is added. This is shown in Fig. 6.

4. Sideband Power

In Fig. 8B a comparison of the amplitudes of the several sidebands with each other and the carrier indicates that; first,carrier power diminishes during modulation; second, it is possible for one or more sidebands to contain more power than the carrier.

Modulation Index	Number of Significant Sidebands		Bandwidth Required (f = frequency of audio signal)
	Above Carrier	Below Carrier	
0.01	1	1	2f
.02	1	1	2f
.03	1	1	2f
.04	1	1	2f
.05	1	1	2f
0.1	1	1	2f
.2	1	1	2f
.3	1	1	2f
.4	1	1	2f
.5	2	2	4f
1.0	3	3	6f
2.0	4	4	8f
3.0	6	6	12f
4.0	7	7	14f
5.0	8	8	16f
6.0	9	9	18f
7.0	10	10	20f
8.0	12	12	24f
9.0	13	13	26f
10.0	14	14	28f
11.0	16	16	32f
12.0	17	17	34f
13.0	18	18	36f
14.0	19	19	38f
15.0	20	20	40f

Fig. 7. Bessel Function Chart.

The power that is taken from the carrier, during modulation, is distributed among the various sidebands. The louder the modulating signal, the greater the energy that will be taken from the carrier. In fact, it is perfectly possible for the carrier, during one of these modulation sweeps, to contain no energy at all; the sidebands then possess it all. A moment's reflection should show that a transfer of some or all of the original carrier energy to the sidebands must occur, because the total frequency-modulation signal does not vary in amplitude. Thus, the only way to satisfy this condition, during modulation, is to transfer part (or all) of the carrier energy to the sidebands. This is a characteristic of FM.

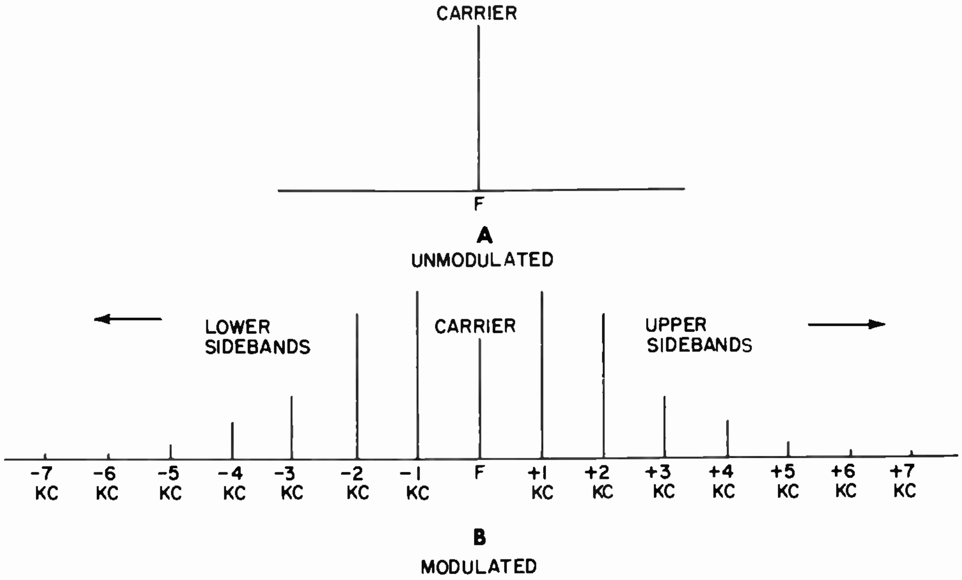


Fig. 8. An FM Signal With its Sideband Developed as a Result of Audio Modulation.

G. Summary Questions

1. Define the term modulation.
2. Describe the principle of amplitude modulation.
3. Describe the principle of frequency modulation.
4. What is the bandwidth for FM transmission?
5. What characteristic of the FM modulated carrier determines the output frequency?
6. What does modulation index refer to?
7. What determines the instantaneous bandwidth for an FM station?
8. What determines the number of sidebands for an FM station?

COMPARISON OF THE AM TO THE FM RECEIVER

Objective

To study the similarities of the two receivers and to learn the major differences between the two.

References

Lesson Content

A. Introduction

When studying AM radio you found the most popular receiver circuit was the superheterodyne. This is also true of FM receivers. An FM superheterodyne contains most of the circuit components needed for AM reception so it is quite easy to build sets which will receive both types of transmission.

The block diagram, Fig. 1, shows the principal parts of a receiver designed for reception of frequency-modulated and amplitude-modulated signals. Some such receivers are arranged to also receive short-wave signals. To the antenna coupling circuits may be connected a dipole or modified dipole for FM reception. In addition, a built-in loop antenna is used for standard broadcast (AM) reception, and an external L-type or capacitance antenna for short-wave and standard broadcast reception.

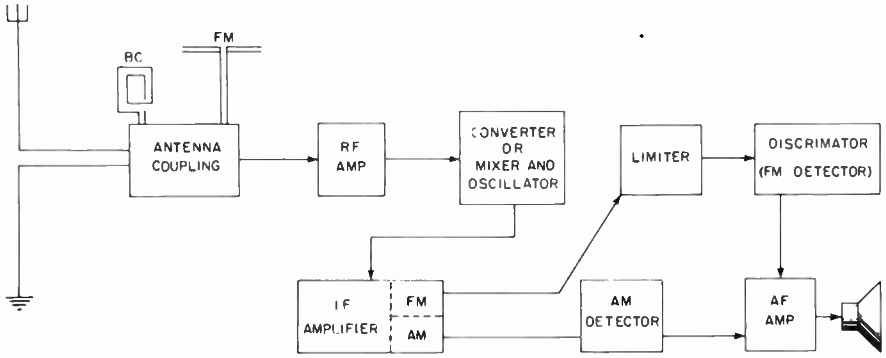


Fig. 1. Principal Parts of a Receiver Designed for Both FM and AM Reception.

Different bands may be selected by operation of a band-selector switch. Band switching is required between the antenna circuits and the control grid circuit of an RF amplifier tube; also between the RF output and the signal output to the converter, or mixer; in the tuned circuits for an oscillator or the oscillator circuit of the converter; and in the grid and plate circuits of the IF amplifier stages.

The limiter stage in the FM receiver is used to limit the amplitude variations of the carrier signal as it is applied to the FM discriminator which is the FM detector stage. If the amplitude modulated signals pass through this stage the intelligence will be removed from the carrier.

FM detection depends upon a change of carrier frequency rather than a change in amplitude; therefore, a slight difference in the detector circuits will be noted.

The audio amplifier stages are common to both AM and FM because the audio frequency range remains the same regardless of the type of modulation.

B. Receiver Tuning Units

Separate tuning circuits in the RF and IF stages will be necessary because the carrier frequencies for AM are from 550 kc to 1700 kc, and for FM the carrier frequency is from 88 mc to 108 mc. FM receivers sometimes have very special tuning mechanisms due to the very high frequency of the RF carriers.

FM receiver tuning devices will vary with manufacturers. Some manufacturers will use variable capacitance while others will use variable inductance. Many combinations may be obtained from these two variables.

Since the FM Broadcast frequencies are so much higher than the AM broadcast frequencies, the tuning capacitors or variable coils for FM will be considerably smaller for FM reception.

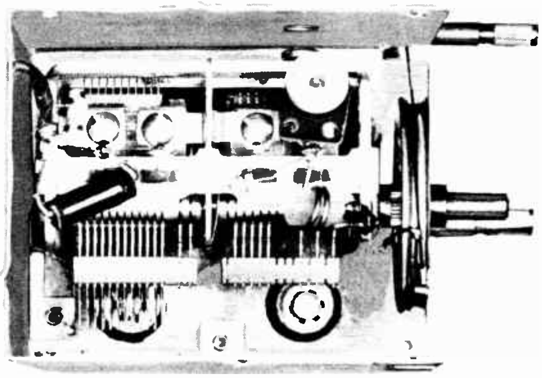


Fig. 2. Top View of an AM - FM Tuner Showing the FM Tuning Capacitors.

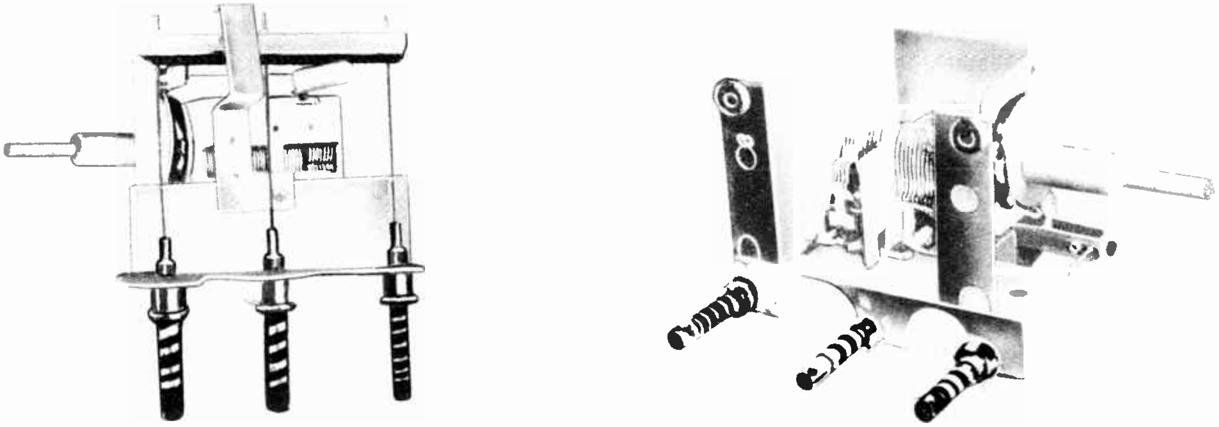


Fig. 3. Two Methods of Mounting and Tuning Permeability Coils Used in FM Receivers.

The most widely used type of tuning is variable capacity. In AM-FM receivers, the small, widely-spaced plates for FM will be mounted on the same shaft as the larger AM plates. The stator plates will be insulated and connected to a switch to select the proper set of plates for the band to be received. Fig. 2 is a photograph of this type tuner.

An inductively tuned receiver would use the same general approach. The tuning coils would be smaller for FM. All the slugs would move into or out of the coils at the same time. A switch would select the coils to be used for either AM or FM operation.

Several arrangements have been worked out for tuning AM capacitively and FM inductively from the same shaft. Such an assembly is shown in Fig. 3. This device provides AM or FM tuning from the same shaft by mounting the FM coils on the gang capacitor by a special bracket. The part showing to the front of Fig. 3 normally faces down. In this tuner a powdered iron core is moved up and down in a coil, thereby producing corresponding inductance variations. Four wires instead of one are used in winding the coil to overcome the difficulty of obtaining the necessary inductance change for a complete travel of the core within the distance alloted to it on the dial, as is shown in Fig. 4. A tuner similar to that shown in Fig. 3, is shown in Fig. 5 as it appears in the chassis of an AM-FM Receiver.

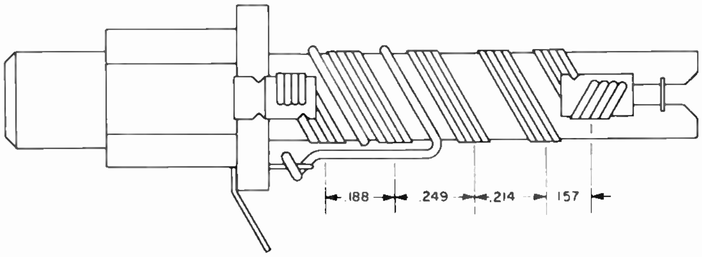


Fig. 4. A Four-Wire Permeability-Tuned Coil. The Variable Pitch Produces a Linear Characteristic.

There are two other types of tuners which have been used for FM tuning. The Mallory Inductuner and the GE "Guillotine" tuner are two very specialized approaches to FM tuning. The Inductuner, as the name implies, varies inductance to change the resonant frequency. Ten complete turns of the coil carries the sliding contacts from one end of the coil to the other. The position of the contact on the coil determines the number of turns being used and, therefore, determines the amount of inductance in the circuit at a given setting.

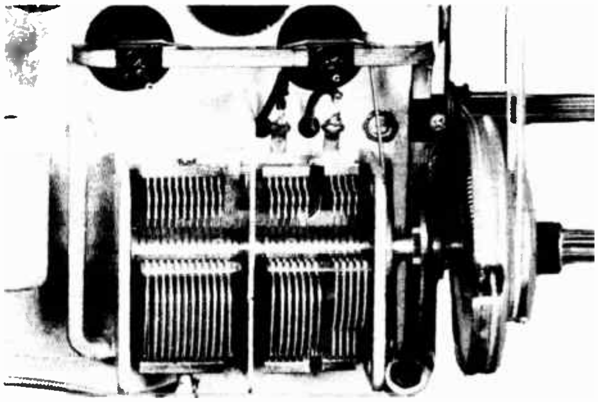


Fig. 5. Top View of an AM - FM Tuner Using Permeability-Tuned Coils for FM Reception.

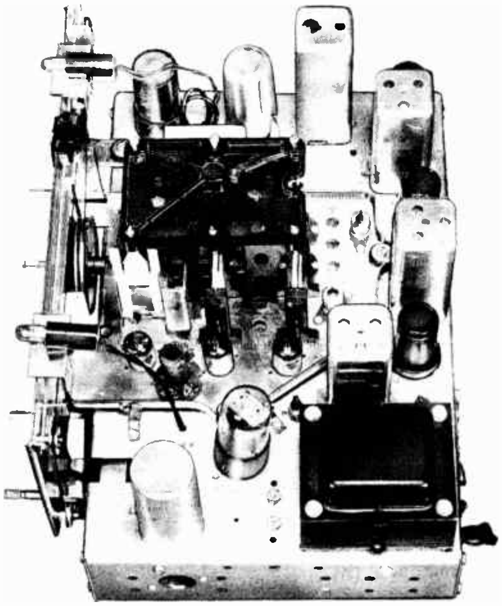


Fig. 6. An AM-FM Receiver Employing a "Guillotine" Tuner.

The G. E. "Guillotine" tuner consists of two identical brass frames, when connected at their open ends, form a two-turn inductance. The sliding brass blade acts as a shorted turn to vary the inductance and mutual coupling. A receiver using this type of tuner is shown in Fig. 6.

C. FM Receiver Block Diagram, Fig. 1

1. The RF Amplifier

To obtain frequency stability and sensitivity in the front end of the FM tuner, a low interelectrode capacitance miniature-type tube is used. This tube will have high gain at the high frequencies. The tube usually is of the remote cut-off type in order that AVC (Automatic Volume Control) may be applied. The purpose of this stage is to select and amplify the desired RF signals from the FM transmitters and reject the undesirable signals. As the tube is amplifying the desired signals, however, the tube noises will be impressed onto the desired carrier by causing the amplitude of this carrier to vary in accordance with the noise. In AM sets this noise would be demodulated and heard. In FM receivers, however, this noise is amplified but limited in another portion of the receiver and will not be demodulated and heard. The output of this RF amplifier is fed to the mixer or converter RF grid where it will be heterodyned with the local oscillator frequency. The plate load for the RF amplifier must pass a 150 kc bandwidth to reproduce each of the deviation ratio signals which is carried by the RF carrier.

2. Mixer or Converter Stage

Fig. 7 shows a circuit which may be used in FM receivers between the antenna and the input to the IF amplifier. Here the antenna is inductively coupled to the control-grid circuit of the RF amplifier. There is an RF choke coil L1 in series between the plate and B plus. Signal transfer is through coupling capacitor C1 to the signal grid, with the tuned circuit "A" between the signal grid and ground.

Mixer and oscillator functions are combined usually in a pentagrid converter tube, as in Fig. 7. Other types of converters, such as a pentode-triode, sometimes are used or dual triode tubes may be used. The oscillator circuit of Fig. 7 is shown at B in the diagram and is of the Hartley type. This oscillator is connected between the oscillator grid and the cathode of the converter tube.

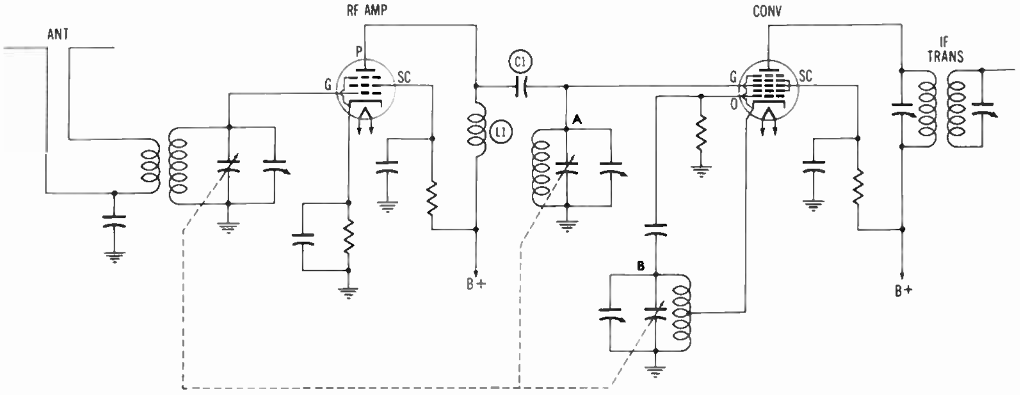


Fig. 7. Circuits Between a Dipole Antenna and the First IF Amplifier.

The oscillator frequency will combine or heterodyne with the incoming signal frequency and produce, in the output of the mixer or converter stage, an intermediate frequency (IF). A common value for IF frequency is 10.7 mc. It is desirable that none of the incoming carrier frequencies be the image frequency of any other received carrier, for this avoids interference between two carriers which may enter the amplifiers at the same time. If, for example, the lowest received carrier is at 88 mc and the highest at 108 mc, we desire that the image of the 88 mc frequency be higher than 108 mc. We know that the image of the 88 mc frequency will be higher by twice the intermediate frequency, and to get this image above the high limit of the band it must be above 108 mc. If we make the intermediate frequency 10 mc, twice its value will be 20 mc, and 20 mc added to our 88 mc make 108 mc, which is just at the top of the band (high end). Then to throw the image a little higher, we must use an intermediate frequency of more than 10 mc. It works out in all cases that the intermediate frequency should be more than one-half of the full frequency range of carriers to be received.

In our example the full range is from 88 mc to 108 mc, a band of 20 mc. (108 minus 88 equals 20 mc) and we have found that the intermediate frequency should be more than 10 mc, which is half of the 20 mc bandwidth.

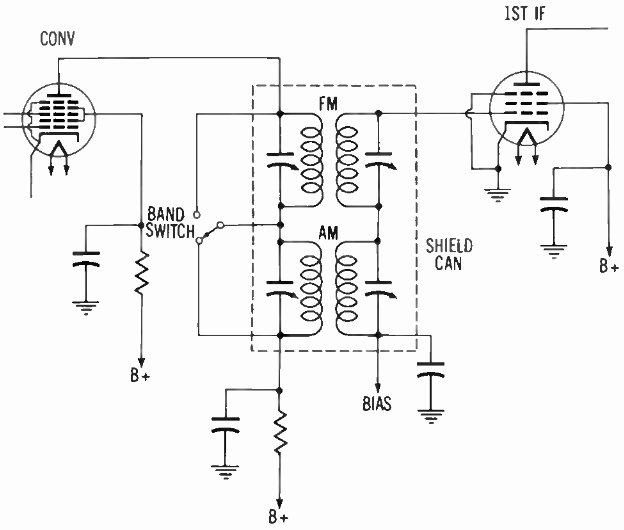


Fig. 8. A Dual IF Transformer for AM and FM Coupling.

3. Intermediate Frequency Amplifiers

The AM-FM combination receiver employs the same IF amplifier tube by means of a band switching arrangement, Fig. 8. The IF transformers have one section for FM and another for AM coupling. The AM sections connect through to the AM detector which is of the usual diode type, as shown in Fig. 9. The FM sections connect to a limiter or partial limiter stage which normally removes any amplitude modulation of the signal which may have come through the preceding stages or which may have been introduced by the receiver circuits. This connection is shown in Fig. 9.

Usually there are two, and sometimes more than two IF circuits because of the wider frequency range of the FM signal. The AM receiver normally uses only one IF stage because necessary gain may be obtained for the 10 kc bandwidth.

We will assume that the maximum deviation in FM will be 150 kc or 75 kc in each direction from the carrier resting frequency. At minus 75 kc and again at plus 75 kc we have gains of about 63 percent of maximum as shown in Fig. 10. At the center or resting frequency, which would be the unmodulated intermediate frequency, the gain is about 70 per cent. The peak gains occur at around minus 40 and plus 50 kc. This curve, Fig. 10, may be obtained by rather close coupling between the primary and secondary of the IF transformers or by connecting a resistor of the correct value across one or more of the secondary windings.

Because of the relative gains varying between minus 75 kc and plus 75 kc there will be a resultant in a variation in the amplitude of the IF carrier, and the limiter stage will not receive a constant amplitude which has been transmitted from the transmitter. Other variations in the amplitude are caused by noise which originates quite likely in the preceding RF amplifier and converter stages.

4. The Limiter Stage

The limiter stage is relied upon to remove whatever amplitude modulation is introduced by the amplifier stages. With an input to the limiter such as represented by Fig. 11A, we might operate the limiter tube in such a manner that its own maximum output can be only that corresponding to a gain of 50 on the curve shown in Fig. 10. That is, the limiter stage may be constructed and operated so that no matter how much the input exceeds a certain value (our assumed 50 per cent for example) the limiter output will remain constant.

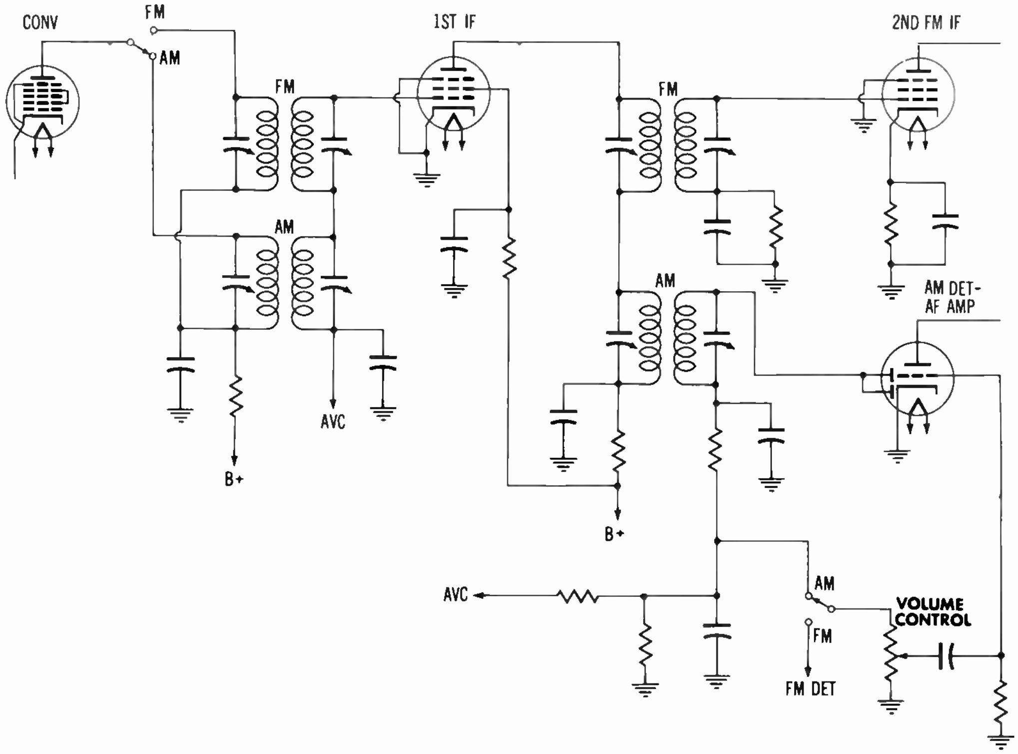


Fig. 9. A Circuit Employing the First IF Tube for Amplification of Both AM and FM Signals.

There are two methods of obtaining a constant output amplitude from the limiter: One is by using a grid leak bias type of limiter and the other is by using the low voltage type of limiter.

The grid leak bias type of limiter is shown in Fig. 11B. This type of limiting is accomplished by the grid leak resistor and capacitor when their action will allow the plate current to saturate and then cut off. The limiter stage using a sharp cut-off tube with grid leak bias will saturate on positive peaks and cut off on negative peaks. This action will produce a constant amplitude in the IF carrier and will not effect the intelligence which is within the change in carrier frequency.

The limiter grid capacitor and resistor are not necessarily connected only as shown by Fig. 11B, but may be anywhere in the grid circuit so long as they are in parallel with each other and in series between the control grid and cathode.

The time constant of the capacitor and resistor is chosen chiefly with reference to the highest audio-frequency to be reproduced, which will be also the highest noise frequency reproduced. To prevent the noise frequency from driving the plate to cut-off and holding it there, the time constant must be considerably shorter than the period of the highest audio frequency. This means the charge of the grid capacitor must be allowed to leak off between successive pulses of excess amplitude when the pulses are recurring at some audio frequency.

5. The FM Detectors

When receiving an amplitude modulated carrier, the type of detector is the common diode detector which responds to the change in amplitude on each positive alternation. This produces a PDC (Pulsating Direct Current) at the rate of the carrier frequency. This PDC is stored in a

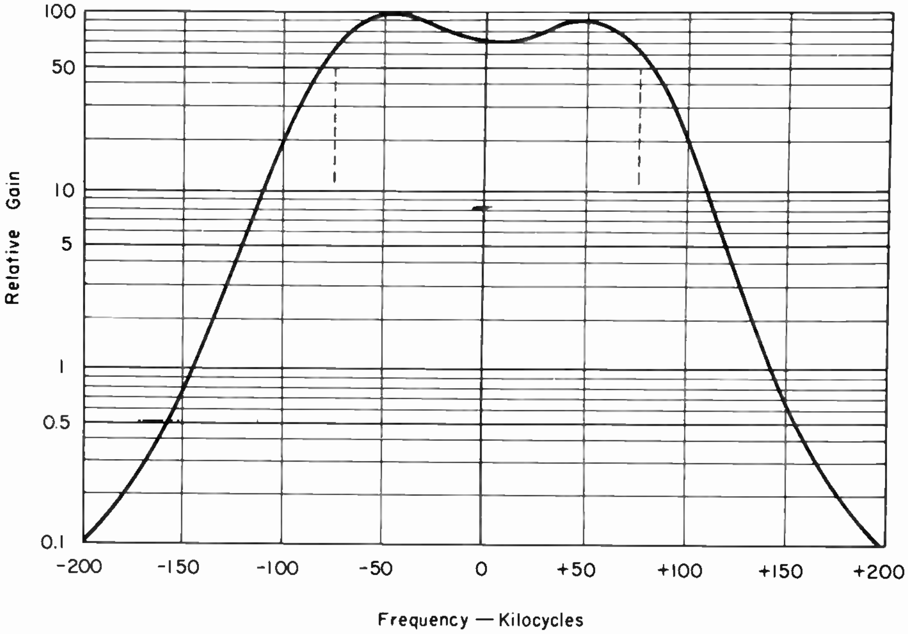


Fig. 10. Gain at Various Deviations in a Typical IF System.

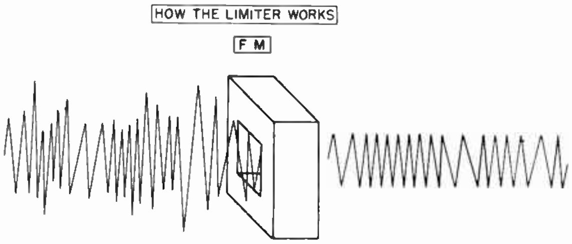


Fig. 11A. How the Limiter Functions to Smooth out the Amplitude Variations in the Frequency Modulated Signal.

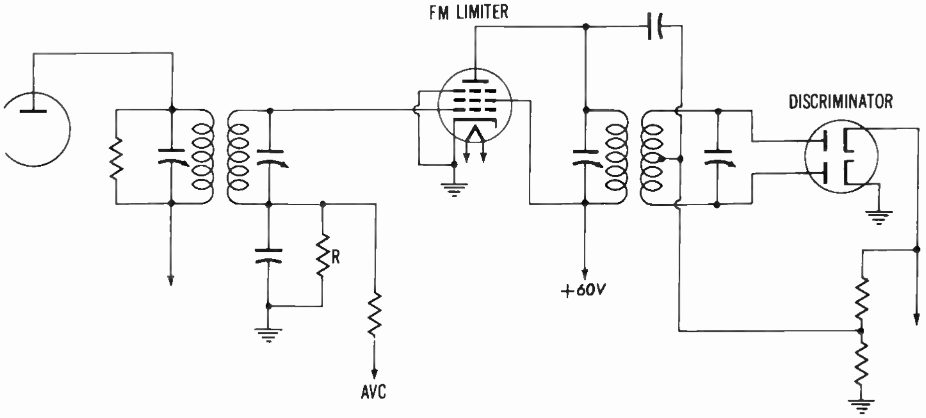


Fig. 11B. An FM Limiter Stage Employing Grid-Leak Bias.

capacitor and the discharge of this capacitor on the negative alternations of the carrier must pass through the diode load resistor and will not discharge at the rate at which it charged. This filtering will eliminate the RF carrier frequency and recover the audio variations which are represented in the carrier amplitude.

The FM detector must respond to a change in carrier frequency; therefore, a slightly different system must be used to detect the signal. Fig. 12 shows the double tuned discriminator. The primary circuit L1 is tuned to the IF value of 10.7 mc. The upper tuned secondary L2 is tuned to a frequency of 100 kc above the IF value; therefore, this circuit is resonate to 10.8 mc. The lower tuned secondary circuit L3 is tuned to a frequency of 100 kc below 10.7 mc which gives it a value of 10.6 mc. From this it can be seen that each tuned secondary is tuned equally above and below the incoming IF signal.

When the frequency of the IF carrier shifts above 10.7 mc the upper circuit L2, will be more near resonant to this signal and will receive or develop the greatest voltage across the tuned circuit. This voltage is applied to the upper diode tube and this tube will conduct more than the lower tube, whose voltage has decreased.

When the frequency shift of the IF carrier is below 10.7 mc, the lower circuit L3 will be more nearly resonant to this change and it will have a greater voltage drop than the upper circuit.

The above voltages will change from tube to tube at an audio rate; therefore, the output voltage across the diode loads R1 and R2 due to the capacitor and resistor filter action, will produce or recover the audio intelligence which is represented with a change in carrier frequency.

The Audio Amplifiers are common to both FM and AM. They are designed to pass a wide audio frequency range to obtain a higher fidelity when receiving FM signals.

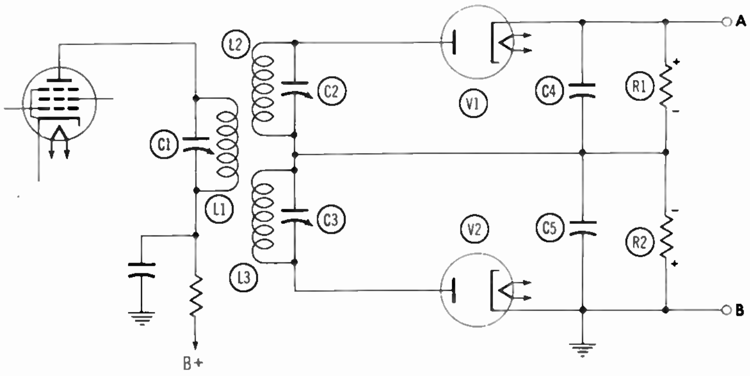


Fig. 12. The Double-Tuned Discriminator.

D. Audio Coupling Circuits

There is a noticeable difference in the method of coupling the AF signal from a discriminator in respect to AM detection. Typical circuits used between the discriminator and the first audio-frequency amplifying tube are shown by Fig. 13. Shown in Fig. 13A are connections to an AF amplifier which has cathode bias, and in Fig. 13B are connections which may be used when the AF tube is biased by the contact potential developed across R3. The control grid of the AF tube is fed from the slider on the volume control voltage divider R2.

The AF output from the discriminator, as shown by many preceding diagrams, is taken from one end of the resistor and capacitor or capacitors which are between the cathodes of the discriminator diodes or rectifiers. This may be called the "high side" of the AF output. The other side of the AF output is through ground, to which is also connected the other end of the resistors and capacitor which are between the discriminator cathodes. The connections shown by Fig. 13 are those from the "high side" through to the AF amplifier. As mentioned before, the AF amplifier elements may be in the same tube envelope with the diodes for the discriminator.

Both of the circuits shown by Fig. 13 include low-pass filters which attenuate or weaken the higher audio frequencies. The filters consist of series resistor R1 and bypass capacitor C1. In some cases, the addition of another bypass capacitor, shown by broken lines, is used. Capacitor C2 is a coupling capacitor between the filter and the volume control.

Attenuation of the higher audio frequencies is required because these frequencies have been accentuated at the transmitter. The accentuation or strengthening of the higher audio frequencies usually is called pre-emphasis, and their attenuation in the receiver is called de-emphasis. Audio pre-emphasis increases the deviation at high audio frequencies without increase of amplitude. Interference which adds itself to the modulated carrier has, in relation to signal strength, more strength at these higher frequencies than at lower frequencies in the audio range. Then the pre-emphasis brings about a more favorable ratio of signal to noise in the modulated carrier, and the accentuation of the higher audio frequencies is easily eliminated by the de-emphasis circuits in the receiver.

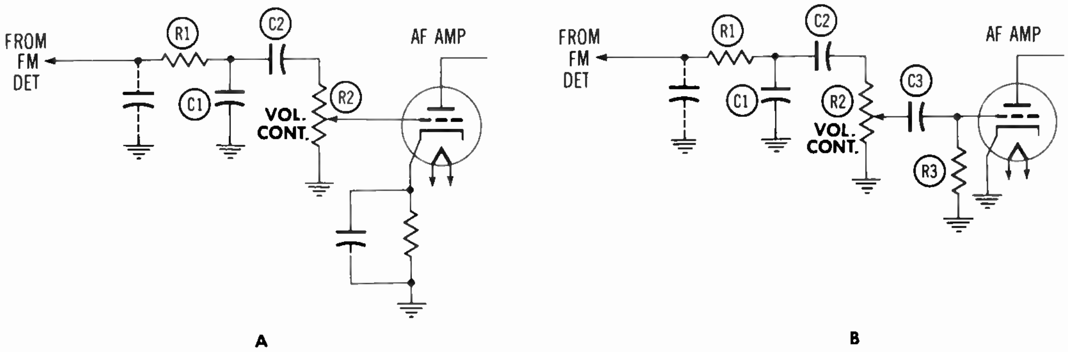


Fig. 13. Circuits Used Between The Discriminator and First AF Amplifier.

The range of audio frequencies in high-fidelity FM transmission and reception may extend up to 15,000 cycles per second, although in many commercial receivers the AF response does not extend to more than 9,000 or possibly 10,000 cycles. To reproduce both the high and low audio frequencies the receiver may be equipped with a dual loud speaker; one section for lows and another for highs, much as is used for some public address systems.

E. Summary Questions

1. What two circuits are present in FM receivers between the IF and AF stages which are not present in AM receivers?
2. Why is a limiter stage used in FM receivers?
3. What is the purpose of the discriminator stage?
4. Describe how the limiter is biased by grid rectification? Refer to Fig. 11B.
5. Why are broad-band amplifiers used ahead of the limiter stage?
6. What is the basic principle of all discriminator circuits?
7. Why are amplifiers used ahead of the mixer-oscillator stages?
8. What is the purpose of IF amplifier stages?
9. What general type of tube is used as a good limiter?
10. What is the relative gain of a typical FM-IF system at the center frequency?
11. What stages of an AM-FM receiver are common for operation of AM as well as FM?

FM DISCRIMINATORS

Objective

To learn how a frequency-modulated carrier is demodulated.

References:

Lesson Content

A. Introduction

The double-tuned discriminator shows the basic fundamentals of how the FM detector demodulates the carrier frequency which is changing in frequency at an audio rate. The detector stage of an FM receiver may use any one of several different circuit arrangements such as the Discriminator, Ratio Detector, and the unbalanced Ratio Detector, all of which produce essentially the same results. The principles employed in most FM detector circuits may be explained with the help of Fig. 1 which schematically shows a discriminator type of FM detector.

B. The Fostor-Seeley Discriminator, Fig. 1.

The transformer at the left is the one whose primary L1 is in the plate circuit of the limiter. The secondary winding is center tapped, with a connection coming from limiter plate through capacitor C2 to the tap. Connected to each of the outer ends of the secondary is a half-wave rectifier. The rectifiers are shown here as separate diodes, A and B. In practice the diodes would be in a single tube, and sometimes this tube will contain additional elements, such as those for a triode used in other circuits. The discriminator diodes would be parts of a multi-purpose tube, just as the AM detector diodes are parts of such tubes in AM receivers.

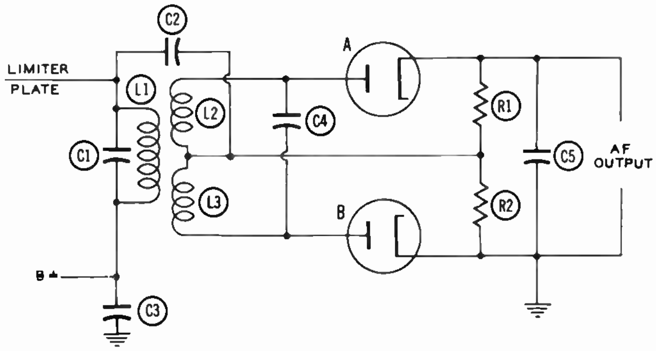


Fig. 1. A Circuit Illustrating the General Principles of the Discriminator.

The diode cathodes are connected to series resistors R1 and R2, and from between the resistors a return lead connects to the center tap of the transformer secondary. Between the cathodes, and across the ends of the resistors, is capacitor C5 in which are produced audio-frequency voltages which are fed to the AF amplifier. Capacitor C1 tunes the transformer primary, and C4 tunes the entire secondary. These may be adjustable trimmer capacitors, or they may be fixed capacitors with the trimming adjustments made with movable cores for the coils. Capacitor C3 is a bypass to ground from the primary of the transformer.

C. The PDC Path for the Diodes

Portions of the diagram in Fig. 1 have been drawn separately in Fig. 2, to show the rectifier circuits in their relation to the secondary winding of the transformer. Potential differences applied to diode A result from EMF's induced in section L1 of the winding, and those applied to diode B result from EMF's induced in section L2. When the diode plates are made positive during alternations of applied potential there will be electron flow as shown by arrows. These flows are from cathode to plate in the diodes, then through the transformer sections to the return connection at the center tap, and through resistors R1 and R2 to the cathodes.

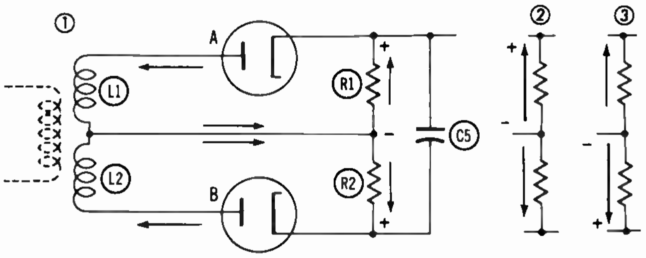


Fig. 2. The DC Circuits for the Discriminator Diodes.

Electron flows in the two resistors are in opposite directions, so that the potential differences developed across the resistors oppose each other. If the electron flows are equal in the two diodes and in the two resistors, the opposing potential differences will be equal and they will counterbalance each other to leave no net potential difference applied to capacitor C5 and to the AF amplifier which follows. If, as at point 2, there is greater electron flow in the upper resistor its potential difference will more than counter balance the potential difference across the lower one, and will make the upper end of the combination more positive than the lower end. If, as at point 3 there is greater electron flow in the lower resistor, the lower end of the combination will be more positive than the upper end.

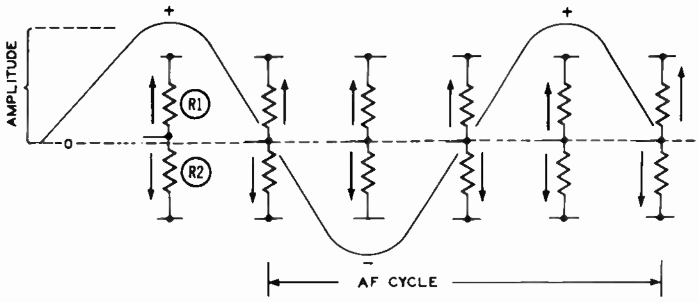


Fig. 3. Audio Frequency Potentials Result From Variations of Electron Flows and Potential Differences in the Discriminator Resistors.

When the electron flow in the two diodes and the two resistors alternate in strength at audio-frequency rates, the net potential differences across the two resistors, and the potential differences applied to C5, will alternate in polarity. These alternations will form cycles of audio frequency amplitudes, as shown by Fig. 3. When electron flow in diode A and resistor R1, is greater than in diode B and resistor R2, we will have a positive alternation. When the relative flow rates reverse in strength we will have a negative alternation. When the flows are equal we will have the zero points in the AF cycle.

D. General Operation

The amplitude (volume or loudness) of the audio signal will vary with the amount of electron flow in the diodes and with the resulting charge voltage on capacitor C5. The greater the electron flows the greater will be the AF amplitudes.

The frequency in the audio output will be the frequency with which charges on capacitor C5 are reversed in polarity. The more rapid the reversals of polarity, the higher will be the audio frequency.

In frequency modulation, the audio amplitude is represented by the extent of frequency deviation away from the center frequency. Then it follows that in the discriminator, the greater the deviation of frequency away from the center intermediate frequency, the greater must be the rate of electron flow produced in the diodes or rectifiers and their resistor loads R1 and R2. Thus, we shall change frequency deviation into AF amplitude, and have these two proportional to each other.

In the original frequency modulation, the audio frequency is represented by the number of times per second that there is frequency deviation extending from the center frequency to maximum deviation one way, then to maximum the other way, and back to the center frequency. If we translate frequency deviations into AF amplitudes we will get the correct translation into output audio frequency, because our audio amplitudes will occur at the same times as the frequency deviations.

We have at the input to the discriminator, a frequency-modulated intermediate frequency whose center frequency may be 10.7 mc, which is far above audibility. In the audio output we must have frequencies ranging to only about 15,000 cycles per second. The intermediate high frequency is eliminated, and the lower audio frequency is brought forth, just as in an AM diode detector system. There are pulses of electron flows in the diodes or rectifiers at the intermediate frequency. These pulses cause corresponding pulses of potential which charge capacitor C5. The time constant of the resistors R1 and R2, and capacitor C5, is such that the average charge of C5 varies at the audio frequency of modulation rather than at the intermediate frequency. The charge cannot leak off at the IF rate, but only at the AF rate. The pulses of potential shown in Figs. 2 and 3 occur at the IF rate and at the rates due to deviations, but the average charge on C5 increases and decreases proportionately to the variation of the pulses over periods which are at the AF rate. This result is obtained because of the fairly long time constant of the capacitor and resistors.

E. The Diode Circuits.

The circuits for each diode are shown in Fig. 4. The circuits include the transformer primary winding as well as half of the secondary winding. We have seen how each diode is subjected to potentials developed in the corresponding half of the secondary. Now we shall see how potentials from the primary are combined with those from the secondary, so that each diode is subjected to the combined effects of the two potentials at the same time instants.

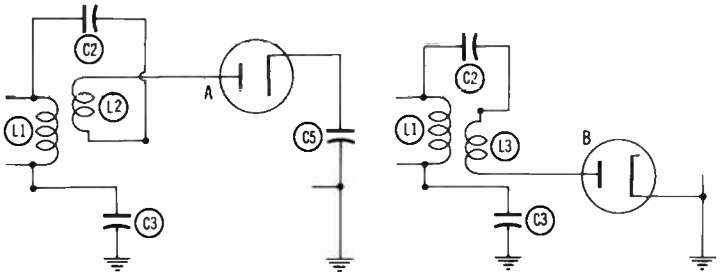


Fig. 4. The Diode Rectifier Circuits Which Include the Primary of the Transformer.

At the left in Fig. 4 is the circuit for diode A. We may start from ground and trace through the high-capacitance low-reactance capacitor C3, then through primary winding L1, coupling capacitor C2, the upper-half L2 of the secondary, and to the diode plate. From the cathode of this diode the circuit continues through capacitor C5 to ground, and thus the one circuit is completed. At the right is the circuit for diode B. This circuit passes from ground through the bypass C3, the primary L1, capacitor C2, the half secondary L3, to the plate of the diode. From the cathode, there is a return to ground. Capacitor C5 has a reactance of only about 300 ohms at 10.7 mc, and so its inclusion in the circuit for diode A and its omission from the circuit of diode B, makes little difference. In each circuit the primary winding is in series with half of the secondary and with one of the diode rectifiers. Consequently, each diode will be simultaneously subjected to the primary potential and to the potential from its half of the secondary. Now we are ready to observe how the primary and secondary potentials combine to vary the electron flows in accordance with deviations of frequency.

F. Phase Relation Operation

Variations of current are shown in Fig. 5. Fig. 5 also shows voltage in the transformer primary, and voltage in the secondary during two IF cycles. In the first vertical column are shown relations when the deviation is zero, in the middle vertical column are shown relations when there is deviation to a higher frequency, and in the right-hand column are shown relations when there is deviation to a lower frequency. The vertical lines indicate certain instants of time, which are the same along a given line for voltages and current.

With zero deviation (left-hand column) the applied frequency is the center frequency. It is the frequency to which both the primary and secondary windings are tuned, and so it is the resonant frequency. At a resonant frequency the reactances in a tuned circuit are balanced, leaving only resistance to oppose flow of current, and consequently the primary current and primary voltage are in phase with each other. This is shown by the upper two curves.

Secondary voltage, or EMF, is induced by changes of primary current and of magnetic fields which accompany the primary current. This secondary voltage, like counter EMF in the primary, leads the primary current by 90 degrees as shown by the third curve from the top in the left-hand column. This will be the secondary voltage which affects one of the diodes, which we assume to be diode A.

Fig. 2 shows that the two diodes are connected to opposite ends of the secondary. When one end of the secondary winding is positive the other end must be negative. Consequently, when the plate of one diode is positive the plate of the other must be negative, and so the secondary potentials applied to the two diodes are of opposite phase. At the bottom of the left-hand column we show the secondary voltage for diode B as being opposite in phase to the secondary voltage for diode A.

In the middle column of Fig. 5, the phase relations are shown for a deviation to a higher frequency. We assume that the primary current, which is also the plate current for the preceding limiter tube, is controlled by changes of potential applied to the limiter grid and so in this column we start at the top with the same primary current as for zero deviation.

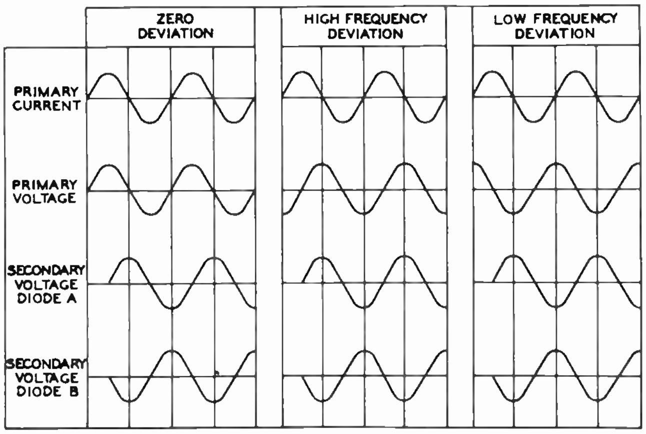


Fig. 5. The Phase Relations at the Same Instants of Time in the Primary and Secondary Windings of the Transformer, for Three Degrees of Deviation.

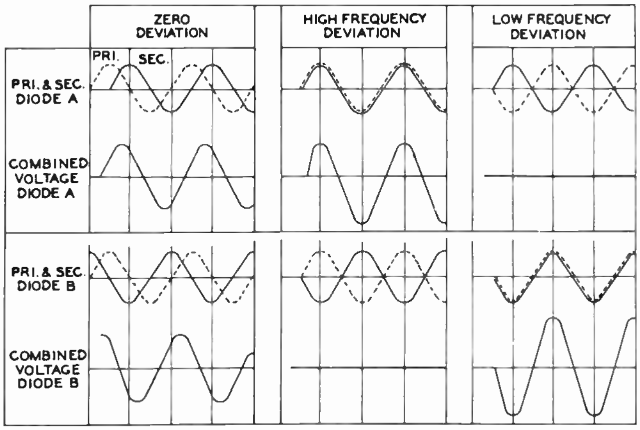


Fig. 6. How the Instaneous Primary and Secondary Voltages Combine in the Circuits for the Two Diode Rectifiers.

At frequencies higher than resonance the capacitive reactance of the tuned secondary circuit decreases and the inductive reactance increases. This is because the reactance of a capacitor decreases with rise of frequency, and the reactance of an inductor increases with rise of frequency. If the deviation could be made so great, and the frequency so high, as to result in practically no capacitive reactance and very great inductive reactance the primary would act like a circuit containing mostly capacitance with some resistance. In the extreme case, the primary current then would lead the primary voltage, and the primary voltage would lag the primary current by 90 degrees. These relations are shown by the two curves at the top of the middle column.

The secondary voltages, as applied to the two diodes, still have the same phase relations to the primary current as before, or the same as with zero deviation. These secondary voltages for the two diodes are shown by the two curves at the bottom of the middle column.

The right-hand column of Fig. 5 shows phase relations when the deviation is to a lower frequency. At a lower frequency the capacitive reactance of the primary increases, and the inductive reactance decreases. With a very great deviation and a very low frequency the inductive reactance would become so small and the capacitive reactance so great as to leave nearly all the current in the inductor. Then the circuit would act like one containing only inductance and a little resistance, and the voltage would lead the current by 90 degrees. These relations are shown by the two upper curves in the right-hand column. Again we have no change in the secondary voltages, which are shown by the two lower curves.

In Fig. 6 we combine the primary and secondary voltages applied to the two diodes. The three columns apply to zero deviation and to high and low frequency deviations just as in the preceding graph. The separate primary and secondary voltages are taken from the preceding graph. Primary voltages are shown by broken-line curves, and secondary voltages by full-line curves. The resulting diode voltages are shown by full-line curves. These curves show the instantaneous voltages which are the combination of primary and secondary voltages in the same circuit.

With zero deviation (left-hand column) the combined voltage in the circuit for diode A has exactly the same amplitudes as the combined voltage in the circuit for diode B. The fact that these two combined voltages are out of phase with each other makes no difference, because they are in the separated circuits shown by Fig. 4. These equal voltages cause equal electron flows in the two diodes and their load resistors. The resulting equal potential differences across the two load resistors oppose, as in Fig. 2, and cancel to leave no net voltage for the audio frequency output.

With high-frequency deviation (center column) the primary and secondary voltages are in phase with each other for diode A, and combine to form a high voltage in the circuit for this diode. In the circuit for diode B the primary and secondary voltages are in opposite phase. They cancel to leave zero voltage for this diode. Then with deviation toward higher frequencies we have increasing voltage and current for diode A, and decreasing voltage and current for diode B. How far the voltage increases for diode A and decreases for diode B depends on how much the frequency deviates. As the frequency deviates from zero the voltages on the two diodes will change from the equal values shown in the left-hand column toward the maximum possible values shown in the middle column.

With low-frequency deviation (right-hand column) the phase relations for diodes A and B are reversed with respect to those shown for high frequency deviation. Again the separate primary and secondary voltages are taken from Fig. 5, and are shown combined there. With deviation toward lower frequencies the voltage for diode A decreases from the value shown in the left-hand column toward the zero value shown in the right-hand column while the voltage for diode B increases from the value shown in the right-hand column.

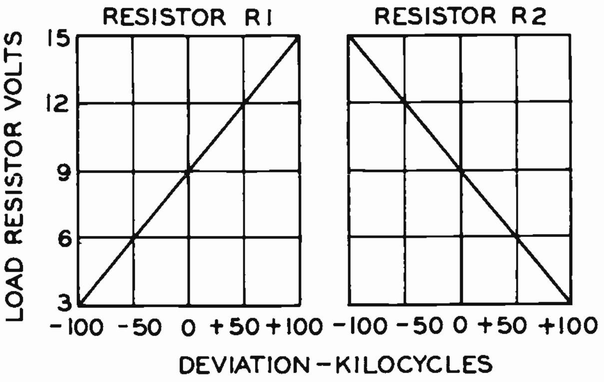


Fig. 7. Load Resistor Voltages Which Result from Frequency Deviation.

We have seen how deviation of frequency causes changes of voltages and currents for the two diodes and their load resistors in the discriminator circuit. The resulting changes of potential drop across the load resistors, R1 and R2 of Fig. 2, may be shown as in Fig. 7. We are assuming that the diode currents, when deviation is zero, are such as to cause a potential drop of 9 volts across each of the load resistors. This would correspond to the conditions in the left-hand column of Fig. 6. As deviation goes to higher frequencies the potential drop across R1 increases, while the drop across R2 decreases. This corresponds to conditions in the center column of Fig. 6. With deviation toward lower frequencies the changes of potential difference are reversed in the two resistors.

We show in Fig. 7, maximum and minimum potential drops of 15 and 3 volts respectively, and show frequency deviation as far as 100 kc each way from the center frequency of zero deviation. With the zero diode potentials shown for certain conditions in the middle and right-hand columns of Fig. 6 there would be zero diode currents and zero potential drops across resistors R1 and R2. Such extreme conditions would not occur in practice, because there would never be enough deviation to cause them. Consequently, we take for our minimum potential drop, in Fig. 7, a value of 3 volts rather than a zero value.

Now we must recall the fact that potential drops in the two load resistors oppose each other, as shown by Fig. 2. The audio output voltages built up across capacitor C5 in that figure will result from the differences between the potential drops in the two resistors. These differences are shown by Fig. 8. As an example, Fig. 7 shows that for a deviation of 50 kc there will be a drop across R1 of 12 volts and a drop across R2 of 6 volts. The difference is 6 volts. On the graph of Fig. 8 we show this 6-volt difference as positive (above the center horizontal line) because we are assuming that a greater potential difference across R1 means a positive audio output as shown in Fig. 3.

Positive and negative in alternating quantities are assumed merely for convenience to show opposite directions of flow and potential differences. Either direction might be called positive, and then the other direction would be called negative.

The remaining points along the curve of Fig. 8 are similarly derived from the values shown by Fig. 7. When the greater potential drop is across R1 we call the net voltage positive, and when the greater drop is across R2 we call the net voltage negative. The curve of Fig. 8 is called a discriminator characteristic curve. The values shown are quite typical of general practice, but other combinations of output voltage and deviation frequency would result from using different constructions and values of parts in the discriminator circuit.

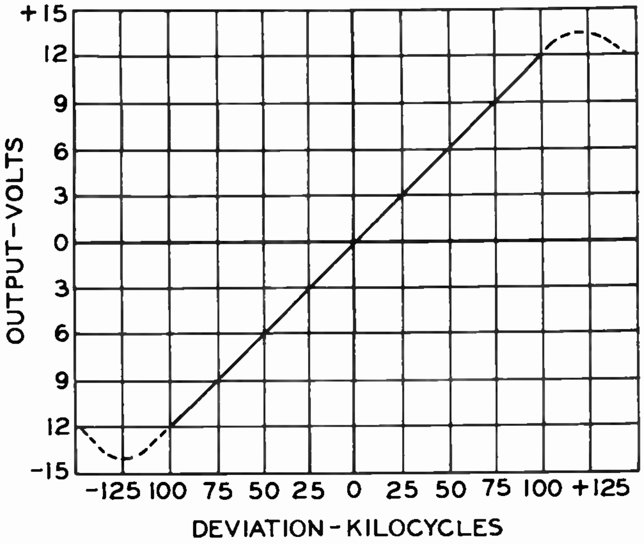


Fig. 8. A Discriminator Characteristic Curve Showing the AF Output Voltages Corresponding to Frequency Deviations.

At the top and bottom of the straight portion of the characteristic are curved broken-line extensions. These peaks are due to the fact that the discriminator transformer acts like any other closely coupled tuned transformer in having output peaks above and below the frequency to which the primary and secondary are tuned, or in having the familiar double-hump resonance curve. In Fig. 8 the portion of the characteristic on the left of the zero deviation line really is turned upside down to show the reversal of output voltage that occurs when one diode carries more current than the other. The curve would appear more familiar were it drawn as at the left in Fig. 9, where we have one resonant peak A at a frequency below the tuned frequency, and another peak B at another frequency above the tuned frequency. The tuned frequency is the frequency to which both primary and secondary are tuned. It is the center frequency or the intermediate frequency without frequency deviation.

Were the graph extended over a greater range of frequencies the response of the discriminator circuit would appear as at the right in Fig. 9. The frequency separation between the resonant peaks is increased by closer coupling between primary and secondary windings of the transformer, also by anything which lowers the Q-factor of the tuned circuits. This is true of any double-tuned transformer.

The straight portion of the discriminator characteristic in Fig. 8 must extend in each direction at least to the maximum deviation frequency, which we have taken, as 75 kilocycles, in order that audio output may be undistorted in relation to the deviation. It follows that the coupling and the Q-factor of the tuned circuits must be such as will bring the peaks beyond the maximum deviation by enough to insure the necessary length of the straight portion of the characteristic in between the peaks. In Fig. 8 we have a straight portion extending over a total range of 200 kc for our assumed total deviation of 150 kc.

The discriminator will demodulate a frequency-modulated signal anywhere along a straight or nearly straight portion of the response curve. If, during alignment of a discriminator transformer, we were to tune the primary and secondary to a frequency corresponding to point C at the right in Fig. 9, rather than to the intermediate frequency, the audio signal would come through because we would be working on a straight portion of the response curve. There would be reception also with tuning to a higher frequency at point D. The straight portions of the curves are relatively short at these points, and large deviations would be distorted.

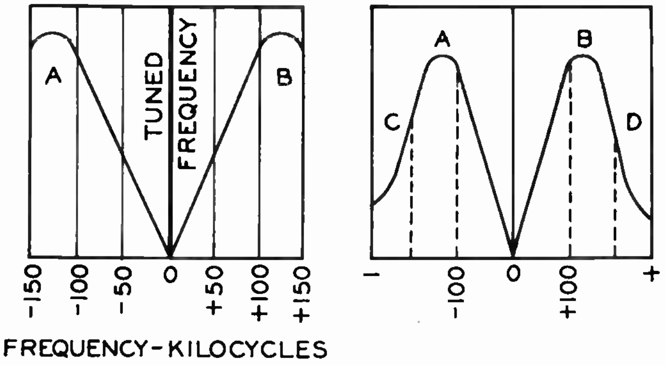


Fig. 9. The Discriminator Characteristic Curve Drawn to Show the Double-Hump Resonance Effect Produced by the Transformer.

G. Discriminator Circuit Diagrams

Up to this point, explanations of discriminator action have been based on the circuits shown by Fig. 1 and 2. Many variations of this circuit are employed in practice. Certain basic principles are common to all of the circuits in general use. In all of them, there are produced two voltages whose phase relations are varied by changes of frequency which are the deviation frequencies. The out-of-phase voltages are combined to produce in the output of two rectifiers an alternating potential which varies at audio frequency in accordance with frequency deviation.

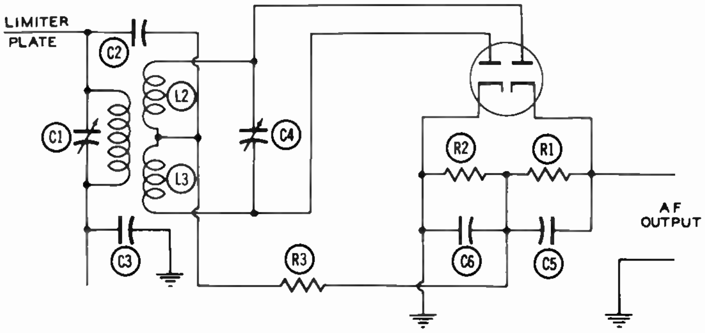


Fig. 10. A Typical Discriminator Circuit.

Fig. 10 shows one type of discriminator circuit. The tube is a double-diode, but might be a double-diode triode or some other combination type with the diodes used as the discriminator section. Instead of a single capacitor across both R1 and R2 there are two separate capacitors in series. In the return line from the connection between R1 and R2 to the center tap of the transformer secondary there is a resistor R3. Instead of this resistor we find in some circuits, a radio-frequency choke coil.

Fig. 11 shows a discriminator circuit employing a double-diode tube having only a single cathode for operation with both plates. The halves of the transformer secondary are connected together through capacitor C5. Resistors R1 and R2 have their common connections run through coupling capacitor C2 to the limiter plate, and their other ends connect across the capacitor C5. The AF output is taken across capacitor C5 and the ends of resistors R1 and R2. It is apparent that the action in this circuit will be essentially the same as in the previously explained.

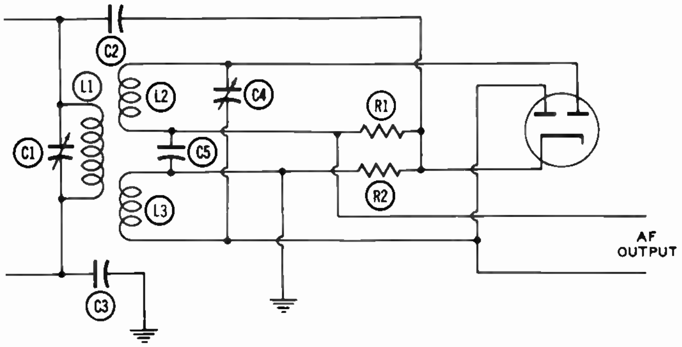


Fig. 11. A Discriminator Circuit Employing a Dual-Diode Tube with a Single Cathode.

In Fig. 12 the plate circuit of the preceding limiter contains a tuned coupling impedance consisting of coil L1 and its trimmer capacitor. Coupling capacitor C3 feeds directly to the right-hand diode plate, and through the tuned parallel-resonant circuit L2 to the left-hand diode plate. Thus, a deviation of frequency above or below the tuned frequency will cause a phase shift in the line to the left-hand diode plate with reference to the right hand plate, and currents in the two diodes will be shifted with reference to each other. The AF output connections, including resistors R1 and R2, and capacitor C5, are like those previously examined.

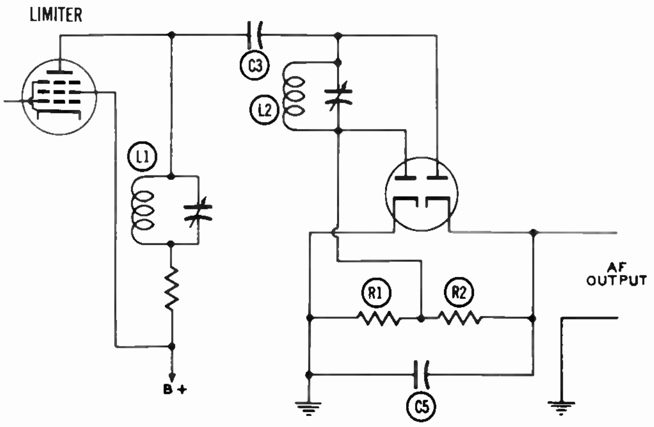


Fig. 12. A Discriminator Circuit Having Phase Displacement for Only One of the Rectifier Lines.

Figs. 10, 11, and 12 illustrate some of the modifications which may be made in discriminator circuits while retaining the operating principle of variations of phase shift and output amplitude in accordance with frequency deviation. Various other circuit modifications are used in FM receivers. Any of the circuits shown as having double-diode tubes may have other combination tubes containing diode plates. Some circuits contain the two discriminator diodes and also an additional diode acting as the AM detector. Instead of diode tubes for the discriminator, some FM receivers have crystal detectors which are especially designed for high-frequency operation. Then each diode, with its cathode and plate, is replaced with a crystal unit.

H. Audio Coupling Circuits

Fig. 13 shows typical circuits used between the discriminator and the first audio-frequency amplifying tube. Fig. 13A shows connections to an AF amplifier which has cathode bias, and Fig. 13B are connections which may be used when AF amplifier tube is biased by contact potential. The control grid of the AF amplifier tube is fed from the slider on the volume control voltage divider, R2.

The discriminator AF output as shown by preceding diagrams, is taken from one end of the resistors and capacitors which are between the cathode of the discriminator diodes or rectifiers. This may be called the "high side" of the AF output. The other side of the AF output is through ground, to which is also connected the other end of the resistors and capacitor which are between the discriminator cathodes. The connections shown by Fig. 13 are those from the "high side" through to the AF amplifier.

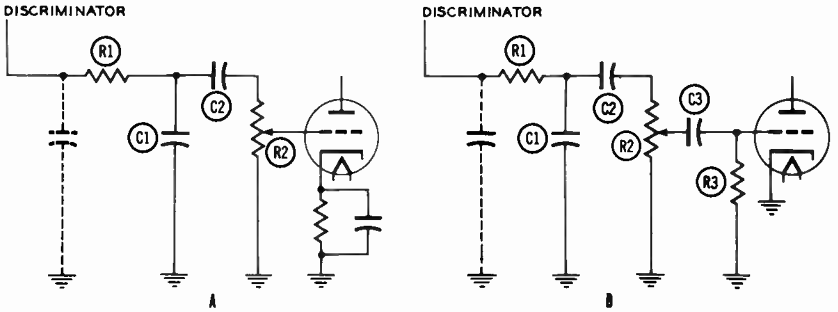


Fig. 13. Audio Coupling Circuits Used Between the Discriminator and First AF Amplifier.

The circuits shown by Fig. 13 include low-pass filters which attenuate or weaken the higher audio frequencies. The filters consist of series resistor R1 and by-pass capacitor C1, with sometimes the addition of another bypass capacitor shown by broken lines. Capacitor C2 is a coupling capacitor between the filter and the volume control.

The higher audio frequencies must be attenuated because their frequencies have been accentuated at the transmitter. The accentuation (strenghtening) of the higher audio frequencies usually is called pre-emphasis, and their attenuation in the receiver is called de-emphasis. Audio pre-emphasis increases the deviation at high audio frequencies without increase of amplitude. Interference which adds itself to the modulated carrier has, in relation to signal strength, more strength at these higher frequencies than at lower ones in the audio range. Then the pre-emphasis brings about a more favorable ratio of signal to noise in the modulated carrier, and the accentuation of the higher audio frequencies is easily eliminated by the receiver de-emphasis circuits.

Audio Frequency ranges in high-fidelity FM transmission and reception may extend up to 15,000 cycles per second, although in many commercial receivers the AF response does not extend to more than 9,000 or possibly 10,000 cycles. To reproduce both the high and low audio frequencies the receiver may be equipped with dual speakers; one for lows and another for highs, much as used for some public address systems.

I. Summary Questions

1. Why is a limiter stage ahead of the discriminator?
2. What is the purpose of the discriminator stage?
3. What is the basic principle of the discriminator circuit?
4. Explain why RF pulses do not exist across C5, Fig. 1.
5. Explain why the voltage applied across the diode plate and cathode is the sum of the primary voltage and one half the secondary voltage.
6. Explain why the primary voltage will lag the primary current with high frequency.
7. Explain why the primary voltage will lead the primary current with low frequency deviations.
8. What type of rectifiers may be used in place of vacuum tubes for FM detection?
9. Can a tube with one cathode common to two plates be used in a discriminator circuit?
10. Why are de-emphasis circuits used in FM receivers?
11. Why do transmitters used pre-emphasis circuits?
12. What provision may be used to reproduce high and low frequencies in the FM receiver?

FM RATIO DETECTORS

Objective

To learn how ratio detectors can demodulate the FM carrier and limit the amplitude variations at the same time.

References

Lesson Content

A. Introduction

In the discriminator circuits, there are a rather wide variety of circuit arrangements. The ratio detectors will also have a variety of circuit arrangements such as the balanced and unbalanced types. Variations of each of these will also be found. The ratio detector has become very popular because of its ability to appreciably limit the amplitude variations in the carrier. This is an advantage over the discriminator because it eliminates the limiter stage and therefore the signal requires less amplification within the IF amplifier stages.

B. The Balanced Ratio Detector, Fig. 1

The transformer at the left is the one whose primary, L1, is in the plate circuit of the last IF amplifier. The secondary winding is center tapped, with a connection coming from the IF amplifier plate through capacitor C2 to the tap. Connected to each of the outer ends of the secondary is a half-wave rectifier with the cathode of one diode connected to the top end of the secondary while the plate of the other diode is connected to the bottom end of the secondary. This differs from the discriminator in that the tubes are connected in series aiding while the discriminator diodes are connected in parallel opposing.

The rectifiers are shown here as separate diodes, A and B. In practice the diodes would be in a single tube envelope. This same condition is found for the discriminator stages.

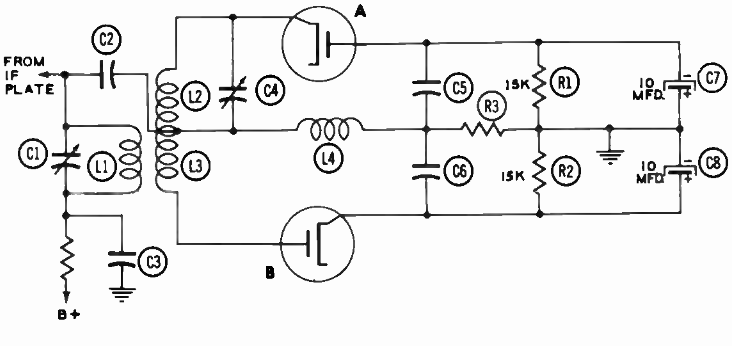


Fig. 1. The Balanced Ratio Detector.

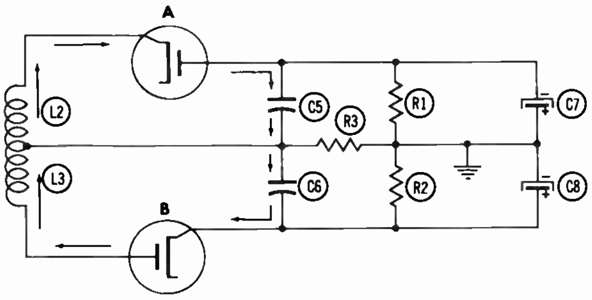
The plate of diode A is connected to the series resistor R1 and capacitor C5. Resistor R1 is connected to resistor R2, while capacitor C5 is connected to C6. Resistor R2 and capacitor C6 are connected to the cathode of diode B. This makes these combinations in series with the diodes. Between the capacitor C5 and C6 a return lead connects to the center tap of the transformer secondary and the resistor R3 is connected from this junction to ground. The voltages developed across capacitors C7 and C8, are connected in series between diode A plate, and diode B cathode, and this network is grounded at the center connection. Capacitor C1 tunes the transformer primary, and C4 tunes the entire secondary. These may be adjustable trimmer capacitors, or a fixed capacitor and variable inductance consisting of a moveable powdered iron core for the coils. Capacitor C3 is a bypass to ground from the transformer primary.

C. Electron Flow Analysis

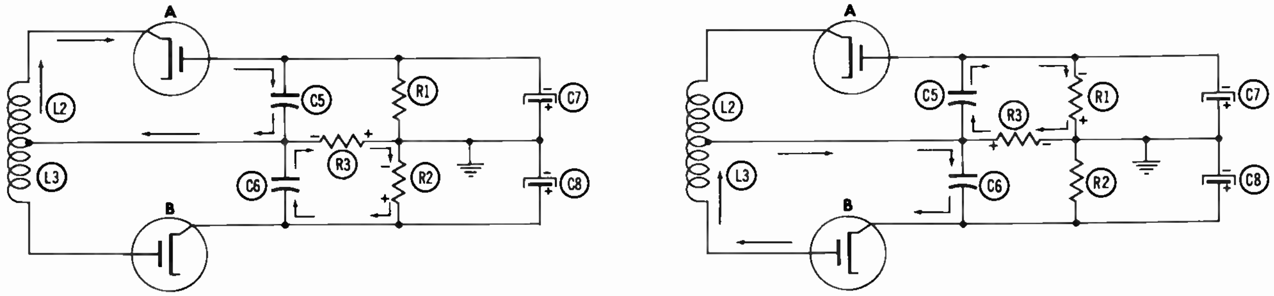
In Fig. 2, portions of the diagram in Fig. 1 have been drawn to show the rectifier circuits in their relation to the secondary winding of the transformer. Fig. 2A illustrates the potential differences applied to diode A, EMF's induced in section L2 of the winding, and those applied to diode B result from EMF's induced in section L3 of the winding. When diode B plate is made positive during alternations of applied potentials in respect to diode A cathode, there will be electron flow as shown by the arrows. These flows are from cathode to plate in diode B then through the transformer sections to the cathode then to the plate of diode A and through the capacitors C5 and C6, thereby allowing these capacitors to charge to the average carrier level.

1. Electron flow at the resting frequency, Fig. 2A

Capacitor C5 and C6 are in series with the electron flow, therefore equal voltage drops will be present across each since C5 equals C6. These voltages added together and neglecting all losses, will equal the average carrier level. Let us assume this level to be 10 volts. Connected in parallel with capacitor C5 is resistor R1 and capacitor C7. The voltage drop across



A. Electron Flow At the Resting Frequency.



B. Electron Flow When the Frequency Shift is Above the Resting Frequency.

C. Electron Flow When the Frequency is Below the Resting Frequency.

Fig. 2. Electron Paths in the Balanced Ratio Detector Impressed Onto the RF Intermediate Frequency Carrier.

this parallel network will be 5 volts at the resting frequency. Resistor R2 and capacitor C8 are in parallel with capacitor C6, therefore, the voltage drop across this parallel network will be 5 volts. When these two voltages are added together they will equal the average carrier level. It will be noted there is no electron flow through resistor R3, therefore no audio signal voltage is produced. R3 has no electron flow through it because capacitor C5 and C6 cannot discharge through the audio load resistor R3, R1, and R2 at the IF rate.

2. Electron flow when the frequency shift is above the resting frequency.

   If as in Fig. 2B there is a greater electron flow through the upper tube A, than in the lower tube B, the greater potential difference appears across the upper capacitor C5. C6 will then discharge through R3 and R2 producing a potential difference across R3 as shown. The left-hand side being of negative potential in respect to the right-hand side (ground). This voltage will be an audio voltage due to the time constant of this discharging network.

3. Electron flow when the frequency shift is below the resting frequency

   If, as in Fig. 2C, there is a greater electron flow through the lower tube B, then in the upper tube A, the greater potential difference across the lower capacitor C6 will result. With no electron flow through tube A at this instant of time, capacitor C5 will discharge through R1 and R3 developing a potential difference in the opposite direction of the illustration in Fig. 2B.

4. Varying the electron flows at an AF rate.

   When the electron flows in the two diodes and the two capacitors C5 and C6 alternate in strength at audio-frequency rates, the net potential differences across the two capacitors will appear across R3. The voltage drop across R3 will alternate in polarity. These alternations are to form our cycles of audio-frequency amplitudes, as shown by Fig. 3. When electron flow in diode A and capacitor C5 is greater than in diode B and capacitor C6, we will have a negative alternation. When the relative flow rates reverse in strength we will have a positive alternation. When the flows are equal we will have a zero point in the AF cycle.

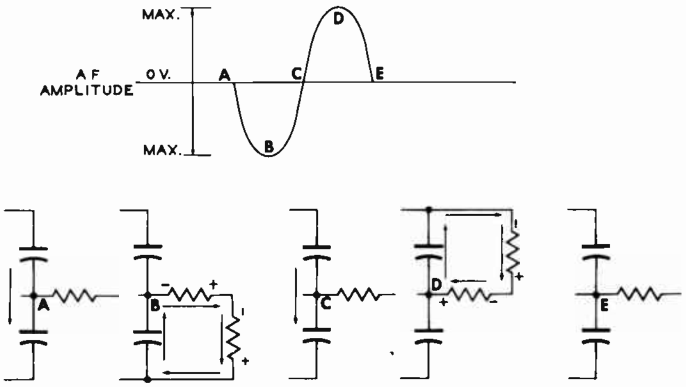


Fig. 3. The Net Potential Differences Appearing Across R3.

In the original frequency modulation, the audio amplitude is represented by the extent of frequency deviation away from the center frequency. Then it follows that, in the ratio detector, the greater the deviation of frequency away from the center intermediate frequency the greater must be the rate of electron flow produced in the diodes or rectifiers and their capacitor loads C5 and C6. Thus, we shall change frequency deviation into AF amplitudes, and have these two proportional to each other.

In the original frequency modulation, the audio frequency is represented by the number of times per second that there is frequency deviation extending from the center frequency to maximum deviation one way, then to maximum the other way, and back to the center frequency. If we translate frequency into output audio frequency, our audio amplitudes will occur at the same times as the frequency deviations.

The amplitude (volume or loudness) of the audio signal will vary with the rates of electron flow in the diodes and with the resulting discharge voltage through resistor R3. The greater the electron flow, the greater will be the AF amplitudes.

The frequency in the audio output will be the frequency with which changes of voltage drops across R3 are reversed in polarity. The more rapid the reversals of polarity, the higher will be the audio frequency.

At the input to the ratio detector we have a frequency-modulated intermediate frequency whose center frequency may be 10.7 mc. When this intermediate carrier frequency is shifted by 75 kc above and below, it will be far from audibility. In the audio output we must have frequencies ranging to only 15,000 cycles per second. The intermediate high frequency is eliminated, and the lower audio frequency is brought forth, just as in the AM diode detector system or the discriminator FM detector. There are pulses of electron flow in the diodes or rectifiers at the intermediate resting frequency and each frequency change on either side of this resting frequency. These pulses cause corresponding pulses of potential which charge capacitor C5 and/or C6. The time constant of the resistors R1 plus R3 and capacitor C5, is such that the average discharge of C5 through R3 varies at the audio frequency of modulation rather than at the intermediate frequency. This applies to the discharge of capacitor C6 through R3 in the same manner. The charge on the capacitors C5 or C6 cannot leak off at the IF rate, but only at the AF rate. The pulses of potentials shown in Figs. 2 and 3 occur at the IF rate and at the AF rate due to deviations, but the average discharge of C5 or C6 increases and decreases proportionately to the variation of the pulses over periods which are at the AF rate; this results because of the fairly long time constant of the resistor and capacitor combination.

C. The Diode Capacity Coupling Circuits

Fig. 4 shows the circuits for each diode. The circuits include the transformer primary winding as well as half of the secondary winding. We have seen how each diode is subjected to potentials developed in the corresponding half of the secondary. Now we shall see how potentials from the primary are combined with those in the secondary, so that each diode is subjected to the combined effects of the two potentials at the same instant of time.

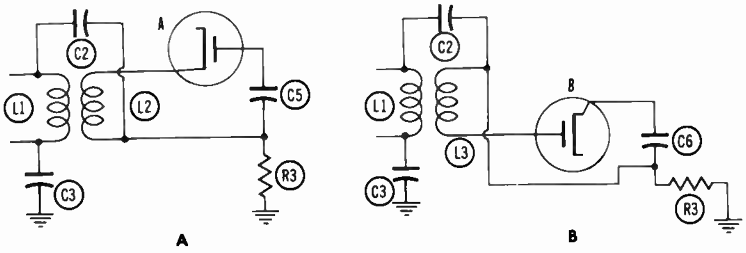


Fig. 4. The Diode Rectifier Circuits Which Include the Primary of the Detector Transformer.

Fig. 4A is the circuit for diode A. We may start from ground and go through the high-capacitance low-reactance capacitor C3, then through the primary winding L1, coupling capacitor C2, the upper half of the secondary L2, and to the diode cathode. From the plate of this diode, the circuit goes through capacitor C5, through resistor R3 to ground, and thus the one circuit is completed. In

Fig. 4B is the circuit for diode B. This circuit goes from ground through the bypass C3, the primary L1, capacitor C2, the lower half of the secondary winding L3, and to the plate of the diode B. From the cathode there is a connection to capacitor C6 through resistor R3 to ground. In each circuit the primary winding is in series with half of the secondary and with one of the diode rectifiers. Consequently, each diode will be simultaneously subjected to the primary potential and to the potential from its half of the secondary. Now we are ready to observe how the' primary and secondary potentials combine to vary the electron flows in accordance with deviations of frequency.

1. Phase relation at resonance to the resting IF carrier frequency.

In Fig. 5 are shown variations of current and voltage in the transformer primary, and of voltage in the secondary during two IF cycles. In the middle column there are shown relations when there is deviation to a higher frequency, and in the right-hand column are shown relations when there is deviation to a lower frequency. The vertical lines indicate certain instants of time, which are the same along a given line for the current and all the voltages.

With zero deviation (left-hand column) the applied frequency is the center frequency. It is the frequency to which both the primary and secondary windings are tuned, and so it is the resonant frequency. At a resonant frequency the reactances in a tuned circuit are balanced, leaving only resistance to oppose flow of electrons, and consequently the primary current and primary voltage are in phase with each other. This is shown by the upper two curves.

Secondary voltage, is induced by changes of primary current and of magnetic fields which accompany the primary current. This secondary voltage, like counter EMF in the primary, leads the primary current by 90 degrees as shown by the third curve from the one in the left-hand column. This will be the secondary voltage which affects one of the diodes, which we assume to be diode A.

As shown by Fig. 2, the two diodes are connected in series with the secondary winding. When one end of the secondary winding is positive the other end must be negative. Consequently, when the plate of diode B is negative the cathode of diode A is positive and so the secondary potentials applied to the two diodes are of opposite phase and both diodes are non-conducting. When the alternation of the cycles change, both tubes conduct on the same half-cycle.

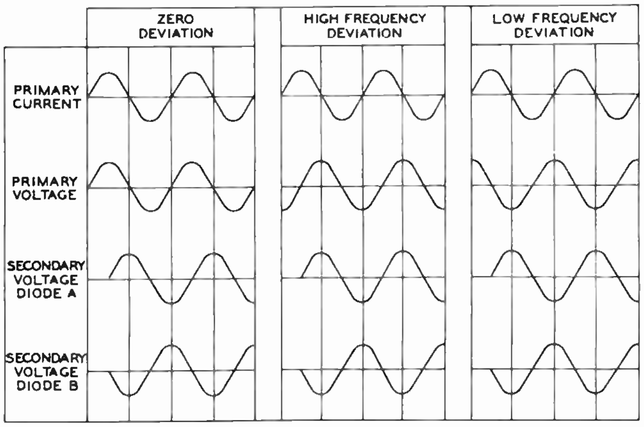


Fig. 5. The Phase Relations at the Same Instants of Time in the Primary and Secondary Windings of the Transformer, for Three Degrees of Deviation.

2. Phase relation when the IF carrier shifts to a higher frequency.

Refer to the middle column of Fig. 5, where phase relations are shown for a deviation to a higher frequency. We assume that the primary current, which is also the plate current for the preceding tube, is controlled by changes of potential applied to this tube's grid, and so in this column we start at the top with the same primary current as for zero deviation (left-hand column).

At frequencies higher than resonance, the capacitive reactance of the tuned primary circuit decreases and the inductive reactance increases. This is because the reactance of an inductor increases with a rise of frequency.

3. The primary of the plate tank circuit

   The plate tank circuit is a parallel resonant circuit, therefore if the deviation could be made so great, and the frequency so high, as to result in practically no capacitive reactance and very great inductive reactance, the primary would act like a circuit containing only capacitance and some resistance. In this extreme case, the primary current then would lead the primary voltage, and the primary voltage would lag the primary current by 90 degrees. These relations are shown by the two curves at the top of the middle column. The secondary voltage, as applied to the two diodes, still has the same phase relations to the primary current as before, or the same as with zero deviation. These secondary voltages for the two diodes are shown by the two curves at the bottom of the middle column.

4. Phase relation when IF carrier shifts to a lower frequency.

   The right-hand column of Fig. 5 shows phase relations when the deviation is to a lower frequency. At a lower frequency the capacitive reactance of the primary increases, and the inductive reactance decreases. With a very great deviation and a very low frequency the inductive reactance would become so small and the capacitive reactance so great as to leave nearly all the current in the inductor. Then the circuit would act like one containing only inductance and a little resistance, and the voltage would lead the current by 90 degrees in the primary. These relations are shown by the two upper curves in the right-hand column. Again we have no change in the secondary voltages, which are shown by the two lower curves in this column.

D. Combining the Primary and Secondary Voltages

In Fig. 6 we combine the primary and secondary voltages applied to the two diodes. The three columns apply to zero deviation and to high and low frequency deviations, just as in the preceding graph. The separate primary and secondary voltages are taken from the preceding graph. Primary voltages are shown by broken-line curves, and secondary voltages by full-line curves. The resulting diode voltages are the combinations of primary and secondary voltages in the same circuit.

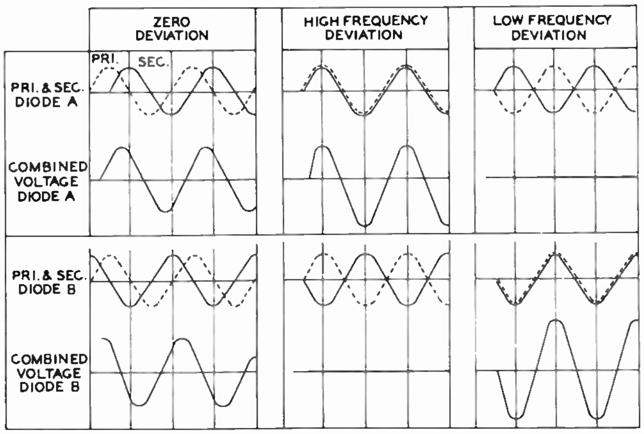


Fig. 6. How the Instantaneous Primary and Secondary Voltages Combine in the Circuits for the Two Diode Rectifiers.

1. Zero deviation

   With zero deviation (left-hand column), the combined voltage in the circuit for diode A has exactly the same amplitudes as the combined voltage in the circuit for diode B. The fact that these two combined voltages are out of phase with each other makes no difference, because they are in the separated circuits shown by Fig. 4. These equal voltages cause equal electron flows in the two diodes and their load resistors. The resulting equal potential differences across the two capacitors, C5 and C6, add as in Fig. 2 and no electrons will flow through R3 and leave no net voltage for the audio-frequency output.

2. With a high-frequency deviation (center column) the primary and secondary voltages are in phase with each other for diode A, and combine to form a high voltage in the circuit for this diode. In the circuit for diode B the primary and secondary voltage are in opposite phase. They cancel to leave zero voltage for this diode. Then with the deviation toward higher frequencies we have increasing voltage and current for diode A, and decreasing voltage and current for diode B. How far the voltage increases for diode A and decreases for diode B depends on how much the frequency deviates. As the frequency deviates from zero the voltages on the two diodes will change from the equal values shown in the left-hand column toward the maximum possible values shown in the middle column.

3. Low-frequency deviation

   With low frequency deviation (right-hand column) the phase relation for diodes A and B are reversed with respect to those shown for high-frequency deviation. Again the separate primary and secondary voltages are taken from Fig. 5, and are shown combined here. With deviation toward lower frequencies the voltage for diode A decreases from the value in the left-hand column toward the zero value in the right-hand column, while the voltage for diode B increases to the maximum value shown in the right-hand column.

   Now we have seen how deviation of frequency causes changes of voltages and currents for the two diodes and their load in the ratio detector circuits. The resulting changes of potential drop across the audio output load resistor R3 is shown in Fig. 7. This curve results from the same operation which applies to the Foster-Seeley discriminator.

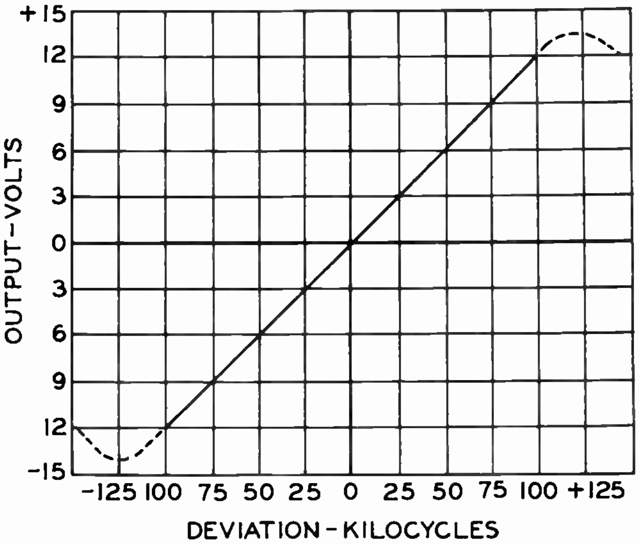


Fig. 7. A FM Detector Characteristic Curve Showing AF Output Voltages Corresponding to Frequency Deviations.

E. The Unbalanced Ratio Detector, Fig. 8

The unbalanced ratio detector differs from the balanced ratio detector as follows:

1. The ground connection is made at the cathode of the bottom tube B rather than at the junction of the diode load resistor.
2. The bottom end of resistor R3 is grounded rather than connected to the junction of the diode load resistors.
3. The final difference is, only one electrolytic is connected across the diode load.

The operation up to the discharging of C5 and C6 is identical to the balanced ratio detector. This being the same, we will devote our attention to the discharging of C5 and C6. In Fig. 9A you will notice that there is no electron flow through R3 at the resting frequency. In Fig. 9B electron flow is heaviest through the diode A,and capacitor C5 charges to a greater value than it has at resting frequency. C6 discharges through R3 to ground and back to C6. When the frequency shift is below the resting IF value the lower tube conducts thereby charging capacitor C6 to a larger value,and capacitor C5 discharges through R1 to ground then through R3 and back to the capacitor C5.

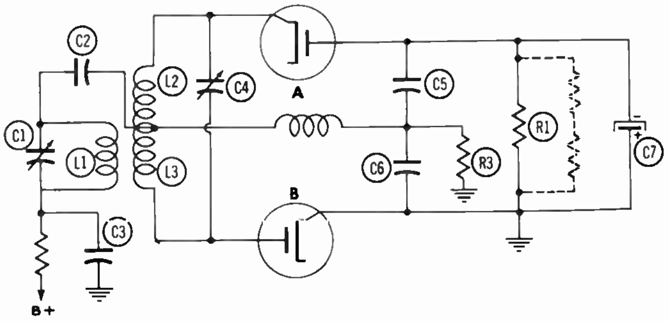
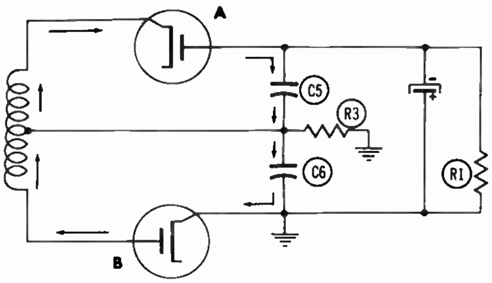
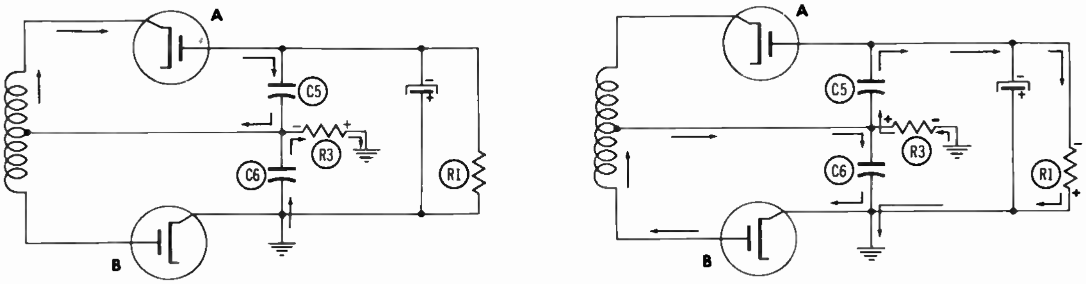


Fig. 8. An Unbalanced Ratio Detector.

The unbalanced type detector is most often used since it supplies an audio voltage source which has one side of the signal line grounded. The load resistor R3 is usually the volume control. To simplify explanation, this load is shown as a single resistor in Figure 9. In practice, this load will consist of the volume control, a series coupling capacitor and a de-emphasis network.



A. Electron Flow At the Resting Frequency.



B. Electron Flow When the Frequency Shift is Above the Resting Frequency.

C. Electron Flow When the Frequency Shift is Below the Resting Frequency.

Fig. 9. Electron Flow in an Unbalanced Ratio Detector.

F. Summary Questions

1. Explain the phase relation of the secondary voltages with respect to the primary current and voltage.
2. The audio voltage is developed across the audio load resistor or capacitor. Explain the action of the capacitors and resistors in the RF filter circuit.
3. Explain the major difference between a balanced and an unbalanced ratio detector.
4. What is the major difference between a ratio detector and a Foster Seeley discriminator?

ANTENNA PRINCIPLES

Objective

To consider the requirements of high frequency antennas.

References

Lesson Content

A. General

Investment in a good antenna system yields greater returns per dollar than anything which can be done to the receiver itself. In localities where signals from television transmitters are strong it is possible to have excellent reception with an indoor antenna or with an antenna built into the receiver. But in outlying districts, so-called fringe areas, an outdoor antenna mounted high as possible is a practical necessity for good reception.

It is desirable that an antenna system deliver to the receiver the maximum possible strength and the minimum of electrical interference. These two requirements are best met with an antenna which tunes quite sharply to the frequencies of only one selected channel, and one which is most strongly responsive to signals from the direction of a desired station while responding weakly to unwanted signals from other directions.

At the same time it is desirable that the antenna system will respond to frequencies throughout the entire television spectrum, which calls for very broad tuning, and there should be good response to signals arriving from any of many stations which may be in many different directions. Obviously, the two sets of requirements are in direct conflict with each other. Practical designs must involve compromises.

B. Wave Propagation

Electromagnetic waves at frequencies used for standard broadcast and medium short wave transmission are reflected back and forth between a layer of ionized gases high in the atmosphere, or in the ionosphere, and the moist earth and bodies of water. These successive reflections carry such waves for long distances. Very-high and ultra - high frequency waves are not reflected from the ionosphere, and can be received in practice only so far as points which are in an unobstructed straight line or a "line of sight" from the transmitting antenna. The maximum line of sight distance in which there is reliable reception is the sum of distances D1 and D2 of Fig. 1, these being the distances from transmitting and receiving antennas to their common horizon. Assuming uniform curvature of the earth's surface, and no high intercepting objects near the horizon, each of the distances may be computed from this formula.

Miles = 2 X antenna height in feet

Any additional height which ordinarily is possible at the receiving antenna is too little to make much difference in the horizontal distance. The chief purpose of added height of the receiving antenna is to get it above sources of interference and above nearby objects where might interrupt or reflect the radiation.

Occasionally there may be satisfactory reception at distances somewhat greater than the sum of those shown by Fig. 1, because of some refraction or bending of the electromagnetic waves at and near the horizon. Unusually high transmitting antennas allow reception at great distances. With the approximately 6,000 foot elevation of transmitters on Mount Wilson, near Los Angeles, the theoretical or computed horizon distance is nearly 110 miles, and as a rule, there is good reception as far as San Diego, 116 miles away.

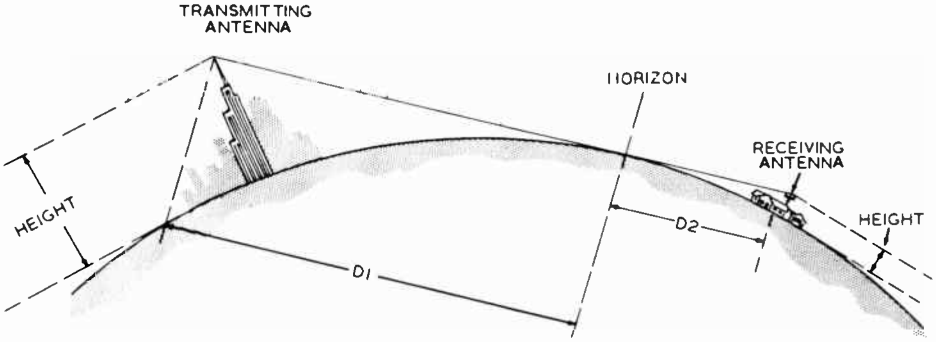


Fig. 1. Factors Which Affect Television and FM Radio Reception Distance.

C. Polarization

An electromagnetic wave, as employed for television and FM radio transmission and reception consists of electric force acting alternately one way and the opposite in a horizontal direction, and of magnetic force acting alternately up and down or vertically. Such a wave is represented by Fig. 2. The waves travel away from the transmitter and carry their energy in a direction at right angles to both electric and magnetic forces. Velocity through space is the same as that of light, 300,000,000 meters per second or about 186,000 miles per second.

Polarization of a wave refers to the direction of its electric lines of force. Horizontal polarization is used for television as well as FM broadcast radio, and is shown by Fig. 2. Horizontal polarization requires the use of a horizontal antenna conductor at the receiver. Horizontal polarization, compared with vertical allows a better ratio of signal to noise, since most electrical interference travels with vertical polarization. Horizontal polarization provides decided directional properties at the receiving antenna, whereas, an antenna for vertical polarization is not directional. Waves horizontally polarized when leaving the transmitting antenna may become tilted slightly one way or the other, but this effect is slight in the short distances for television reception.

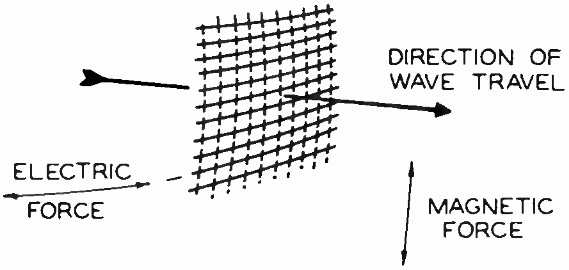


Fig. 2. Forces in an Electromagnetic Radiation Wave.

D. Ghosts and Reflections

Radiation waves at very-high and ultra-high frequency are reflected quite effectively from metallic objects and those consisting largely of metal and other good conductors. The strength or completeness of such reflections increases at higher frequencies or shorter wave lengths, because then the lines of force may more nearly complete their action toward one side or the other within the distance spanned by the reflecting object.

Both the direct and the reflected waves may reach a receiving antenna, as shown by Fig. 3. Although the reflected wave at the receiving antenna normally is weaker than the direct wave, the reflection still may act as a complete picture signal and produce on the screen of the picture tube an image of its own, in addition to the desired image formed by the direct wave.

The reflected wave, having traveled farther through space, will arrive at the receiving antenna slightly later than the direct wave. During the interval between arrivals of the two waves the beam in the picture tube will have traveled toward the right on the screen. Then the image formed by the reflected wave will appear slightly to the right of the image formed by the direct wave. The extra image, due to the reflected wave, usually is called a ghost wave. If the reflected wave has traveled 500 feet farther than the direct wave, the ghost image will be displaced slightly more than 1/8 inch from the regular image on the face of a 16-inch picture tube. Actual separation may be greater with longer travel of the reflected wave, or with short extra travel the two images may be so close as to cause only a blurring effect.

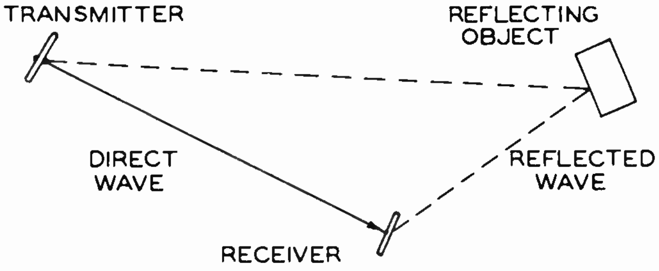


Fig. 3. Wave Reflection Which May Cause Ghost Images.

Wave reflections and resulting ghost images ordinarily are more troublesome where there are large buildings, bridges, large smoke stacks, gas tanks, and such objects. Usually there is little of this trouble in districts of single homes and in suburban areas in general.

If reflected and direct waves reach the receiving antenna from considerably different directions it usually is possible to rotate or orient the antenna to strengthen the direct signal and weaken the reflected one. If the two waves arrive from nearly opposite directions, as in Fig. 3, a reflector behind the antenna usually helps. Strength of the reflected wave may vary greatly within short distances, and moving the antenna may so weaken reception from the reflected wave as to remedy matters. An antenna director may so sharpen the directional effects of the antenna as to make the direct wave much stronger than the reflected one.

There are cases where the reflection is stronger than the direct wave, which may encounter obstructions not in the path of the reflection. Then the antenna may be oriented for regular reception from the reflected wave. What otherwise would be a direct wave may be completely blocked by objects between transmitting and receiving antennas. Naturally, any object which reflects a wave does not allow the wave to pass through it, unless possibly with greatly reduced strength. Thus there often are shadow effects, where the receiving antenna is in the electrical shadow of some interfering object.

E. Dipole Antenna

All television and FM antennas are either simple half-wave dipoles or else some modification of or evolution from the half-wave dipole.* The electromagnetic radiation which is the radio or television signal consists of electrostatic lines of force which are horizontal, and of magnetic lines of force which are vertical, as represented in Fig. 4. As the wave sweeps through space, from left to right in the figure, the lines of force act alternately in opposite directions and go through zero values in between.

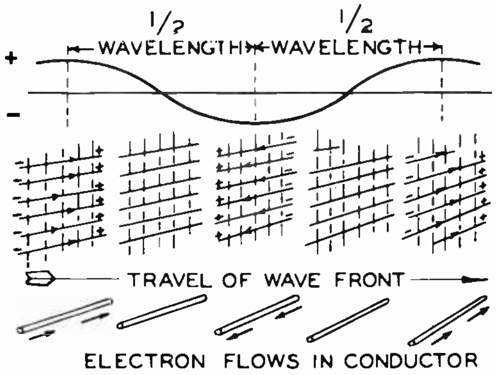


Fig. 4. The Electrostatic Force of the Radio Wave Causes Alternating Electron Flows in the Antenna Conductors.

If a conductor is held horizontally, extending in the same direction as the electric lines of force, electrons in the conductor will move in the directions of these lines, from negative to positive. When a surge of electrons comes to one end of the conductor they are reflected back in the opposite direction. Upon arriving at the opposite end of the conductor these electrons again are reflected back toward the first end. If the conductor is of such length that the electric field reverses just as the electrons are reflected from one of the ends, and reverses again as the electrons are reflected from the other end of the conductor, then the electric forces build up the maximum possible surges of electrons of the greatest possible alternating current in the conductor.

That is just what happens if the length of the conductor is equal to one-half wave length of the signal. When maximum strength of the electric force is as represented at the left, in Fig. 4, and the electrons surge toward and reach the corresponding end of the conductor, the maximum strength of the electric force will be in the opposite polarity, as at the center in Fig. 4, just as the electrons come to the opposite end of the conductor. The next reversal will be as at the extreme right, in Fig. 4, with electrons back at their original location. So the action continues so long as the signal waves continue to pass through the conductor.

The next step is to open the conductor at its center, as in Fig. 5, and connect the two ends through a transmission line to the antenna coupling coil of a receiver. So long as the transmission line runs vertically, or nearly so, it is not affected to any great extent by the horizontally polarized electrostatic lines of force in the signal. The transmission line merely carries surges of electrons from the antenna conductors, where they are induced, to and through the coupling coil. Electron flow or current then alternates back and forth in the coupling coil at the signal frequency, and resulting induced EMF or voltages in the coupler are applied to the RF amplifier of the receiver.

1. Length of a Dipole Antenna

It is quite apparent that maximum rates of electron flows will occur in the antenna conductors, and in the receiver coupler, only when the overall length of the antenna conductors is equal to a half wavelength of the signal to be received. Only then will the electric forces work to give maximum assistance to the natural back and forth surges of the electrons. If the antenna is too

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*Some UHF-VHF antennas use stubs which cause a half-wave dipole at VHF frequencies to act as 1 1/2 or 3 wave length antenna at UHF frequencies.

short, the electrons will have been reflected back before the electric forces reverses, and their movement will be opposed. If the antenna is too long, the wave will have reversed before the electrons come to the end of the conductor, and again the electron flow will be opposed.

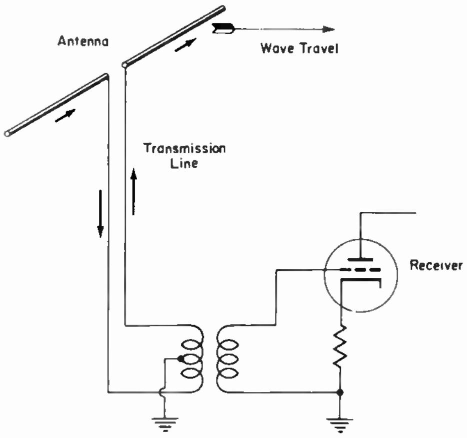

Fig. 5. Connection of a Dipole Antenna Through a Transmission Line to the Receiver.

Channel Number	Center Freq., mc	Antenna Length		Wavelength in air, Inches
		Feet	Inches	
2	57	7.94	95.3	207.2
3	63	7.18	85.2	187.5
4	69	6.56	78.8	171.3
5	79	5.73	68.8	149.5
6	85	5.32	64.0	139.0
7	177	2.56	30.7	66.8
8	183	2.48	29.7	64.6
9	189	2.40	28.8	62.5
10	195	2.32	27.9	60.6
11	201	2.25	27.0	58.8
12	207	2.18	26.2	57.1
13	213	2.12	25.5	55.5

Fig. 6. Lengths of Half-Wave Antennas.

When travel is through free space or through air, and is unaffected by surrounding materials which are either conductors or insulators (dielectrics). Frequencies in megacycles may be changed to equivalent wavelength as follows.

$$\text{Wavelength in meters} = \frac{300}{\text{megacycles}}$$

$$\text{Wavelength in feet} = \frac{984.25}{\text{megacycles}}$$

$$\text{Wavelength in inches} = \frac{11811}{\text{megacycles}}$$

When the electric field of the signal is around a conductor, and resulting electron flow is in the conductor, wavelengths would be computed according to the preceding formula where the conductors are responsible for some slowing down of the electron flow. For usual diameters of antenna rods or tubing (1/4 to 1/2 inch) at frequencies in the low and high bands of very-high frequency television transmission, the physical length has to be about 2 1/2 per cent less than given by the formulas.

There is further slowing down due to effects of conductor and dielectrics which must be used for antenna supports, and to such materials which usually are somewhere near the antenna with ordinary installations. These effects may slow down the electron travel by another 5 or 6 per cent.

The resultant of all this is that the physical length of the antenna should be based on something like 90 to 92 per cent of wavelength in free space or in the air. Then the formulas for length of a half-wave TV antenna become:

$$\text{Antenna length in feet} = \frac{452.7}{\text{frequency in megacycles}}$$

$$\text{Antenna length in inches} = \frac{5433}{\text{frequency in megacycles}}$$

The chart in Fig. 6 gives the antenna lengths for the various VHF television channels. Other similar tables may give lengths differing from these by something like one per cent, this makes no practical difference in operation.

Antenna lengths are overall lengths from one end to the other. Maximum signal voltage is developed at the frequency for which the dipole length is cut, with diminishing response at both higher and lower frequencies. A single antenna usually is used for all the low-band VHF channels, numbers 2 through 6, by making the length suitable for a mid-band frequency or for channel 4, which is very nearly in the middle of the low band. The response remains amply high for most reception conditions at frequencies down through channel 2 and up through channel 6. A single antenna may be used also for the entire high-band VHF channels, 7 through 13, by making its length match channel 10, which is in the middle of this band. But a simple half-wave dipole does not have response broad enough to receive both in the low-band and high-band channels of the very-high frequency range.

Instead of cutting a simple dipole antenna for the middle of a band, it may be cut for the frequency of a channel in which there is most difficult reception, or a channel in which signals from existing stations are weaker than from stations operating on other channels in the same band. For example, were the greatest difficulty encountered on channel 8, the dipole might be cut to the length giving best reception in this channel, and it still could be used throughout the remainder of the high-band VHF channels where signals are stronger.

2. Directional Properties of Dipoles

Fig. 7 shows the directional properties of a simple half-wave dipole antenna. Relative lengths of the arrows indicate relative response of the antenna to signals of equal strength arriving from the directions of the arrows. There is maximum response to signals traveling on a line at right angles to the length of the antenna conductors. There is minimum response to signals traveling in line with the conductors.

For best reception of signals from any given direction the antenna should be at right angles to that direction, although, as shown in Fig. 7, the response will remain almost as good when the antenna is turned as much as 15 degrees to either side. With the simple dipole now being discussed, there is maximum response to signals from two opposite directions, and minimum response in two other opposite directions.

When reception is to be from several channels or from several stations, the dipole may be placed at right angles to the direction of the weakest signal, and the lessened response to signals from other directions will be more or less counteracted by greater strength of those signals.

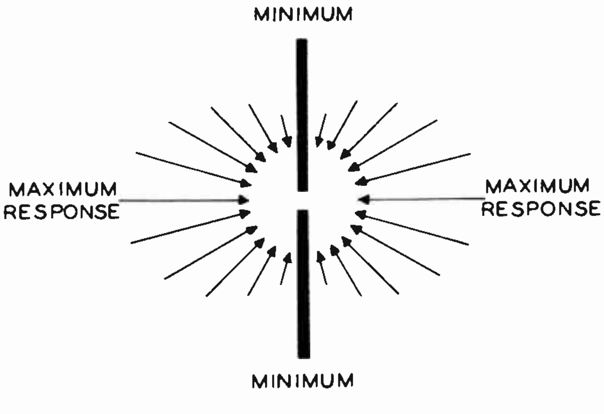

Fig. 7. Directional Properties of a Simple Half-Wave Dipole Antenna. The Length of the Arrows are Proportional to the Relative Signal Developed in the Antenna.

Often it is possible to greatly attenuate or possibly eliminate an undesired interfering signal by placing the antenna conductors in line with the direction of that signal. Response to desired signals usually will remain satisfactory. The angle for minimum response is relatively narrow. To cut out an interfering signal the antenna conductors must be almost exactly in line with the path of that signal, whereas, a desired signal may be well received with the conductors turned several degrees either side of the maximum point.

The directional pattern of Fig. 7 is based on having the antenna far from all other conductors, and from large bodies having poor dielectric characteristics.

To take full advantage of the maximum and minimum response angles when receiving from stations in widely different directions, the antenna sometimes is mounted so that it may be rotated into the best position for each station. Rotation may be by hand, or by remote control, by means of a motor or a form of selsyn control.

The directional response of the dipole antenna remains practically unchanged as the conductor length is made less than a half-wavelength, and does not change a great deal as the length is moderately increased. Entirely different patterns result, however, when the conductors become some multiple of a half-wavelength in their own overall length. At 1 1/2 wavelengths, usually called a three-halves wavelength, the directional response becomes about as shown by Fig. 8. Maximum reception now is from any of four directions, there still is good reception, but not maximum, at right angles to the conductors, and there still is minimum response for signals traveling in line with the conductors,

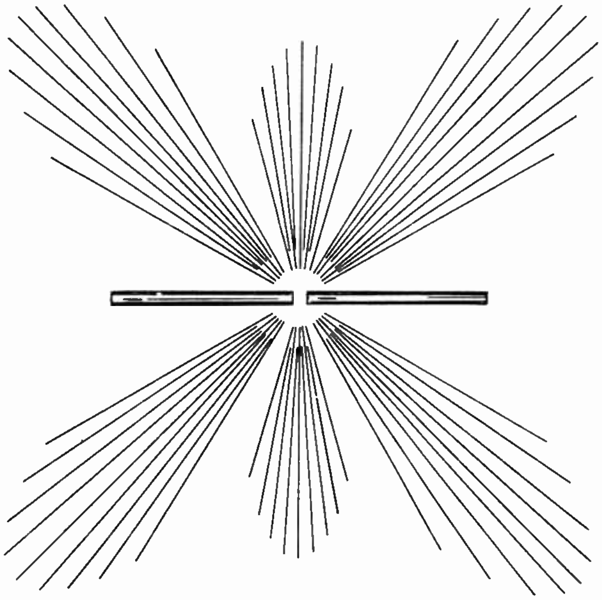

Fig. 8. Directional Response of a Dipole Cut for Three-Halves Wavelength. The Length of the Arrows are Proportional to the Relative Signal Developed in the Antenna.

An antenna to be used for all the low band VHF television channels, numbers 2 through 6, might be cut for the mid-band frequency of 71 mc. The decrease of frequency in reaching the bottom of channel 2 then would be about 24% and the increase to reach the top of channel 6 would be about 24%. An antenna for all the high band VHF channels, numbers 7 through 13, might be cut for the mid-band frequency of 195 mc. Then the decrease in frequency to reach the bottom of channel 7 and the increase to reach the top of channel 13 would be somewhat less than 11%. Even with a frequency change of as much as 25% in either direction, reception will be quite satisfactory with a simple dipole in areas where signal strengths (field intensities) are high.

To have a single antenna serve for both low band and high band VHF television channels with the antenna cut for the mid-frequencies of 135 mc, the change in frequency would be 60% down and another 60% up in reaching the extreme frequencies. This may be done with any number of antennas having more elaborate design than a simple dipole, but it is difficult at best. In any case, the signal strength at the points of reception should be fairly high.

A simple dipole is inherently a rather sharply tuned circuit of high Q factor. For wide frequency response it is necessary to reduce the Q factor and thereby sacrifice some gain. One way of broadening the frequency response of a simple dipole is to use large-diameter tubing for the antenna conductors. For appreciable advantage the diameter would have to be one inch and preferably more for reception in television bands.

F. Summary Questions

1. Why is the high frequency antenna critical?
2. Define polarization of a frequency wave?
3. The square root of 2X antenna heights in feet is equal to what factor?
4. What is the general result from a reflected high frequency wave in the TV band?
5. What is the formula for calculating a dipole antenna in feet?
6. Why is it necessary to match antenna impedance to the receiver?

ANTENNA DESIGN

Objective

To study antenna characteristics, types, and installation.

References

Lesson Content

A. Folded Dipole

The half-wave folded dipole antenna of Fig. 1 has much broader frequency response than a simple straight dipole. The folded dipole, as usually constructed, consists of a long piece of tubing bent into the form of a flat loop with one side continuous and with the other side open at the center. The transmission line to the receiver is connected to the ends of the tubing at the open gap. The loop is mounted with its plane vertical, with one side above the other. The open gap may be in either the top or bottom side. The distance between ends of the loop is made equal to a half wavelength for the frequency at which the antenna is to be resonant or at which it is to have greatest gain.

Like the simple dipole, the folded dipole has maximum response to signals traveling at right angles to the length of the antenna and has minimum response to signals traveling in line with the conductor. The directional pattern of the folded dipole is like that of the simple half-wave dipole, when supported sufficiently far from other objects and when operated at or near the frequency for which it is cut.

Separation between top and bottom sides of the folded dipole usually is something between 1 1/2 and 3 inches, center to center of tubing. The larger the tubing diameter the greater is the separation. Too much separation results in losing some of the broad band advantage of this type of antenna.

Since the center of the unbroken side of the loop is at zero RF potential, it can be grounded. Therefore, the antenna is often connected to the mast at this point without an insulator.

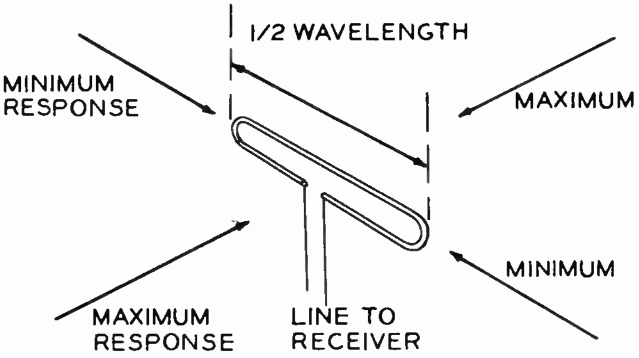

Fig. 1. Half-Wave Folded Dipole Antenna and Its Directional Properties.

B. The Double-V Dipole Antenna

Fig. 2 shows the basic design of a number of antennas having broader frequency response than a simple dipole. The overall length is equal to a half wave length at the frequency for which gain is to be maximum. The angle between the top and bottom usually is somewhere between 15 and 30 degrees. This type may be called a double-V dipole. The upper and lower sides of each V-section lie in the same vertical plane.

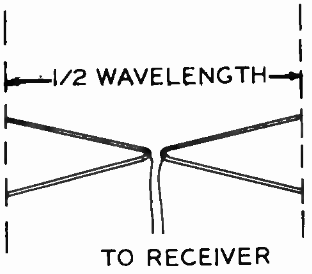

Fig. 2. A Double-V Dipole Antenna.

C. The Conical V Antenna.

An extension or modification of the V-principle is illustrated by Fig. 3A, which may be called a conical antenna or a conical V-antenna. The upper and lower arms form on each side of the V-member, with these two arms in a vertical plane. The center arms are set in a little way back of this vertical plane. Adding more and more arms to this arrangement would result in two opposed cones, as shown by the sample sketch Fig. 3B. Complete conical antennas of this style sometimes are used for ultra-high frequency reception.

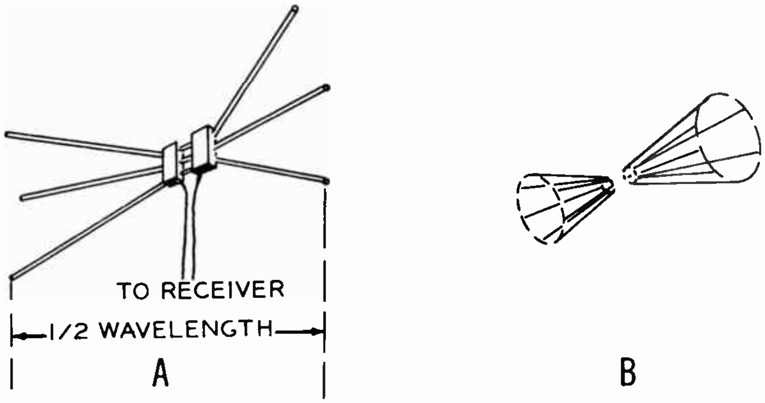

Fig. 3. A Half-Wave Dipole Which May be Called a Conical Antenna or Conical V-Antenna.

D. Parasitic Elements

1. Reflector

Fig. 4A shows a half-wave dipole antenna with a reflector. The side of this antenna nearest the transmitter will be called the front. Back of the dipole antenna (often called the "driven element"), at a distance of 1/4 wavelength, is a straight conductor which is not electrically connected to the antenna conductors or to anything else. This second conductor (called a reflector), is longer than the dipole so it will act as an inductance and cause a lag in current.

Fig. 4B shows how a signal reaching the dipole antenna from the front not only induces electron flow in the dipole conductors, as previously explained, but also goes on to the reflector. Part of the signal energy is reflected from this second conductor and travels back to the dipole, arriving there in phase with the signal existing at the dipole to reinforce that signal. The result is a decided increase of electron flow in the dipole, and a stronger signal delivered to the receiver.

Signals approaching the antenna from the back arrive first at the reflector, where part of their energy is absorbed and is reflected away from the antenna or dissipated in the reflector. Any signal being reradiated will not add to the signal at the dipole due to the out-of-phase condition. Thus there is attenuation of interfering signals coming toward the back of the antenna, and their strength at the receiver is reduced.

The reflector usually is one continuous length of tubing of the same diameter and kind as used for the dipole conductors, or for convenience in manufacturing and assembly the reflector may be in two pieces. It is not necessary that the reflector conductor be insulated, it may be in contact with the antenna mast.

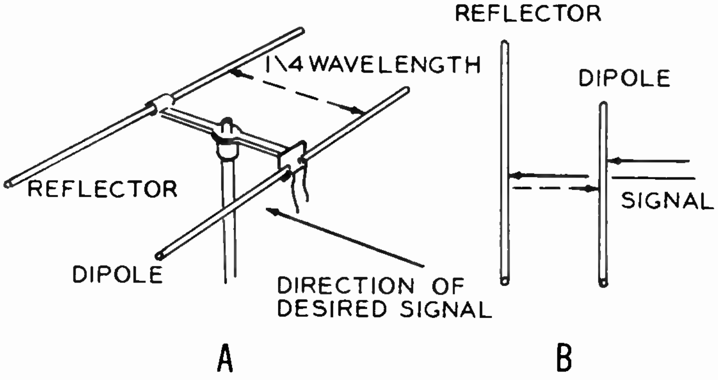

Fig. 4. A Half-Wave Dipole Antenna with a Reflector Element Back of it.

Maximum gain in signal strength is had with the reflector 1/4 wavelength or 0.25 wavelength back of the dipole. There is some drop of gain with either more or less spacing. If the spacing is made less than 1/4 wavelength there is somewhat more effective attenuation of interfering signals arriving from the back which may be of enough advantage to warrant the loss of front gain with the reduced spacing.

If the reflector is spaced 1/4 wavelength back of the dipole its overall length may be the same as the overall length of the dipole. If the spacing is less than this the reflector must be longer than the dipole by something like 5 to 10 per cent, the closer the spacing the greater the length of the reflector. With spacing greater than 1/4 wavelength, the reflector may be somewhat shorter than the dipole. These recommendations for reflector length are based on getting the best gain for the spacings mentioned.

Reflectors are used with all forms of antennas whose conductors lie in vertical planes or approximately so. A single straight reflector may be used for the folded dipole of Fig. 1 , for the double-V of Fig. 2, and for the semi-conical antenna of Fig. 3.

If the reflector is of the same form as the dipole itself, rather than a straight conductor for the broad band types, the response is made somewhat broader in frequency coverage. For example, the reflector for a folded dipole might have the form of a folded dipole.

2. Director

In Fig. 5, is shown an antenna system consisting of three elements. The element used for pickup of a signal carried to the receiver is pictured as a folded dipole, although a straight dipole or any of the modified or broad-band types might be used. Back of the dipole is a reflector, whose functions already have been explained. In front of the dipole is the third element, which is being used as a director. The director acts for signal energy somewhat as a glass lens would act for light energy; the signal energy is focused toward the dipole. The increase in signal pickup, and in energy delivered to the receiver, is somewhat greater with a correctly designed director than with a correctly designed reflector.

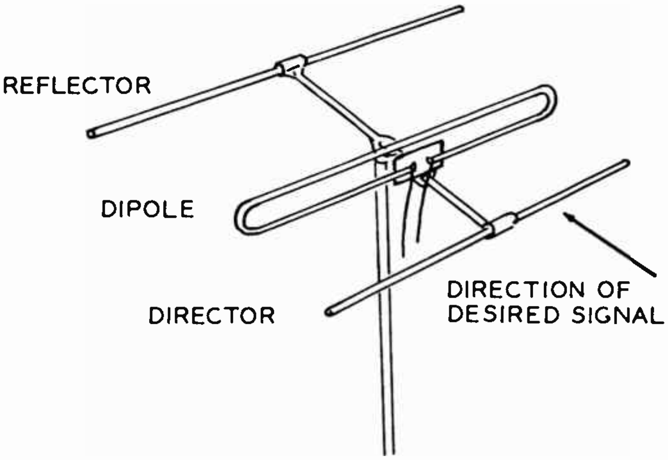

Fig. 5. A Folded Half-Wave Dipole with a Reflector Element Back of it and a Director Element in Front.

The mechanical and electrical construction of a director element is like that of a reflector. The director ordinarily is a continuous length of tubing. It may or may not be insulated from the supports and the antenna mast, and there are no electrical connections from the director to the dipole or to anything else.

If a director is mounted more than 1/10 wavelength in front of the dipole element, the director must be somewhat shorter than the dipole in order to have maximum increase of gain due to director action. If the director is 1/10 wavelength in front of the dipole, the director may be of the same length as the dipole, and if still closer together the director would have to be somewhat longer than the dipole. Because spacings almost always are 1/10 wavelength or more, the director is shorter than the dipole by about 5 to 10 per cent. All these length recommendations are based on preserving maximum gain or maximum increase of gain from the director.

While a director increases gain at the frequency for which the antenna is cut; it also narrows the band of frequencies in which there is good gain. A director, considered by itself, tends to give the antenna a narrow-band rather than a broad-band characteristic. This is true also of a reflector, but the reflector does not peak the response anywhere near as much as does a director. The farther the director is placed in front of the dipole and the shorter the director is made, the broader will be the frequency response but the less will be the gain.

Whether a conductor mounted parallel to the dipole element acts as a reflector or as a director depends on the spacing between this added conductor and the dipole, in terms of wavelength, and on the relative lengths of the two elements. If an antenna is cut for a mid-band frequency, reception at lower frequencies and longer wavelengths effectively moves both a reflector and a director closer to the dipole so far as fractions of a wavelength are concerned. At a frequency low enough, a reflector could change over to director operations, but if the spacing between elements is at least 0.15 wavelength for the lowest frequency in the band, this will not happen in practice. There may be reversal at some frequency below the television band, and interfering signals at this lower frequency might be strengthened by an element intended for a reflector but acting as a director.

As the received frequency increases, the reflector and director are moved farther away from the dipole in terms of wavelength fractions. Then the director might change into a reflector at some high frequency. If the director spacing is not more than 0.15 wavelength at the highest channel in the band, and if the director is cut no longer than the dipole, this will not happen in the very high frequency television bands.

Reflectors and directors may be called parasitic elements. Any type of antenna element with either a reflector, a director, or both, may be called an antenna array.

E. Two Band Antennas

1. The "INLINE " Folded Dipole

There are many antenna designs in which one element or set of elements is cut for the low band and another element or set of elements is cut for the high band of the very-high frequency television spectrum. One such type is illustrated by Fig. 6. Facing the direction from which it is desired to have signals in maximum strength is a folded dipole whose overall length from side to side is suited for reception throughout the high band, channels 7 through 13. Back of this high-band element is another folded dipole whose overall length is suited for reception in the low band, channels 2 through 6. Back of the low-band dipole is a straight reflector element whose spacing from the low-band dipole is such as to increase the gain in this band. Spacing between the two folded dipoles is such that the longer one acts as a reflector for the shorter one, thus increasing the gain in the high-band channels.

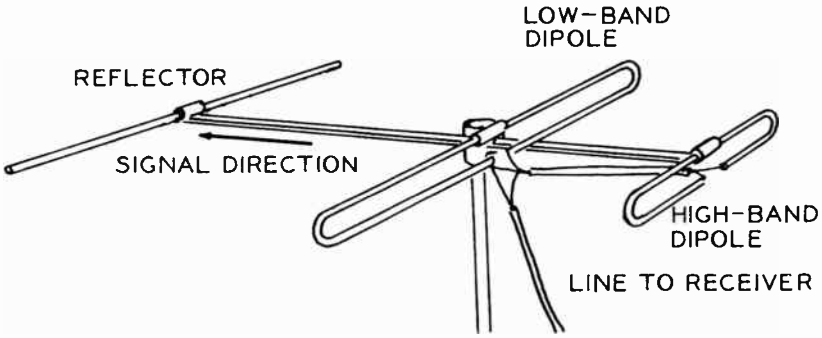

Fig. 6. An "INLINE " Folded Dipole Antenna Having Elements for the High Band and for the Low Band and a Single Reflector Element.

With the high and low-band elements mounted in a fixed parallel relationship to each other, all signals to be received in full strength must come from the same general direction to the antenna location.

2. High-Low Folded Dipole

In localities where desired signals, or signals to be picked up with maximum strength, come from different directions in the high and low VHF bands, the dipoles suited to the two bands may be mounted one above the other as shown by Fig. 7. Either array may be rotated or orientated independently of the other, as may be found most advantageous for local conditions.

The high-band array usually is placed above the one for the low band, although this arrangement may be reversed. Fig. 7 shows the transmission line going from the high-band dipole to the receiver, with an extension or line going from the high-band dipole to the low-band dipole. This arrangement also may be reversed. Both dipoles may be provided with reflectors, as illustrated, or the reflectors may be omitted from either or both arrays — all depending on what is required for signal gain and reduction of interference from undesired signals. Not only the folded dipoles pictured in the figure may be used one above the other, but any other type of antennas may be similarly arranged.

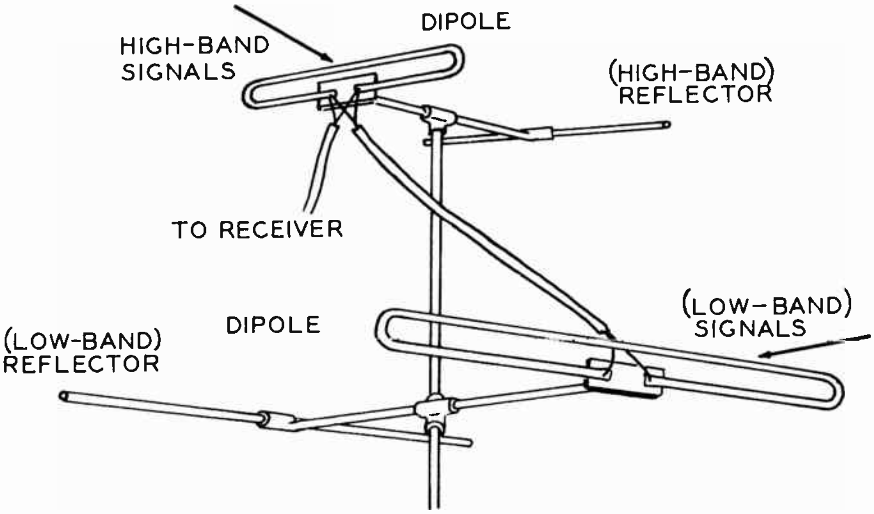

Fig. 7. Folded Dipoles and Reflector Elements for the High Band and the Low Band Mounted for Separate Orientation for the Two Bands.

In some installations, there are separate transmission lines running all the way from each dipole to the receiver. In the antenna coupling of the receiver, a switch operated with the band selector connects the receiver circuits to either one or the other of the dipoles according to the band in which reception is to be provided.

When high-band and low-band elements are connected to a single transmission line going to the receiver, as in Fig. 7, or with any generally similar arrangement, both elements must be in the same location or both must be on the same mast. If the two elements are mounted even a few feet apart, there may be enough difference in time between reception of the same signal on the two elements to cause considerable blurring of the pictures.

3. The Folded-V Antenna

There are a number of combinations of V-elements with straight dipoles whose purpose is to provide satisfactory reception throughout the entire very-high frequency television band with a single antenna or single array. As illustrated by Fig. 8, short loops forming a "V" may be mounted in front of a folded dipole. The V-loops provide response in the high band while the folded dipole acts for the low band.

Fig. 9 shows V attachments consisting of small diameter rods mounted on a simple half-wave dipole. The V's are equally spaced from the dipole center, with the sides of the V's lying in a vertical plane with the dipole. These attachments may be mounted on any straight dipole whose length is suitable for reception in the low band, and will provide good signal pickup for frequencies in the high band. A reflector may be used in the usual position.

4. Collinear Antenna

The Collinear type of antenna illustrated in Fig. 10 consists of several elements placed end to end and having their currents in phase. The current distribution of this antenna would be similar to that shown in Fig. 11. By removing the center half-wave section, there would be two half wave elements with their currents in phase. This is done by replacing the center section with a quarter-wave matching stub (see Fig. 12). The basic collinear antenna is formed in this way. The antenna is non-directional in a plane perpendicular to the antenna, but it is bi-directional in a plane containing the antenna. The response patterns in these planes are shown in Fig. 13.

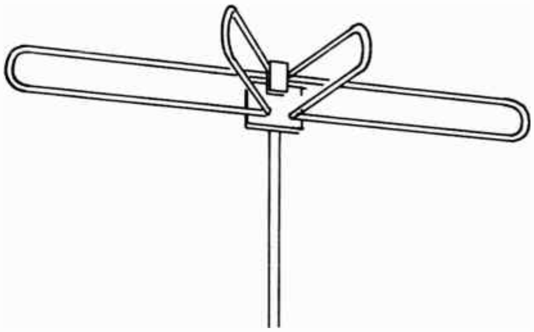

Fig. 8. A Folded Dipole Combination Designed for Reception of both the High and Low Bands.

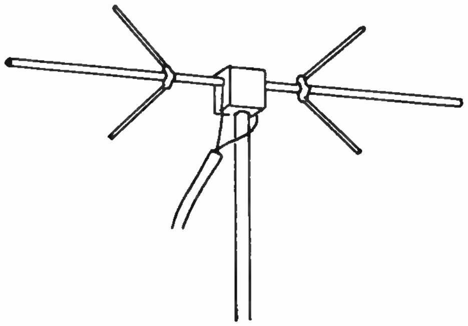

Fig. 9. V-Attachments on a Straight Dipole for Reception of Both Bands.

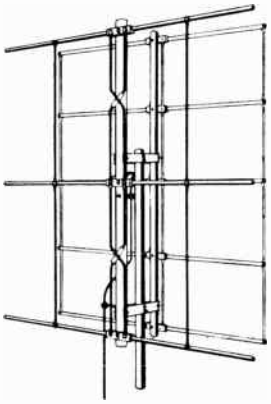

Fig. 10. A Collinear Antenna.

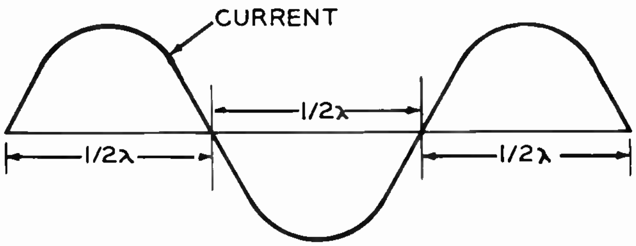

Fig. 11. Current Distribution in a Collinear Antenna.

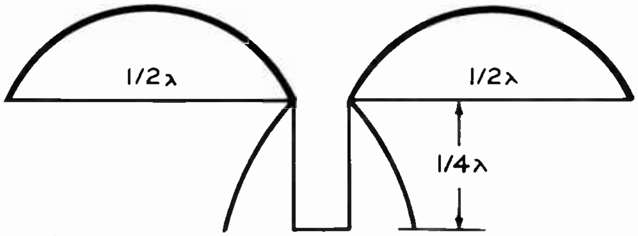

Fig. 12. The Basic Collinear Antenna.

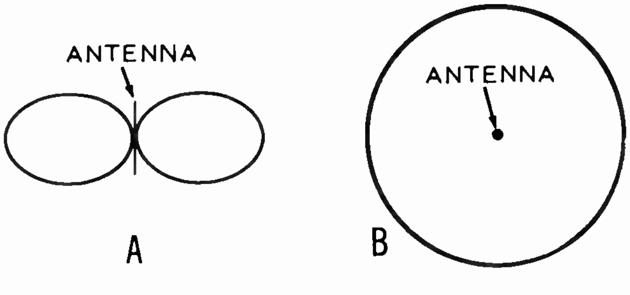

Fig. 13. Response Patterns of a Collinear Antenna. (A) In a Plane Containing the Elements. (B) In a Plane Perpendicular to the Elements.

The lengths of the half-wave elements used in the collinear antenna are not critical, but the lengths should all be the same.

The Q of an antenna is indicative of its broadband characteristics. A high Q produces a sharp response curve and indicates narrow frequency response. Conversely, a low Q produces a broad response curve and is therefore an indication of wide frequency response. The collinear antenna possesses a low Q therefore it is a good broadband antenna. Increased gain and directivity are possible by the addition of half-wave elements as illustrated in Fig. 14. Note that the transmission line is connected to a high-impedance point.

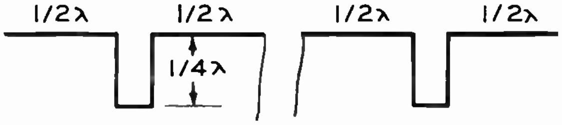

Fig. 14. The Addition of Half-Wave Elements to a Collinear Antenna.

5. The Rhombic Antenna

Rhombic antennas have been used by radio ameteurs for many years. The outstanding feature is the excellent vertical selectivity these antennas possess. The most important limitation to this type was its overall size. The space required often exceeds 50 feet.

When UHF with its shorter wave length and smaller receiving antennas came along the Rhombic antenna became quite practical. Its practical use is limited to UHF frequencies since the size and weight of the VHF Rhombic would introduce installation problems.

The Rhombic antenna requires a loading resistor to insure a correct impedance match to the lead-in line. This resistor is usually supplied as part of the antenna.

Some complex antennas use a rhombic section for response to UHF frequencies with conical elements for VHF reception.

Fig. 15 illustrates an Amphenol UHF rhombic antenna. Fig. 16 illustrates a JFD stacked bi-conical antenna with rhombic sections for UHF reception.

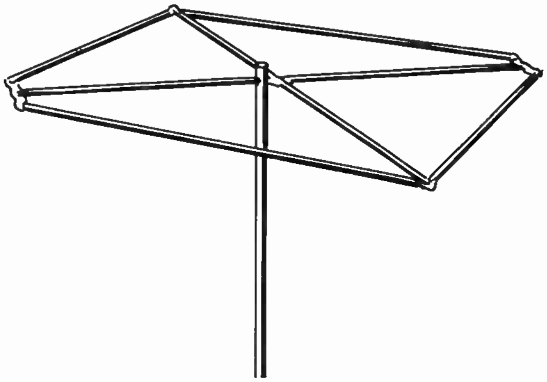

Fig. 15. A Rhombic Antenna for UHF Reception.

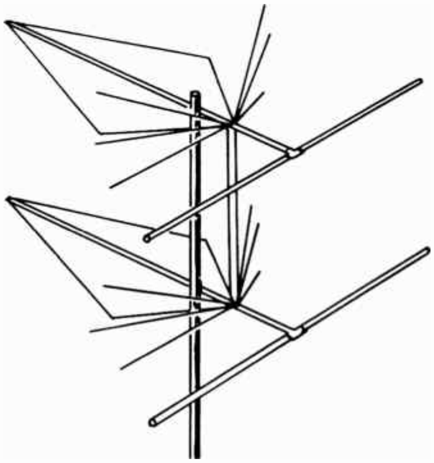

Fig. 16. A Stacked Bi-Conical Antenna with Rhombic Sections for UHF Reception.

6. Bow Tie Antennas

The Bow-Tie antenna is a modification of a simple dipole. The two sections of the dipole are triangular in shape.

Figs. 17A, B, C show types of Bow-Tie antennas. This arrangement is similar to a flattened conical antenna. The triangular shape permits the antenna to be resonant to many different frequencies. This may be visualized by imagining dipoles drawn on the triangles at different positions. As the lengths of the lines change so does the frequency.

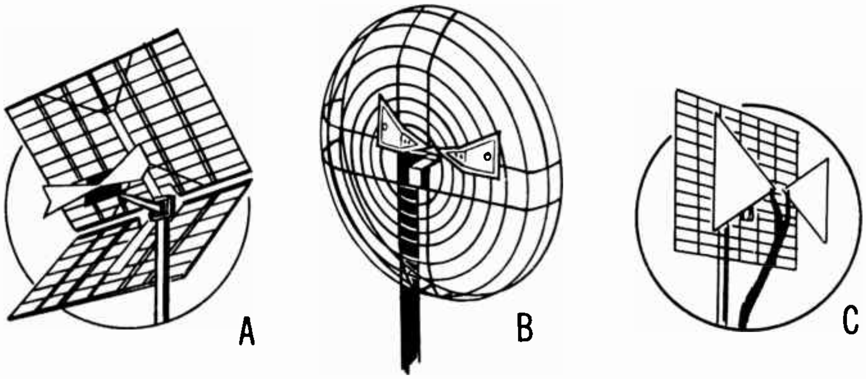

Fig. 17. Bow-Tie Antennas.

This antenna is practical only for UHF because of its size and weight.

Reflectors are usually used behind these units. The 3 most popular types are corner (Fig. 17A), parabolic (Fig. 17B), and flat (Fig. 17C).

F. Yagi Antennas

A Yagi antenna in the usual meaning of the name is one having a single reflector and two or more directors. A Yagi with four directors is illustrated by Fig. 18. Types with as many as seven or eight directors sometimes are used. Most notable characteristics of the Yagi antenna are high gain, narrow bandwidth, sharp directivity in the forward direction, and small back response. Although most of these antennas have sufficient bandwidth for only one or two adjacent channels, some modified styles allow reception in either the entire low band or the entire high band of the VHF spectrum, although with some sacrifice of gain.

Because of its many director elements the Yagi antenna tends to have very low impedance. As a rule, impedance is maintained high enough to match transmission lines by such methods as using three-conductor folded dipoles, or by making the continuous conductor of a folded dipole of greater diameter than the divided element to which is connected the transmission line.

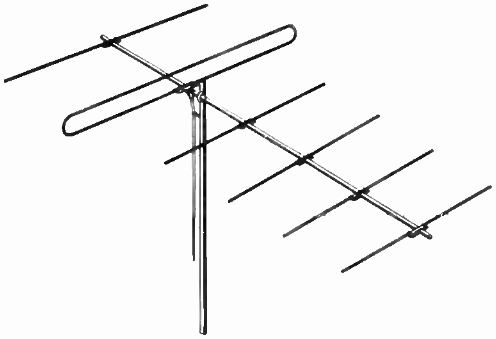

Fig. 18. A Yagi Antenna.

G. Stacked Antennas

In order to provide sufficient signal strength, especially at the higher television frequencies, it may be necessary to use two or more similar arrays mounted one above the other, and suitably connected together and to the transmission line. Such an arrangement, with all the elements or arrays cut for the same frequency or the same band is called a stacked antenna or a stacked array.

Part of the added gain from stacked arrays is due to the fact that they intercept a greater area of the wave front. Energy pickup is proportional to the intercepted area. This area is not merely that of the metallic tubes as projected in the direction of wave travel, but extends to a considerable distance away from the metal in all directions. The effective area becomes somewhat of a rectangle, and for antennas of short length approaches a circle. The effective signal area is approximately proportional to the square of the overall length of the pickup element. Since the average length for the high-band VHF channels is only about 0.40 of the length for low-band VHF channels, the pickup in the high-band is only about 0.16 of that in the low-band for equal field strengths.

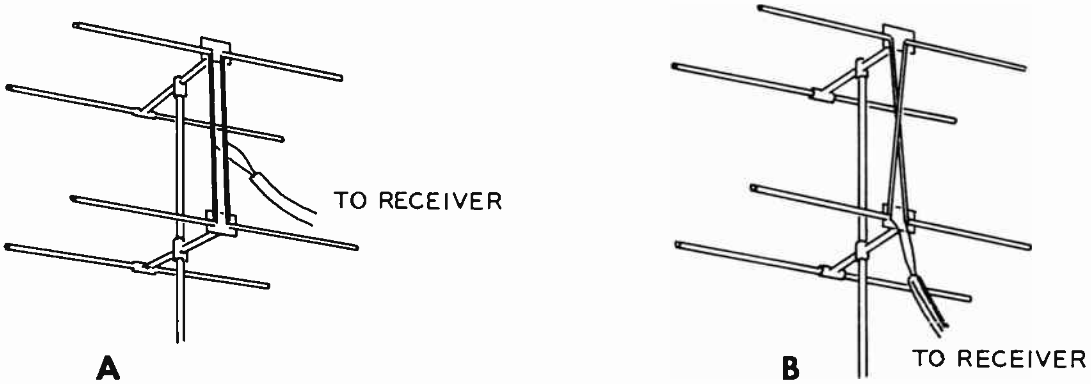

Fig. 19. The Point of Transmission Line Takeoff Determines Whether or Not the Phasing Link is Transposed.

Stacking may be carried out with any style of array, with straight dipoles, folded dipoles, V-type or conical dipoles, or anything else. The two stacked elements, or any number of stacked elements or arrays, must be of the same type. Each pickup element may be used with a reflector, with a director, with both, or with neither. The separate arrays in a stacked assembly often are spoken of as bays.

Vertical spacing between bays is preferably 1/2 wavelength at the frequency for which the elements are cut. Less spacing reduces the gain, but may be necessary in order to limit the overall size, especially in the low band.

The stacked elements, from which the transmission line runs to the receiver, are connected together with phasing links which may be pieces of transmission line, or else may be lengths of wire or tubing in air. When only two bays are stacked, and when the transmission line takeoff point is from midway between them as at the left in Fig. 19A, phase the transmission line by joining like ends of the dipole. That is, the two ends on the left of the gaps are joined together, and the two on the right are joined together. If the takeoff for the transmission line is from one or the other of the bays, as shown from the bottom bay in Fig. 19B, the phasing link is transposed between upper and lower bays.

Were an additional bay to be added above or below, or in both places, to the arrangement shown in Fig. 19A, the phasing links to the outer elements would be transposed. For example, with four bays the transmission line would connect midway along the link between the two middle bays, and this link would not be transposed. The other two links, going to the top bay and to the bottom bay, would be transposed.

It is assumed that the phasing link has an electrical length of 1/2 wavelength at the frequency for which the elements are cut. Because of the reduced velocity constant, a link made of transmission line will be considerably shorter in physical length than a half wavelength in air. Consequently, with a vertical spacing of 1/2 wavelength between bays, a transmission line link will have an electrical length of more than 1/2 wavelength. Link conductors which are separate, and in air, have velocity constants not much less than that of signal waves, and are preferable for phasing links.

H. Impedance of Antenna

Dipole antennas and all the modifications may be considered as tuned circuits which are resonant at the frequency for which the electrical antenna length is equal to a half wavelength. As with all tuned circuits, the inductive reactance and capacitive reactance become equal and balance each other at the resonant frequency. This leaves the high-frequency resistance as the only remaining factor in impedance, provided the frequency is that for resonance and there are no extraneous effects which prevent balancing of the reactances.

So far as reception is concerned, the antenna is the source of signal energy whose internal impedance depends on the type of antenna and conditions of operation. If the impedance of the antenna is matched by or is equalled by the impedance of the transmission line, half the energy picked up in the antenna will be transferred to the line. This represents maximum possible transfer of energy. If the impedance of the transmission line matches the impedance of the receiver input circuit, there will be maximum transfer of signal energy into the receiver.

The impedance at the center gap of a simple half-wave dipole and of other types which are essentially simple dipoles is about 73.2 ohms when the antenna is unaffected by any of the conditions to be mentioned in following paragraphs. The impedance at the center gap of a folded dipole, and of most other types which are developments of the folded dipole, is about 293 ohms, or approximately 300 ohms.

At all frequencies both higher and lower than the one for which the antenna is cut the impedance is greater than the values mentioned, because at all other frequencies there is an excess of either inductive or capacitive reactance. It follows that, if the antenna is longer than it should be for the received frequency, there is an excess of inductive reactance.

Antenna impedance is minimum at the center, and would become much greater were the takeoff point from either side of center. With takeoff from the center of a phasing link on stacked arrays, as in Fig. 19A, the impedance at the takeoff point is one-half that of either antenna element. With takeoff from the bottom, as in Fig. 19B, or from the top, the impedance is the same as that of one of the elements.

A reflector tends to lessen the antenna impedance. The decrease is not great unless the reflector is mounted very close to the pickup element, or is of excessive length. Unless the antenna is supported at least a wavelength or farther from other conductors and from dielectrics of all kinds, the actual impedance will differ materially from theoretical values, usually being increased.

I. Antenna Construction

Antenna conductors should be of weather-resistant metal, and preferably of light weight to reduce stresses on mast and supports when subject to high winds, snow, and icing. Aluminum and aluminum alloys in tubular form best satisfy these requirements. Tubing of hard drawn copper, brass, bronze, and even of copper coated steel may be used where the weight is not objectionable. Soft drawn copper tubing, obtainable from refrigeration supply houses, may be used for setting up experimental antennas. A dipole antenna may be made with two lengths of copper wire for the two conductors, held at the center gap with a radio antenna insulator, and similarly supported at the outer ends. The center gap of any antenna need be only great enough to allow for insulation, connection of the transmission line, and freedom from filling up with dirt.

Antenna insulation and supports must have high mechanical strength as well as good dielectric properties. These requirements are satisfied by such substances as low-loss bakelite and similar phenolic compounds, by streatite and various ceramics, by polyethylene, and under some circumstances by glazed porcelain. Experimental antennas may be set up by using wood which has been well impregnated with paraffin wax in a hot bath.

J. Locating and Orienting the Antenna

If the locality is a fringe area or if signals are known to be generally weak, it is worth while to mount the antenna at the highest practicable point. In many cases an extra five or six feet makes the difference between very poor and good reception. At the selected point it must be possible of course, to erect a mast and needed guy wires without too much trouble. Always keep the antenna as far as possible from sources of electrical interference. Such sources include automobile traffic, public garages, buildings having many electrical machines, electric signs, x-ray and other kinds of medical laboratories. Keep away from large metal objects, such as metal roofs, gutters, and vent pipes.

When a tentative position for the antenna has been selected it is necessary to make a test of actual reception before final installation. With a transmission line of approximately correct length connected to the antenna and to the receiver, the antenna is moved about and rotated while observing the resulting signal strength and quality. This work is done most easily and quickly with one person moving the antenna while another watches the picture tube of the receiver. There must be some means of communciation. The most popular means is a pair of self-energized phones, the kind which work without batteries or other external power, connected together by a cable running from receiver to the antenna location. Many manufacturers discourage the practice of connecting phones through the transmission line, although this sometimes is done with 75-ohm lines.

If the work must be done without the assistance of a helper it is possible to connect to the receiver, somewhere between the video detector load and the picture tube input, a high-resistance voltmeter or a microammeter which is taken to the antenna location. Meters designed for this purpose are available. Any sensitive voltmeter or current meter may be used provided there is a rectifier and filter at the receiver end of the connecting line, so that the high-frequency signals produce a direct current or voltage in the long connecting line and the meter.

A detector probe such as used with an oscilloscope or an electronic voltmeter for high-frequency measurements is entirely satisfactory for use at the receiver. The scheme of connections is illustrated by Fig. 20. The high side of the probe may be connected to either the video detector load, the plate of one of the video amplifier tubes, or the control grid of the picture tube, the contrast control should be turned up to the usual operating position. The meter will indicate only changes in signal strength as the antenna is moved and rotated. Final inspection for picture quality must be made at the receiver with the antenna mounted in the position of greatest signal strength.

With the antenna conductors extending horizontally, rotate the antenna one way and then the other, until the signal strength is at its peak. Then, if the construction allows, the antenna conductors may be inclined from the horizontal. It is possible that objects between the transmitter and the antenna may change the polarization of the signal away from horizontal. If possible to make tests on more than one station, always favor the one which appears to furnish the weakest signal.

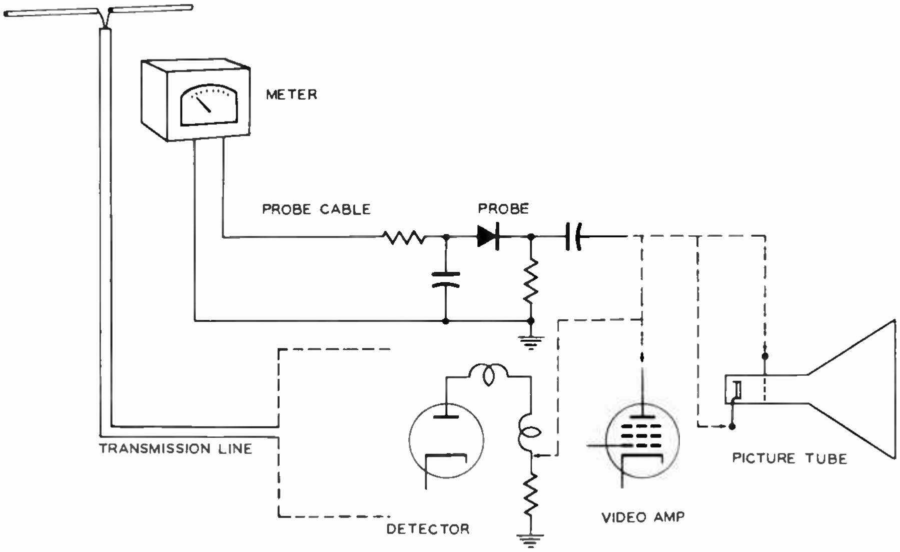

Fig. 20. Connections for a Meter Which is Carried to the Antenna Location During Orientation.

K. Installation of Antennas

The actual mounting of the antenna mast and guy wires often calls for abilities possessed by a combination of carpenter, mason, plumber, electrician, and all around mechanic. It must be remembered that restrictions may be imposed on the height of masts, their location, or the overall size of arrays. Such restrictions may be in leases or in local ordinances. In addition, it is necessary to be familiar with rules of the National Electrical Code for antennas and transmission lines or "lead-ins." Elevated antennas and masts present lightning hazard. A lightning arrester of some type approved by the Underwriters' Laboratories should be used on the transmission line. With most types it is necessary only to clamp the arrester over the line, with or without removing some of the line insulation. If the arrester is grounded on a cold water pipe, keep the transmission line as nearly as possible at right angles to the pipe, never parallel for any distance at all. Often it is easier to drive a grounding rod down to permanently moist earth, solder a number 12 or larger copper wire to the top of the rod and run this wire to a location convenient for the arrester.

If the antenna mast is metal, as usually is the case, it should be connected through a heavy copper wire to a cold water pipe or to the grounding rod. The charge accumulated on an ungrounded mast during dry summer weather, even when there is no lightning, is enough to give a shock that stings even though it is not dangerous.

If the antenna mast is 10 feet or more in height it should be supported by three or four equally spaced guy wires. A swaying antenna causes picture brightness to vary, and signal strength may drop enough to cause loss of synchronization. If guy wires have to come within one wavelength or less of the antenna conductors, one or more radio antenna insulators should be inserted in the guys somewhere within the first three or four feet from the mast.

L. Indoor and Temporary Antennas

Indoor antennas often are satisfactory in areas of fairly high signal strength when used in buildings of frame, brick, stone, or stucco construction. They seldom are wholly satisfactory in steel-frame buildings, nor under metal roofs, nor where there is metal foil heat insulation. Indoor antennas in a building of any construction must be kept away from plumbing and vent pipes, from metal beams, and even from such things as curtain and drape hangers.

Any indoor antenna is handicapped by lack of sufficient elevation to receive signals unaffected by all manner of obstructions in the wave path. From this standpoint an antenna located in the attic is likely to be much more satisfactory than one near the receiver.

A simple half-wave dipole may be formed on the end of a twin-lead transmission line by slitting the line through the center of its insulation for a distance of about 1/4 wavelength, then supporting the two ends in a straight line. The overall length of the spread-out portion should be somewhat shorter than the length specified for a half-wave dipole by the table in the preceding lesson. Lines of 75- or 100-ohm impedance may be used for this type antenna.

A folded dipole antenna for indoor use may be made from 300-ohm twin lead transmission line as shown by Fig. 21. A piece of the transmission line is cut to an overall length as listed in the table for half-wave antenna lengths in the preceding lesson. The wire conductors at both ends are bared for about a quarter inch and twisted or soldered together. Enough insulation is removed at the center of the conductor on one side of the line to allow cutting the conductor at this point and twisting or soldering the exposed ends to the two conductors of another piece of the same kind of line, this second piece being the actual transmission line running to the receiver.

The frequency response of this folded dipole is somewhat narrower than that of a folded dipole made of tubing in the usual manner. In theory the length of the transmission-line folded dipole should be somewhat longer than dimensions listed in the table; but in practice the listed dimensions provide resonance close enough to the centers of the channels.

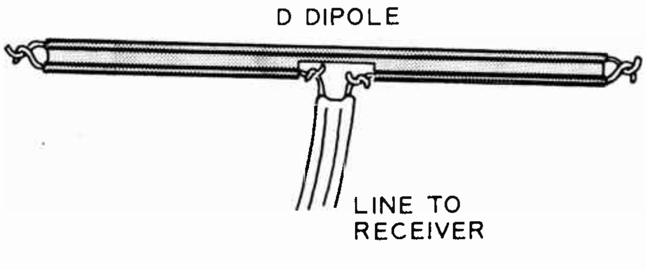

Fig. 21. A Folded Dipole Antenna Made From Transmission Line.

M. Multi-Unit Antennas

Antennas for use in hotels, apartment houses, hospitals, and other multi-unit buildings consist of one well designed antenna with necessary lead-in and transformer stations to receive and redistribute signals from several channels to any part of a large building.

The RCA Antennaplex which was an early development in the field of multi-unit antennas has been expanded for community use in fringe areas.

The community antenna system can provide TV signal pickup and distribution service for an entire community. The new system consists of a master antenna assembly mounted on a tall mast on the highest elevation in the area. A network of coaxial cable, strung over utility poles carries the signal from the antenna to the various customers.

Amplifiers mounted on poles at fixed intervals are used to boost the signal strength. The antenna mast contains separate elements tuned for each channel on which programs are available.

N. Summary Questions

1. What is the name of an additional antenna element other than the dipole?
2. When is an indoor antenna suitable?
3. Why is a test on all TV channels necessary when locating and orientating the antenna?
4. Which antennas are usually used only for UHF reception?
5. What is the advantage of stacking antennas?
6. Which type single-stack antenna may have as many as ten complete elements including directors, reflectors, and the driven dipole?

TELEVISION

Objective

1. To study the principle of converting light energy to electrical energy.
2. To study the RETMA scanning standards used with present black-and-white TV transmission and reception.

References

Lesson Content

A. Introduction

We have means for reproducing sound at a distance from the point where the sound originates. This is not so difficult, because a sound consists of changes of air pressure which occur one after another, and at any one instant of time there is only one degree of pressure to be reproduced as the changes follow one another in correct order.

In television, however, we have means for reproducing at a distance from the original scene all of the simultaneous motions of all the people and objects in a scene. We must reproduce continually varying lights and shadows. Brightness decreases at some points while increasing at others, and remaining unchanged at still other points in the scene — all during the same instant.

The television signals which are to represent all the simultaneous motions and changes of light are transmitted through space with modulated carrier waves in a way similar to the method used for sound broadcasting. These modulated waves have either varying amplitudes (AM) or varying frequencies (FM), but at any one instant of time and in any one point in space there can exist only one amplitude or only one frequency.

At this point we are confronted with the problem of converting hundreds of variations of light which are occurring simultaneously and in different degrees, into variations of carrier modulation voltages which must occur one after another, and cannot occur simultaneously. Then, at the television receiver, we must take these carrier variations which come in one after another and put them together so that all of the changes of light and motion in the original scene appear at the same time, in the correct order and in the same relative positions.

B. Persistance of Vision

Persistance of vision is an important factor in television. When we look at a light, and the light suddenly goes out, we seem to see the light for a period of 1/30 to 1/15 second after it is no longer present.

Assuming that an artist possessing some kind of magic could paint and erase a complete scene within 1/30 second, then paint and erase another complete scene in the following 1/30 second, you would not see the scenes separately but rather as a single continuing picture. Were there gradual changes in the positions of people and objects in the successive scenes, and also gradual changes of light, you would see smooth motion from one place to another, and gradual changes between degrees of brightness. This magic is provided by television.

C. The Television Camera

1. The lens

The television camera views the original scene and converts the reflected light waves reaching the lens, to corresponding electrical impulses. The camera uses lenses like those in high quality still cameras and movie cameras. The TV camera lenses are mounted upon a "lens turret," accomodating 4 different types as shown on front of camera pictured in Fig. 1.

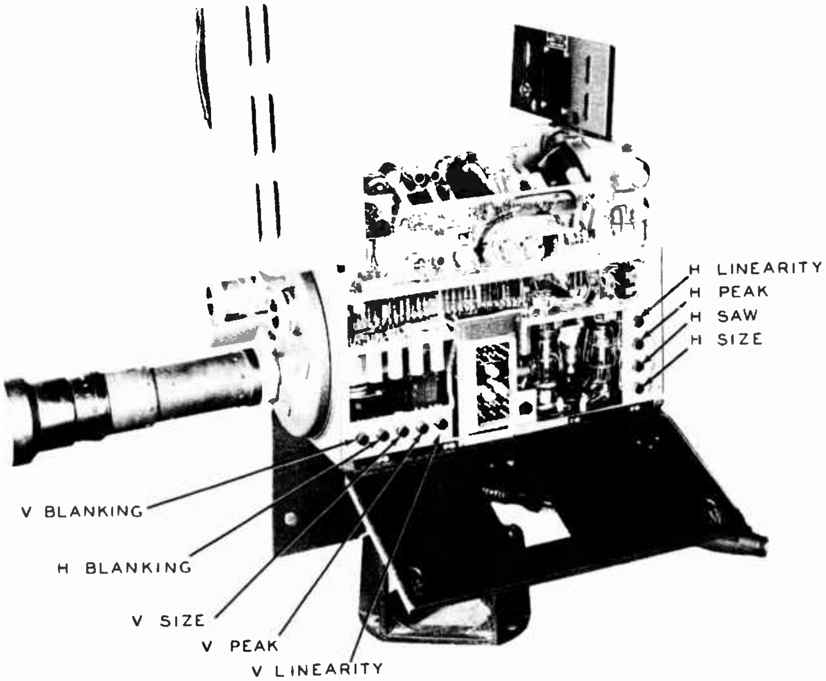

Fig. 1. A Television Camera.

There are two principal types of camera tubes, the Image Orthicon, and the Iconoscope. Fig. 1 illustrates a television camera with the side doors open. The top section is the viewfinder, and is detachable from the lower section. The lower assembly is the pickup head and contains the image orthicon tube and associated coils, the video preamplifier, horizontal and vertical deflection amplifiers, and the blanking circuits. Fig. 2 illustrates the basic action of the Iconoscope tube. An image of the scene is focused by the taking lens. The image is then focused on the surface of a mosiac which is inside the camera tube.

2. The mosaic

The mosaic is the rectangular plate within the iconoscope camera tube. The mosaic surface which is reached by light is covered with photo-emissive material similar to the light-sensitive cathode in a photocell. A mica insulation plate between the mosaic and the signal plate produces a capacitor construction with the mosaic acting as one plate, the mica acting as the dielectric, and the signal plate acting as the other plate of the capacitor.

Every silver globule making up the mosaic is photosensitized so that when a light image is projected on the latter the light causes electrons of a number proportional to the light brilliance to be emitted from each illuminated minute size photosensitive area. The resulting loss of electrons leaves each photosensitive area at a positive potential with respect to its initial condition. This potential is then proportional to the number of electrons which have been released and conducted away so that the mosaic tends to go positive at a rate proportional to the light falling on it. Under normal illumination, and when the electron beam is not scanning the target, the mosaic is approximately three volts positive with respect to the signal plate.

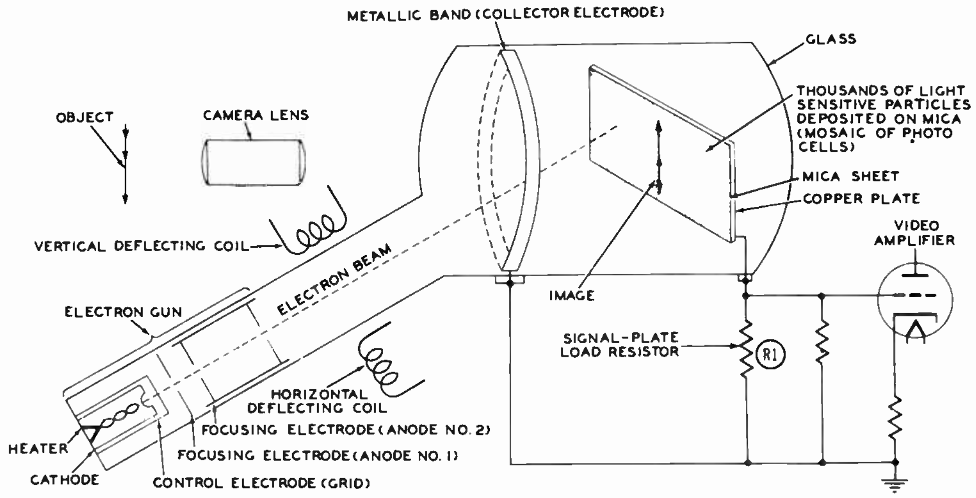

Fig. 2. The Iconoscope Camera Tube.

When the electron beam strikes a bright area, the positive charge is neutralized within that area thereby reducing the total charge of the capacitor. This causes electrons to leave the signal plate, pass downward through R1, through the high voltage power supply, to the cathode of the gun and via the electron beam to the mosaic.

When the electron beam strikes a dark area, secondary emission takes place. The number of electrons knocked off by the beam bombardment on a dark area is momentarily greater than the number of electrons retained. This causes an increase in the total charge of the capacitor and secondary emitted electrons are collected by the collector ring and pass upward through R1 to the signal plate. Note that when the electron beam strikes a bright area, the amplifier grid becomes relatively negative and decreases amplifier plate current; and when the electron beam strikes a dark area, the amplifier grid becomes relatively positive and increases the amplifier plate current.

Analysis of the circuit indicates that the mosaic is electrically connected to the bottom end of R1 via the electron beam and electron path from mosaic to collector ring. Also note that the signal plate is connected to the amplifier grid. This means that the charge across the mosaic to signal plate is applied between amplifier grid and cathode thus serving as grid bias. The greater the total illumination on the mosaic, the greater the charge or grid bias at the first amplifier.

D. Scanning the Image

The electron beam represented in the camera tube of Fig. 2 issues from a part called the electron gun which is inside of a tubular extension on the lower left-hand side of the tube. The electron gun is a device for emitting electrons from a heated cathode, for forming the stream of emitted electrons into a narrow beam, and for accelerating the beam electrons to a high velocity so that they may travel away from the end of the gun and, in the present case, to the mosaic.

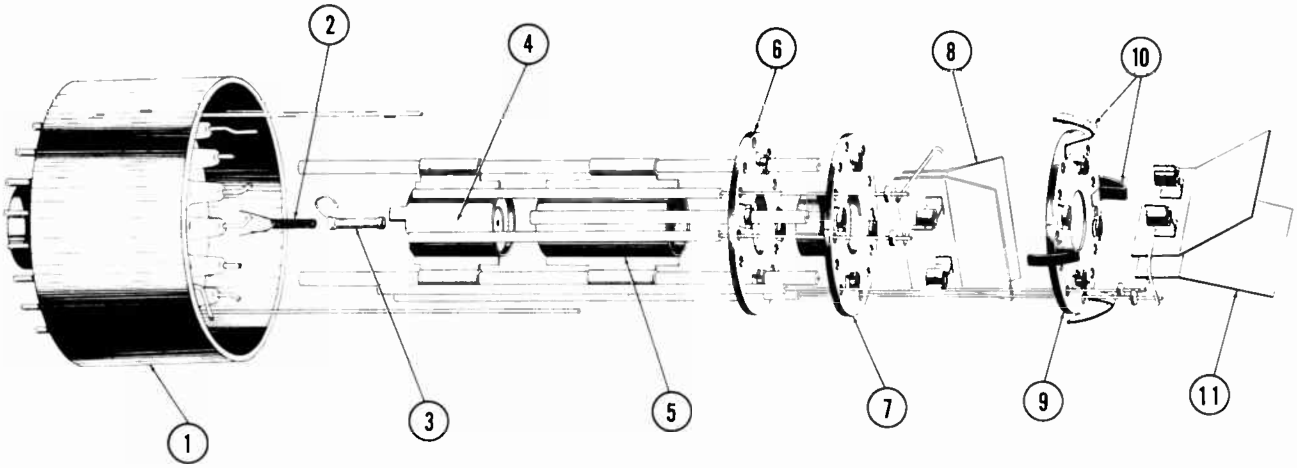

Fig. 3. Construction of a Typical 7" Cathode-Ray Tube Using Electrostatic Deflection (1) Medium Shell Diheptal Base (2) Heater Element (3) Cathode Sleeve (4) Control Grid (5) Accelerating Anode (6) Focus Anode (7) Accelerating Anode (8) Horizontal Deflection Plates (9) Barrier Anode (10) Support and Aquadag Contact Springs (11) Vertical Deflection Plates.

The parts of an electron gun shown in Fig. 3 are numbered 2 to 7 inclusive. A camera tube will usually use external deflection coils to move the beam instead of the plates shown in Fig. 3 as 8 and 11.

1. The deflection coils

The electron gun produces a stream of electrons which will be focused on a single spot on the mosaic. Since this single spot would give us information concerning only one very small speck of the picture, we must find an orderly way to move this spot across all the spots on the mosaic. This process of sampling spots all over the mosaic area in an orderly sequence is called sequential scanning.

When studying basic electricity in the early part of your course, you found you could cause a current to flow in a transformer winding by subjecting it to a magnetic field. The current flow is nothing more than a movement of electrons. By reversing the direction of the magnetic field you could also reverse the direction of flow of the electrons.

Since the beam formed by the "gun" is composed of electrons, it follows that we can make it move by applying a magnetic field. Further, if we reverse the direction of the field, the beam will move in the opposite direction. In television deflection systems (both at the camera and at the receiver) we use two sets of coils. One set is to deflect the beam horizontally, the other to deflect it vertically. Remember that the set which has a vertical axis will move the beam at right angles to this axis (horizontally).

When studying Fig. 4, imagine the gun is pointing at you from behind the paper. The dot is a cross section of the beam as it is striking either a mosaic in a camera tube or the screen in a television receiver.

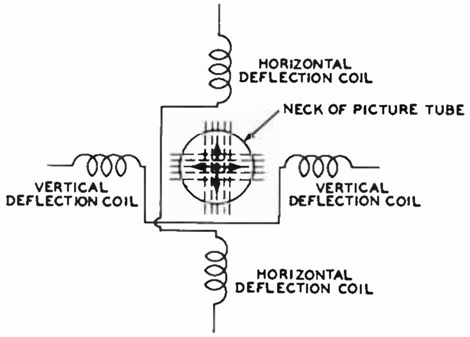

Fig. 4. A Typical Arrangement of Deflection Coils. The Dotted Lines Represent the Magnetic Fields. The Electrons will be Deflected Away From the Lines at Right Angles to the Line. The Direction will Depend on the Direction of Current Through the Coil.

E. The Scanning Raster

By varying the current in the vertical deflection coils we may bring the end of the beam to the top of its travel, and by suitable variation on the horizontal deflection coils we may, at the same time, bring it all the way to the left. Then, looking at the surface of the mosaic or any other surface struck by the beam, the end will be in position 1 of Fig. 5A. If the current is reversed in the horizontal deflection coils the end of the beam will be moved across the surface to position 2. Another reversal, bringing us back to the original polarity, will move the end of the beam to position 3, and the next reversal will move it to 4, and so on.

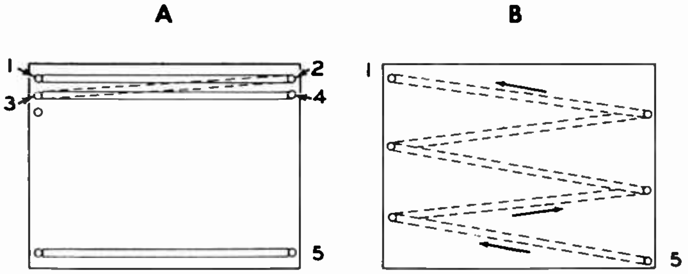

Fig. 5. How an Area is Scanned by Deflecting the Beam Sideways and Downward.

While the current in the horizontal deflection coils are being reversed with great rapidity, the current in the vertical deflection coils are going through a much slower change, so that the beam gradually moves downward, while flying back and forth from side to side, until the end of the beam reaches position 5.

We shall continue the reversals of current in the horizontal deflection coils while rather quickly varying the current in the vertical coils to bring the end of the beam back to position 1. This upward travel is shown by Fig. 5B. Then the whole process may be repeated, over and over.

During its travel, the beam will touch for the briefest moment every droplet on the surface of the mosaic. The separation between adjacent "lines", such as 1-2 and 3-4, and the diameter of the beam are so related that there are no gaps between adjacent lines.

Actually, the beam exists only during the active lines, which are those traced from left to right during the gradual downward travel. During horizontal retraces, as from 2 to 3, and during the vertical retrace, from 5 back to 1, the electron flow from the cathode of the electron gun is stopped, although the reversals of deflection currents continue.

During the instant in which the end of the beam reaches one small droplet on the mosaic we have the action described in connection with Fig. 2 and in resistor R1 of that diagram there is electron flow proportional to the light on the tiny droplet then being struck by the beam, and in a direction that corresponds to whether the light is brighter or less bright than during the travel of the beam over the preceding small area of the image. Thus we have in resistor R1, and in the output of the amplifier tube, changes of electron flow and potential difference that correspond not only to the absolute values of light on each area of the image, but also to whether the light is more or less than on adjacent areas. The changes of electron flow and potential, which form the video signal, follow one another in the same order that the end of the electron beam travels across each minute element or area in the image. This is the process of scanning the image, and of forming the video signal.

F. The RETMA Scanning Standards

1. The frame and aspect ratio (4/3)

The frame at the camera is the mosaic which has a standard ratio of width to height. This ratio for television pictures is 4/3 and is called the aspect ratio. Fig. 2 shows the mosaic much wider than it is high, thus forming a rectangle. This rectangle (frame) will be four units (inches or anything else) in width and three equal units in height.

2. Number of lines per frame (525)

In one standard practice there are 525 active lines per frame. Other numbers of lines have been used, and may be used, but we shall use the 525 line standard for our examples to illustrate the principles involved.

With 525 lines, the picture regardless of its actual height in inches, is divided into 525 narrow horizontal strips during scanning. Any two areas which differ in degree of illumination, and which are separated by not less than 1/525 of the picture heights, will be clearly defined and distinguished from each other. If we pick out any one of these horizontal lines, which really are narrow strips of the picture, the illumination along the line will vary between light and dark as various parts of the image are scanned. Each change from light to dark and back to light causes one cycle of potential and current in the video signal.

There would be no object in being able to distinguish changes of illumination in a horizontal direction which are closer together than those which are separated in the vertical direction. Then in a horizontal distance equal to the vertical height we need distinguish no more than 525 changes of illumination.

With this aspect ratio, we will have 4/3 times 525 elementary areas across the width of the picture, which equals 700 areas or changes of illumination per line.

3. Number of frames per second (30)

The complete image to be reproduced is called a frame. If this image is repeated on the screen 30 times a second it will appear as one picture due to persistance of vision.

4. The camera picture, signal frequency (30 cycles to 4 mc during transmission)

With 525 lines and 700 elementary areas per line we will have 525 x 700 or 367,500 possible changes of illumination per frame. With a standard of 30 frames per second, the number of changes of illumination per second may be 367,500 x 30, or a total of 11,025,000. It takes two changes to cause one cycle in the video signal; changes of white to black and back again, or of black to white and back again. Then the maximum video frequency for 525 lines and 30 frames will be 5,512,500 cycles per second, which is a frequency of more than five and one-half megacycles. Actually we do not need quite so much horizontal as vertical definition in the picture, but even so we should have a video frequency of four megacycles and approximately 30 cycles as a minimum for a good definition.

5. Interlaced scanning (60 fields per second)

The electron beam makes two complete traverses or sweeps from top to bottom in covering the entire area of the picture. As shown in Fig. 6, the beam starts at position 1, in the upper left-hand corner of the picture area, traces an active (illuminated) line from 1 to 2, makes a blanked retrace from 2 to 3, another active line from 3 to 4, and continues thus to the lower right-hand corner. Active lines 1-2, 3-4, and those following are not close together, but between each pair is a space equal to the width of one line which is not covered by the beam. This first downward travel is called the first field.

The vertical retrace now brings the beam or the spot to point 6 on the right-hand diagram. This point is half way across the picture area, as is also the end of the final active line in the first field, at point 5. The last active trace in the first field, and the first one in the second field, are half lines. The second field is scanned from 6 to 7, from 8 to 9, and so on until the beam reaches the lower right-hand corner of the picture area at 10. The following vertical retrace brings the beam back to position 1 for the following field, which again is a first field.

Active line 8-9 of the second field is midway between active lines 1-2 and 3-4 of the first field, and all other active lines in one field are midway between those in the other field. The entire area is covered by the beam or spot during the two fields. Two fields make up what is called one frame. This method of scanning is called interlaced scanning.

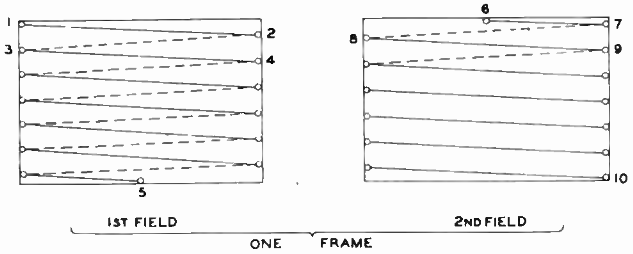

Fig. 6. Two Fields Make One Frame with Interlace Scanning.

G. The Composite Video Signal

The electron beam in the picture tube and the electron beam in the camera tube must do the same things at the same instants. The two beams must remain in step with each other, or they must be perfectly synchronized with each other. All parts or circuits which have to do especially with synchronization are specified as "sync" parts or circuits. The abbreviation sync is pronounced like sink.

Picture blanking and the sync signals are transmitted as follows:

1. Video

   The video (picture) signal consists of rapid variations of modulation which represent changes of light and shadow in the image. This part of the signal must show two features. First, it must show relative changes between light and dark, as showing some one thing twice as light or half as light as something else. Second, it must show the absolute level of light. For example, one object might be twice as light as another in a night-time scene. The whole level of general illumination would have to be shown as brighter for a daylight scene, and darker for the night-time scene. The first requirement is one of contrast between objects. The second is of general illumination or of background brightness.

   Fig. 7 shows three successive lines of a video signal. In the output of the camera tube we have had less potential with brighter light, and more potential with dimmer light. Consequently, in the signal we have the minimum amplitude as representing white and greater amplitudes as representing progressively darker shades. At 75 per cent of the maximum amplitude we have black, and all greater amplitudes leave the picture black. Amplitudes between 75 and 100 per cent of maximum are used for synchronizing while the picture is black, which means while the beam is blanked. Signal variations on line 1 are confined to the middle grays. Those in line 2 range toward white, indicating a light background. Those in line 3 run toward the black, indicating a dark background. The video signal frequencies are from 30 cycles per second to 4 mc during transmission.

2. Horizontal blanking pulse (15, 750 per second)

   At the end of every horizontal line the beam must be blanked by bringing the signal amplitude to the black level.

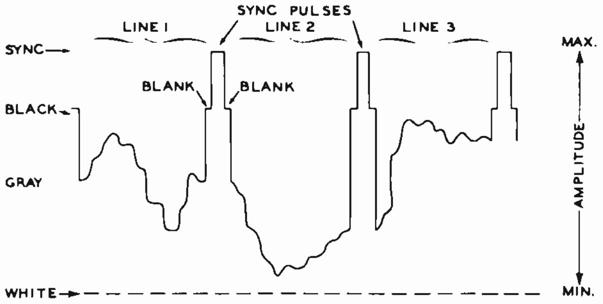

Fig. 7. Three Successive Lines of a Video Signal, Showing Changes of Amplitude Which Correspond to the Modulation.

3. Horizontal sync pulse (15, 750 per second)

   While the beam is blanked, the currents controlling travel of the beam must reverse to bring the beam into correct position for starting the next line. This is done by means of brief (horizontal) sync pulses in which amplitude rises to maximum, and which occur during each horizontal blanking period.

   Each line begins when the blanking interval ends with a drop in amplitude, and ends when the blanking interval commences with a rise of amplitude.

4. Vertical blanking pulse (60 per second)

   Upon completion of all the lines, horizontal blanking periods, and horizontal sync pulses for one field the beam must be blanked during the vertical retrace by bringing the signal amplitude to the black level. The vertical deflection occurs 60 times per second, therefore, the vertical pulse is 60 per second.

5. Vertical sync pulse

During the vertical blanking there must be produced a sync pulse which brings the beam to the top of the picture area. This vertical sync pulse must be of different form from the horizontal sync pulse, so that the receiving apparatus may distinguish between them. The 60 cycle vertical sync pulse is larger in duration and contains 6 equalizing pulses having a frequency of 31,500 per second.

6. Equalizing pulses

Fig. 6 shows that every alternate field must start on a half line, and fields between must start with a full line. The equalizing pulses having a frequency of 31,500 pulses per second will cause the field traverses to be identical.

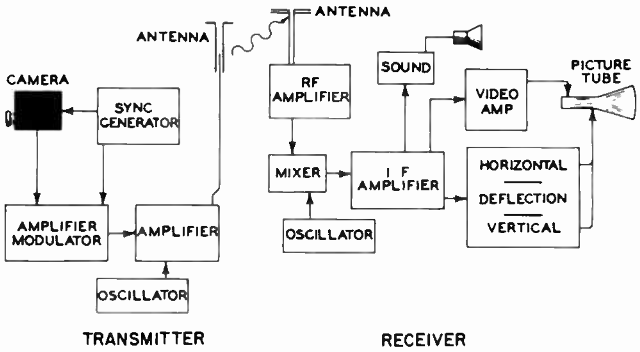

Fig. 8. Relations Between the Principal Parts at the Television Transmitter and at the Receiver.

All of the synchronizing pulses or signals originally are produced at the television transmitter in parts composing the sync generator of Fig. 8. These pulses go to the camera for controlling its beam. The video signal from the camera goes to the amplifying and modulating apparatus where it is combined with sync pulses from the generator to form the modulation for the television signal. The modulation is combined in high-frequency amplifying apparatus with high-frequencies from the oscillator, and the complete modulated signal goes to the transmitting antenna. There is separate apparatus and a separate antenna for transmitting the accompanying sound.

H. Summary Questions

1. What is meant by the term persistance of vision?
2. What is the purpose of the mosaic?
3. Explain briefly the process of scanning.
4. Define the RETMA scanning standards.
5. Define the composition of the video signal.

TELEVISION RECEIVERS

Objective

To consider the purpose of the various sections of a television receiver and to allocate the television composite video signals and the sound signal to the receiver.

References

Lesson Content

A. Introduction

The television receiver as compared to a radio receiver is a much more intricate piece of apparatus. This is true, partly, because the television receiver includes most of the parts for an FM sound receiver in addition to those for picture reproduction. Television receivers may contain more than twenty tubes. In the television portion of the receiver we encounter nearly all of the principles employed in sound receivers, and in addition find many new principles never used in sound reproduction systems.

The travel of the television video and sound signals from the antenna to the picture tube and speaker are shown in Fig. 1 for a typical conventional television receiver. Let us consider the purpose of the different parts by allocating the signals which are received on the antenna.

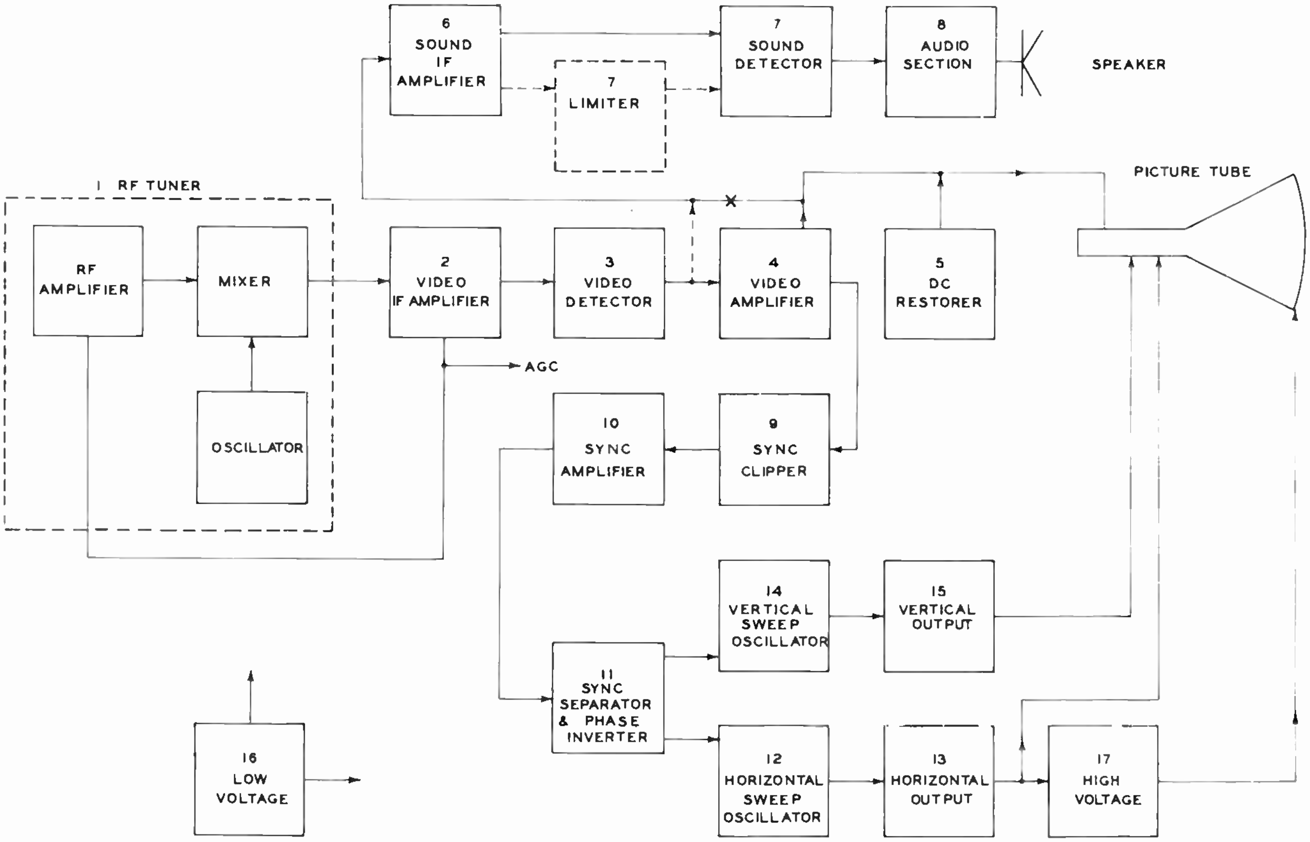

Fig. 1. Block Diagram of a Typical Television Receiver.

B. The Television Receiver, Fig. 1

1. RF Tuner

The RF Tuner usually includes the RF amplifier, the mixer, and the local oscillator. The proper coils for tuning each circuit are switched by a turret mechanism or wafer switch. A complete lesson describing various types of tuners is included in this book. Two IF frequencies are produced in the mixer, one for the picture signal, the other for the sound signal. These will always be 4.5 mc apart as long as we transmit on the frequencies set up by the FCC for television transmission.

2. IF Amplifier

In modern intercarrier type receivers, the bandpass characteristics must be broad enough to pass both the picture and sound IF frequencies as well as their sidebands.

3. Video Detector

The video detector separates the picture information frequencies from the carrier (in this case the IF). Since it is a non-linear device, it will also cause a heterodyning action between the picture IF and the sound IF giving a new IF frequency of 4.5 mc. This frequency is the IF for the frequency-modulated sound. Most often this signal will be taken off after the video amplifier although it may also be taken off after the video detector.

4. Video Amplifier

The video amplifier, usually a resistance-capacitance coupled stage or stages, is especially designed to uniformly amplify the picture or video signal whose range of frequencies may extend to approximately four megacycles.

5. DC Restorer

Now we come to circuits which may or may not use tubes, which provide reinsertion of the DC component. This means that the picture signals are given such average amplitude that they correctly represent the average brightness or background brightness of the scene as well as representing the degrees of contrast between lighter and darker parts of the image. We speak of DC reinsertion because the resistance-capacitance coupled video amplifier passes only AC signal potentials, and it is the restored or reinserted DC component of the original signal that determines the average background brightness of the reproduced picture.

6. Sound IF Amplifier

In intercarrier sets, the sound IF amplifier will always be tuned to 4.5 mc.

7. Sound Detector

When a discriminator is used as sound detector a limiter stage will also be employed. When a ratio detector or gated-beam detector is employed the limiter stage is not used. Sound Detectors are described in detail in other lessons of this book.

8. Audio Section

The audio section of a TV receiver usually consists of an AF amplifier and an AF output stage. The operation is very similar to those used in radio receivers. When the gated-beam detector is used the AF amplifier is omitted and the detector output is applied directly to the AF output stage.

9. Sync Clipper

This stage is often called a Sync Separator. It's purpose is to separate the synchronizing (timing) information necessary to keep the vertical and horizontal oscillators running in exact step with those at the transmitter.

10. Sync Amplifier

The sync amplifier is designed for efficient amplification of the sync signals, whose frequency is much lower than the maximum frequency of the video signals. The amplifier is arranged to amplify the sync pulses while not amplifying the picture variations.

11. Sync Separator or Phase Inverter

Now the horizontal sync pulses and the vertical sync pulses are separated from each other, either with or without the use of a tube or tubes.

12. Horizontal Sweep Oscillator

The horizontal synchronizing pulses are applied to the horizontal sweep generator. This generator is a low-frequency type of oscillator whose operating frequency is adjusted to be just a little slower than the frequency of the horizontal sync signals. Each of these incoming signals then "triggers" the oscillator so that it goes through one cycle, with the cycles occurring at the frequency of the horizontal sync signals. That is, the sync signals operate the oscillator just before it would operate due to the characteristics of its own circuit, and thus bring it into time with the sync signals. The potential changes in the output of the horizontal oscillator are of such form as will move the picture tube beam horizontally during the active lines and the horizontal retraces between lines.

13. Horizontal Output

The output of the horizontal sweep oscillator is amplified and delivered to the deflection coils in the yoke which slips over the neck of the picture tube.

14. Vertical Sweep Oscillator

The vertical sweep oscillator is similar to the horizontal sweep oscillator, but is designed to operate at the lower frequency needed for vertical deflection of the picture-tube beam.

15. Vertical Output

The output of the vertical sweep oscillator is amplified and delivered to the deflection coils in the yoke.

16. Low-Voltage Power Supply

The low-voltage power supply, usually containing one or more full-wave rectifier tubes, furnishes plate, screen grid, and control-grid biasing potentials and currents for the amplifiers, mixer, oscillator, and detector, also for low-voltage elements in the picture tube. Many sets use selenium rectifiers instead of vacuum tubes. These may be used without a transformer in a voltage-doubler circuit.

17. High-Voltage Power Supply

A separate high-voltage power supply usually contains one or more high-voltage, low-current rectifiers of the half-wave type. This supply furnishes the high voltage required for the accelerating or high-voltage anode in the picture tube. The high voltage pulses applied to the high-voltage rectifiers are usually obtained from taps on the output transformer in the horizontal output circuits.

C. Television Receiver Summary

Television — The transmission of moving images either by wire or radio.

Field of view — The total area that is in view of the television camera at the transmitter.

Scanning at the Transmitter — The process of breaking up the field of view into thousands of small sections or elements in a systematic order, permitting analysis of the light values of each element. Scanning is accomplished in the same way that a person reads a book. He reads a page of printed matter by reading from left to right one word at a time starting with the top line and progressing down one line at a time until the bottom line is read. Television cameras read much faster. They can scan the field of view several times per second.

Picture Signal — The electrical impulses corresponding to the light values of the picture elements obtained when scanning the field of view.

Scanning at the Receiver — The process by which the observer receives visual information on the screen from one element at a time in the same systematic order used to break up the field of view at the transmitter. This is similar to a person typing on paper. The typewriter records one letter or one element at a time in a systematic order.

Scanning Line — A single continuous narrow strip which is determined by the process of scanning.

Line Frequency — The number of scanning lines produced per second.

Frame Frequency — The number of complete pictures transmitted per second.

Interlaced or Fractional Scanning — A process of scanning in which the vertical sweep must be repeated to completely cover one frame.

Field Frequency — The number of times the vertical sweep is repeated per second.

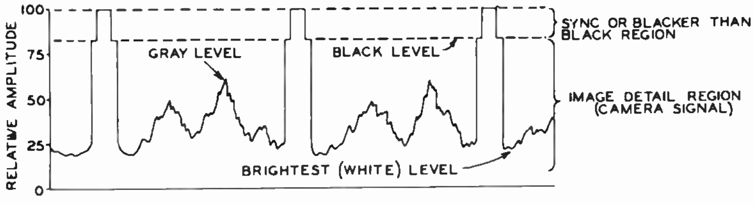

Fig. 2. Negative Picture Transmission.

Negative Transmission — A negative picture is transmitted when an increase in brightness of the televised scene is transmitted as a smaller amplitude signal. Fig. 2 illustrates a signal transmitted in the negative phase. This is standard transmission in the United States. Fig. 3 illustrates positive transmission which is used in some parts of the world.

RETMA Television Standards — Specifications recommended by Radio-Electronics-Television Manufacturers Association, which is the present accepted standard for the United States: (A) 525 line picture (B) 30 frames per second (C) 60 fields per second (D) aspect ratio 4/3 (E) negative transmission.

Synchronization — That function of the television system by which the transmitting and receiving ends of the system are held together in proper time relationship.

Horizontal Blanking Pulse — A pulse produced at the end of each line for the purpose of blanking out the horizontal retrace of the electron beam.

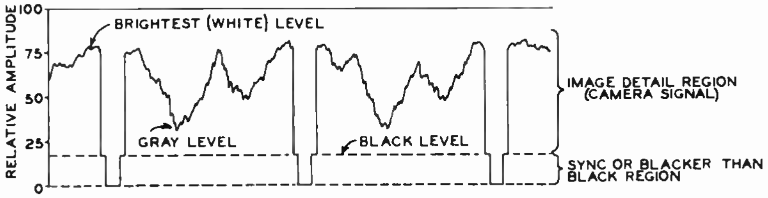

Fig. 3. Positive Picture Transmission.

Vertical Blanking Pulse — A pulse produced at the end of each field for the purpose of blanking out the vertical retrace of the electron beam.

Horizontal Synchronizing Pulse — A pulse produced at the end of each line for the purpose of starting each scanning line at the receiver.

Vertical Synchronizing Pulse — A pulse produced at the end of each field for the purpose of starting each field at the receiver.

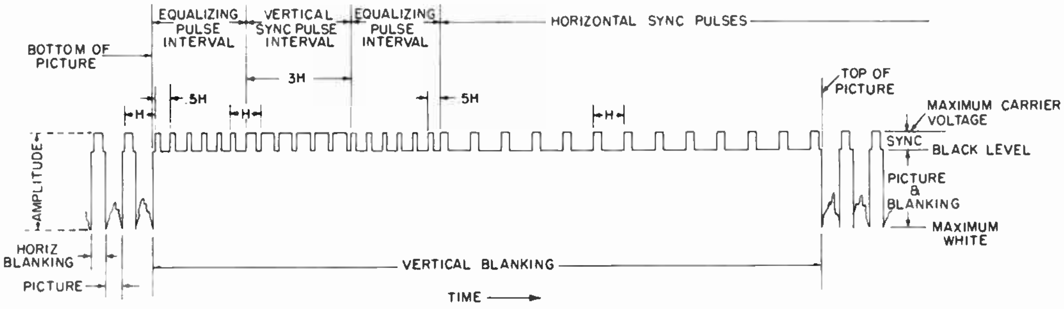

Fig. 4. The Make-Up of the Composite Video Signal.

Equalizing Pulses — Pulses twice the frequency of the horizontal sync pulses, produced during part of the vertical blanking pulse, to make vertical sync impulses for successive fields sufficiently alike to insure correct inter-lacing.

Composite Video Signal — The signal containing all voltages resulting from scanning. This includes the blanking pulses (horizontal and vertical) as well as the picture information. The equalizing pulses would also be included in the Composite Video Signal. Fig. 4 shows all these pulses.

Channel Bandwidth — A 6 megacycle band assigned to a particular broadcaster to transmit television programs. Both the sound and the picture information must be contained within this band. Fig. 5 shows how the various frequencies within the band are allocated.

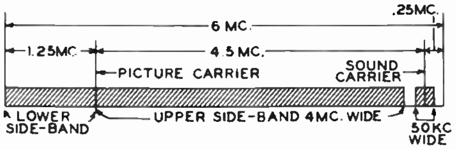

Fig. 5. Frequency Distribution Within One TV Channel.

D. Summary Questions

1. Name the stages used for the sound signals.
2. Name the stages used for the picture signal. (Not including sync or sweep circuits).
3. Name the stages after detection used for the sync pulses.
4. Name the stages used for the deflection of the beam.
5. Draw the block layout of the complete television receiver and label each block.

THE RF AMPLIFIER AND HETERODYNING CIRCUITS

Objective

To consider the construction and operation of the RF Amplifier, Mixer, and Oscillator stages of a television receiver.

References

Lesson Content

A. General

The principal parts of the RF section of the television receiver are the RF Amplifier, Mixer, and Local Oscillator. Carrier frequency signals from the antenna are applied to the grid circuit of the RF amplifier tube and are strengthened. The carrier-frequency signals then pass to the grid of the mixer tube where they are heterodyned with the local oscillator frequency. The difference frequency between the carrier and oscillator frequency appears in the output of the mixer, and is known as the intermediate frequency. In the television system there are two intermediate frequencies — one for sound and one for video. In the RF section are inductances and capacitances which are tuned together for reception of programs in any of the various television channels. Selection or adjustment of inductances and capacitances for each channel is accomplished by switching or other means in the mechanism called the tuner of the receiver. With the channel knob or dial set for any one channel, small changes of RF oscillator frequency may be made in some receivers by the fine tuning control. This allows improved reception in case the oscillator frequency does not at first act to produce the correct intermediate frequency by beating in the mixer tube with the carrier frequency.

B. The RF Amplifier

1. RF Amplifier Characteristics

Signals from the antenna, at carrier frequencies, are applied to the input of the RF amplifier tube, Fig. 1 or 2, and from the output of this tube are taken to the control grid of the mixer.

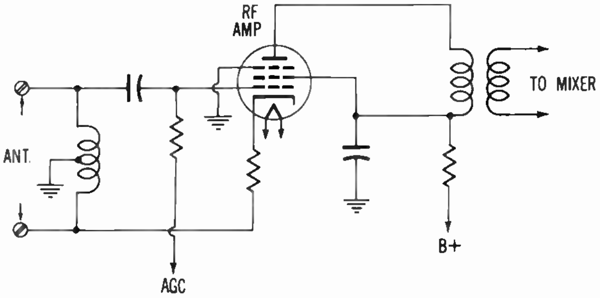

Fig. 1. Untuned Coupling Between the Antenna and RF Amplifier.

The RF amplifier tube may be either a pentode or triode. Although pentodes are inherently "noisier" than triodes, the additional gain which can be obtained in the pentode greatly offsets this disadvantage. Another advantage of pentodes is the reduced grid-to-plate capacitance.

The output circuit of the RF amplifier is always tuned to the frequencies of the channel being received. This provides selectivity against signals in other channels, reduces the possibility of image interference, and prevents radiation from the RF oscillator through the RF amplifier and out the antenna. It is for these reasons that the RF amplifier is useful, even when it contributes negligible gain.

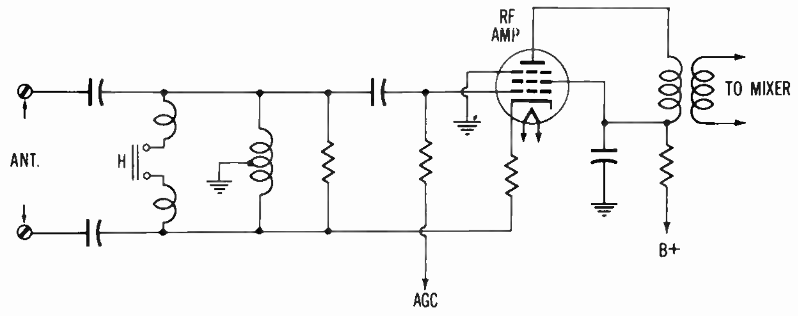

Fig. 2. Input Coupling Whose Impedance is Changed for Different Channels.

2. Pentode RF Amplifier Circuits

Fig. 3 shows two RF amplifier circuits using pentode tubes. In Fig. 3A is illustrated a conventional circuit having a tuned input and output. The two circuits are usually stagger tuned to give sufficient bandpass. Resistors R1 and R3 are shunted across the coils L1 and L2 in order to further increase the bandwidth. The input circuit is series-tuned with the input capacity of the tube used as a portion of the tuned circuit. This is possible due to the high operating frequencies of the circuit.

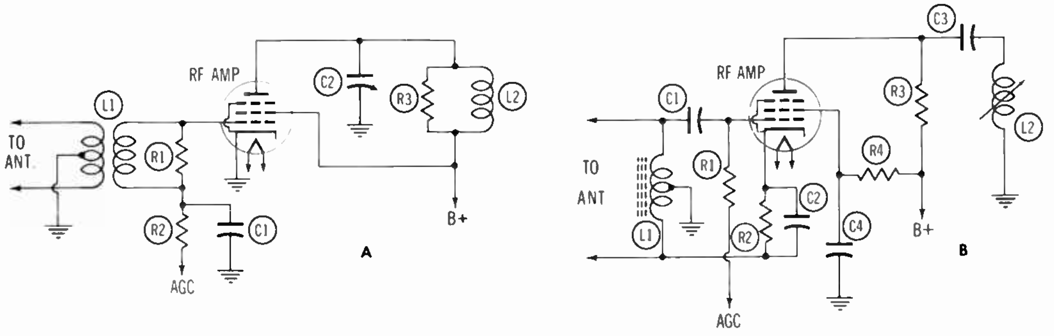

Fig. 3. Pentode RF Amplifier Circuits Having Tuned Inputs and Outputs.

The signal maybe injected into the RF amplifier stage by several ways. It may be grid-driven, cathode-driven, or a combination of both as shown in Fig. 3B. The plate circuit may be series or shunt-fed. In Fig. 3A the plate is series-fed and in Fig. 3B the plate is shunt-fed. In the shunt-fed plate circuit the plate current is removed from the tuned circuit, which is desirable when the tuned circuit has sliding contacts for channel selection.

3. Triode RF Amplifier Circuits

A dual triode tube is used as the RF amplifier in the circuit shown in Fig. 4A. In this circuit the input and output circuits are balanced. Neutralizing capacitors (C1 and C2), usually 1.5 mmf, are connected from the plate of one section to the grid of the other. These 1.5 mmf capacitors are approximately equal to the 1.6 mmf plate-to-grid capacity of the 6J6 tube used in this application.

Since triode amplifier circuits at VHF and UHF frequencies have a tendency to oscilliate due to feedback through plate-to-grid capacitance, the circuit shown in Fig. 4B is sometimes used to eliminate this condition. In Fig. 4B the grid is grounded. The signal from the antenna is applied between the cathode and the grounded grid. The grounded grid acts as a shield between the cathode and the plate and reduces feedback capacitance. Pentode tubes, connected as triodes, with the screen and suppressor grids tied to the plate are sometimes used in this application.

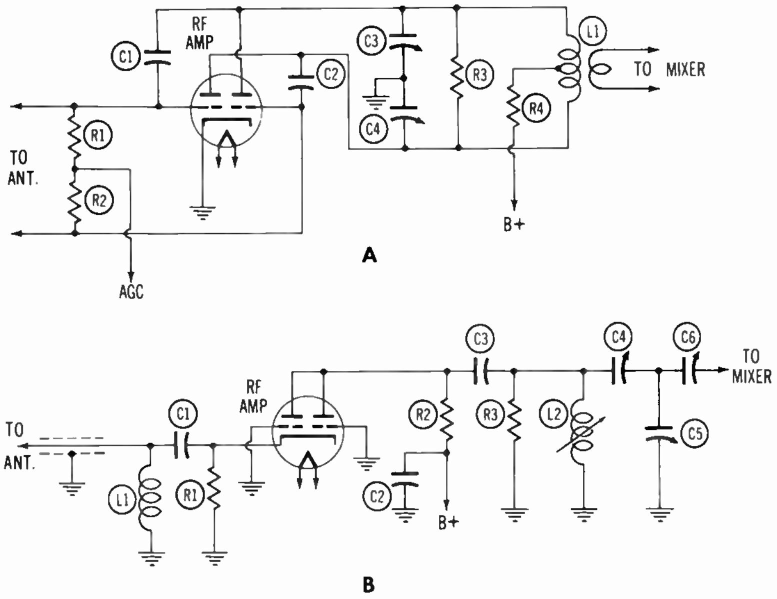

Fig. 4. Triode RF Amplifier Circuits.

4. Cascode RF Amplifiers

Many television tuners have what is called a cascode amplifier in the RF stage. This is a combination of the triode amplifier which has a grounded cathode and another triode amplifier of the grounded grid type. The two amplifiers are the two sections of a twin triode tube designed especially for this and similar applications. Among such tubes are the 6BK7, the 6BQ7, and the 6BZ7, all of which perform satisfactorily at frequencies up to 250 to 300 megacycles and have transconductances on the order of 6000 to 8500 micromhos when operated with usual voltages and element currents.

The principle of the cascode circuit is illustrated by Fig. 5. Fig. 5A shows connections for a grounded grid amplifier. The grid is grounded for RF signal currents and voltages through capacitor C2, and is connected to the cathode through resistor R2 in order to stabilize the DC potential on the grid. Signal input is between cathode and ground, with high impedance at signal frequencies in the cathode-to-ground path furnished by choke L1. Signal output may be taken from the plate circuit in any way suitable for RF amplification. For convenience during explanation we shall designate this grounded grid circuit as V2.

Fig. 5B shows a triode circuit such as might be used as the RF amplifier in a tuner. The cathode is grounded for RF currents and voltage through capacitor C1 which bypasses the cathode-bias resistor R1. Signal input is between grid and ground. The output signal appears across a resistance or impedance load in the plate circuit. This grounded cathode amplifier will be called V1.

Fig. 5C shows the cascode circuit. At the top is the grounded grid amplifier V2. The cathode circuit no longer contains only a simple impedance across which is applied the input signal, instead there is tube V1 between the cathode of V2 and ground. Signal voltage still is applied to the grounded grid amplifier V2, between its cathode and ground, but this is done by inserting amplifier V1 in this position. The load for the plate circuit of V1 is now the input impedance of V2.

The cascode RF amplifier has the overall gain comparable to that from a RF pentode, and at the same time has the lower noise factor that is characteristic of triodes. Minimum noise is important in RF amplifiers because noise voltages originating here will be amplified by all following stages in the receiver. Feedback trouble, such as might occur with ordinary triode circuits is practically eliminated because of the input loading and rather limited gain in the first section and by the grounded grid of the second section.

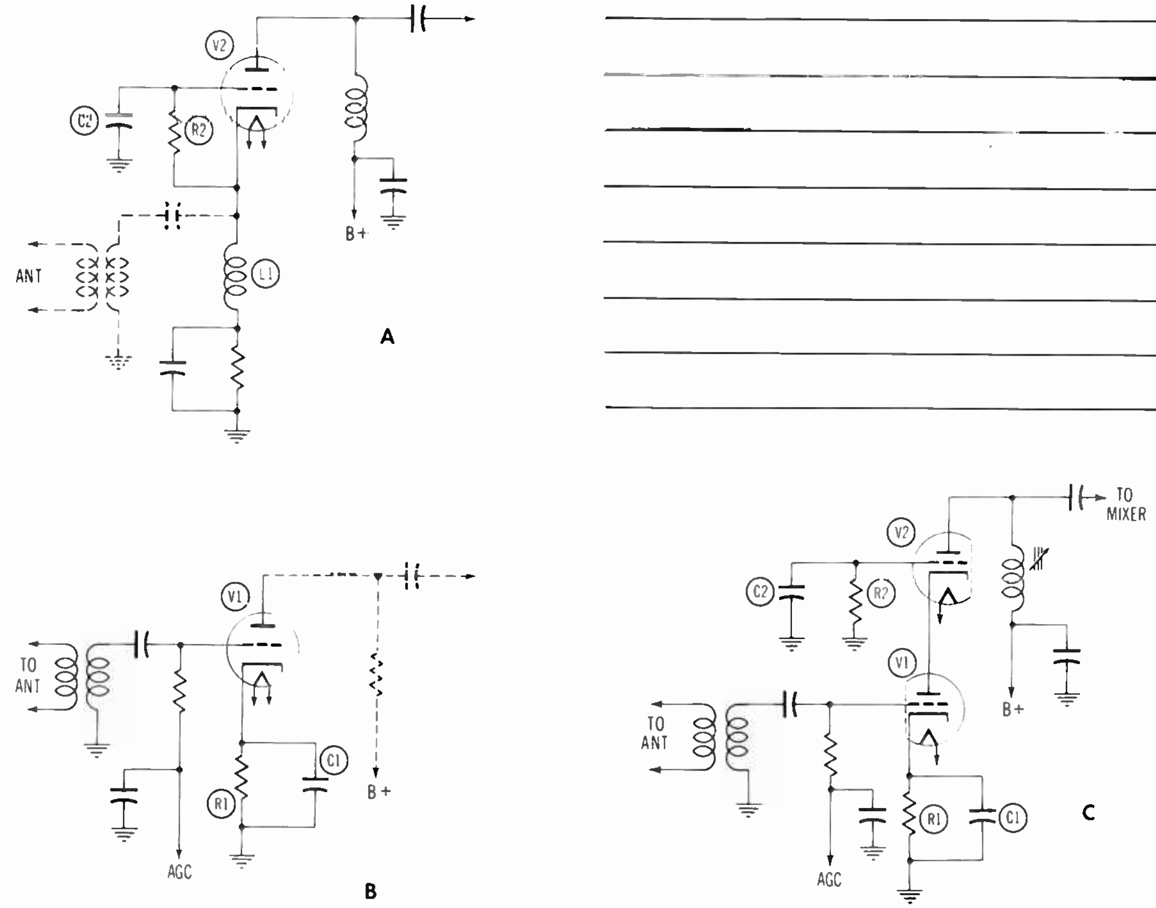

Fig. 5. A Cascode RF Amplifier has the Two Triodes in Series for DC Plate-Cathode Current.

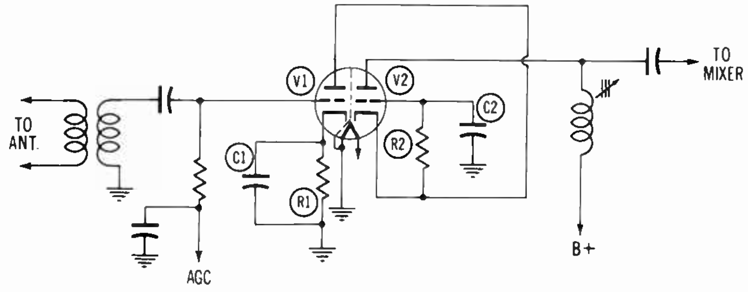

Fig. 6. How a Cascode RF Amplifier May be Shown in Television Receiver Diagrams.

In cascode circuits there may be various arrangements of resistors, capacitors and inductors between one or the other of the plates and the grid of the first section. The purpose usually is stated as neutralization of plate-grid capacitance effects, but the principle effect is the reduction of the noise factor.

The cascode amplifier as just described might be shown with the symbol for a twin triode as in Fig. 6 where all connections are the same as in Fig. 5C. DC voltage from the B supply divides about equally between the two tube sections. Total B-supply voltage usually is about 250V with approximately half of this total used between plate and cathode of each section. Cascode amplifiers of this design require an applied B+ voltage about twice as high as ordinarily used for single-section RF amplifier tubes in tuners.

Automatic gain control (AGC), when used is applied only to the first section, which is the grounded cathode amplifier. When this control becomes more negative, due to a stronger received signal, the more negative grid not only reduces the gain but at the same time increases the plate resistance. Then more of the total B+ voltage appears across this section. Since the applied B+ voltage remains nearly constant, there is a reduction of plate voltage across the second section (the grounded grid amplifier), and there is a decrease of gain in this section. Thus the automatic gain control affects both sections, although applied to only one of them. There is a reduction of plate-cathode current in both sections. Methods of deriving this AGC voltage will be discussed in a later lesson.

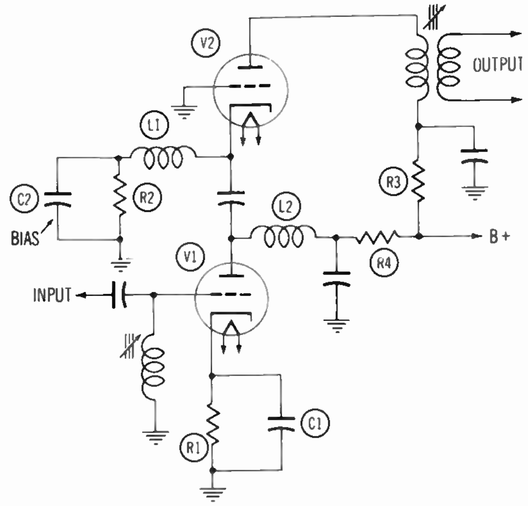

Fig. 7. A Cascade Amplifier With the Two Triodes in Series for Signals, But Not for DC Plate-Cathode Currents.

5. Cascade RF Amplifier Circuits

The cascade amplifier circuit, which is often used is shown in principle by Fig. 7. V2 is still a grounded grid amplifier, and V1 is a grounded-cathode amplifier. But the two amplifiers no longer are in series for the DC plate-cathode currents, although they are in series for RF signal currents and voltages, due to the low impedance or reactance of capacitor C3 between the cathode of V2 and the plate of V1. Total B+ voltage from the DC supply, except for the drops through resistors R3 and R4, is applied to each of the plates. Each section has its cathode bias, consisting of a biasing resistor bypassed by a capacitor to ground.

RF signal voltages and currents are isolated from the DC bias system of V2 by an RF choke (L1) between the cathode and the bias resistor. Signal voltages and currents are isolated from the B supply by another RF choke (L2) in the plate circuit of V1. Then the only low-impedance path from the plate of V2 to the cathode of V1 is through capacitor C3.

RF signal input is between the grid of V1 and ground. Signal output is from the plate circuit of V2. The types of input and output couplings may be as shown or of any other kinds suitable for RF couplings. The types of input and output couplings have nothing in particular to do with the principle of the cascade amplifier.

The cascade circuit of Fig. 7, shown with separate triodes for simplicity of explanation, ordinarily would be shown with a twin-triode symbol in some manner similar to Fig. 8. The same parts are similarly lettered in both diagrams.

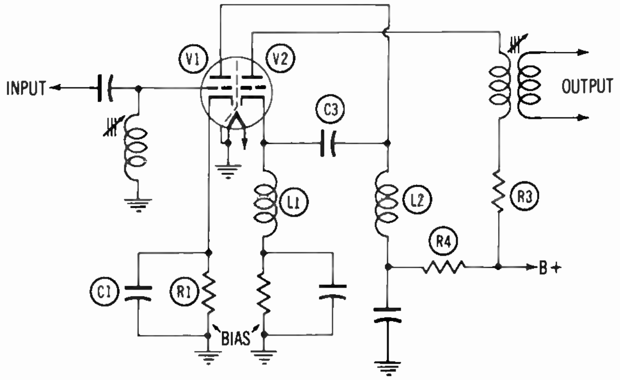

Fig. 8. The Cascade Amplifier of Fig. 7 May also Be Shown in This Manner in Many Diagrams.

C. Local RF Oscillator

A television radio-frequency oscillator produces very-high frequencies which beat with received carrier frequencies to produce intermediate frequencies. This oscillator, which is part of the tuner, is called the RF oscillator or the local oscillator to distinguish it from the television sweep oscillators.

The local oscillator consists of an electronic tube in a circuit which produces alternating currents from direct-current power. Most oscillator circuits include capacitance and inductance whose resonant frequency is the frequency of the alternating current. Energy oscillates back and forth between the capacitance and inductance as the current reverses. Some oscillator circuits include capacitance and resistance, rather than capacitance and inductance. Then the oscillating or alternating frequency is inversely proportional to the capacitive time constant.

To have sustained oscillation it is necessary to compensate for energy losses in the oscillatory circuits. In what are called feedback oscillators, losses in the grid circuit are replaced by energy fed back from the plate circuit. In this group are inductive feedback oscillators and capacitive feedback oscillators, wherein feedback is respectively through inductive coupling and through capacitance. Less common are negative resistance oscillators in which negative resistance developed between plate and cathode of a tetrode tube balances the effective resistance of the oscillatory plate circuit.

So long as circuit losses are balanced by feedback or negative resistance these losses no longer are effective in limiting the oscillating current. Limiting usually results from using plate, screen, and bias voltages with which there is plate-current saturation before undesirable values are reached during the half-cycles in which the grid becomes positive. There is plate-current cutoff during the negative half-cycle.

At frequencies up to a few megacycles both triodes and pentodes are used as oscillator tubes, with pentodes favored when it is desired to limit the feedback which may occur through the grid-plate capacitance of the tube. Triodes are favored for RF oscillators operating in the television carrier frequency range. The grid-plate capacitance of a triode often is part of the resonating capacitance for the oscillator circuit. With any type of tube, the same characteristics which are desirable for amplifiers are desirable also for oscillation.

In the television RF circuit there is practically always a separate tube or separate section of a twin tube serving this one function, rather than having oscillator and mixer functions combined in a converter tube having a single electron stream, as is general practice in radio receivers. Often the television RF oscillator is one section of a twin tube whose other section is the mixer, but there are separate electron streams for the two functions. The great majority of RF oscillator tubes are miniature triodes of high transconductance.

D. Types of Local RF Oscillators Used in Television

1. Colpitts Oscillator

The colpitts circuit is used more than any other for television RF oscillators, but if often appears in such modifications as to make identification rather difficult. The basic Colpitts circuit is shown in Fig. 9A. Tuning to resonance is by means of capacitor C1 in the plate circuit and capacitor C2 in the grid circuit. One side of both these capacitors connects to the cathode, either directly or through ground. The blocking capacitor at C3 keeps DC plate current and voltage out of the grid circuit.

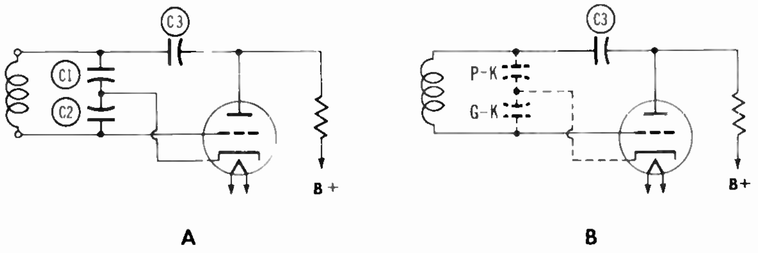

Fig. 9. Colpitts Oscillator Circuits.

At the very-high frequencies existing in television RF oscillator circuits the interelectrode capacitances of the tube are ample for tuning to resonance with only a moderate amount of inductance in the tuned circuit. Consequently, in television circuit diagrams the Colpitts oscillator may appear as shown by the solid lines in Fig. 9B. Tuning of the oscillator coil is accomplished by plate-to-cathode capacitance of the tube, represented by broken lines at P-K, and by grid-to-cathode capacitance represented at G-K. These tube capacitances take the place of capacitors C1 and C2 in Fig. 9A.

Other Colpitts oscillator circuits are shown by Fig. 10. The diagram as shown in Fig. 10A contains fine tuning capacitors C1 and C3. Either one might be used, but not both. The tuning coil and fine tuning capacitor C1 are in parallel with the grid-plate interelectrode capacitance of the tube. Capacitor C3 is in parallel with the plate-cathode capacitance of the tube, which is one of the interelectrode capacitances that tune the coil to resonance. With the fine tuning capacitors removed, the oscillator circuit would be essentially the same as in Fig. 9B. With fine tuning capacitor C1 appearing in a circuit diagram the oscillator could be mistaken for an ultraudion unless values of capacitance, inductance, and frequency were checked to show that C1 is not the principal tuning element.

In Fig. 10B is illustrated still another modification of the Colpitts oscillator. Capacitor C1 is for fine tuning. The RF plate circuit with its plate-to-cathode capacitance is connected to the tuning coil circuit through capacitor C2 and ground. The interelectrode capacitances of the tube are made effective for tuning by isolating the cathode from ground by means of RF choke L1, so far as RF currents are concerned, while maintaining the cathode to ground conductive path for direct current. There are many modifications of the fundamental Colpitts oscillator circuits in addition to those which have been illustrated.

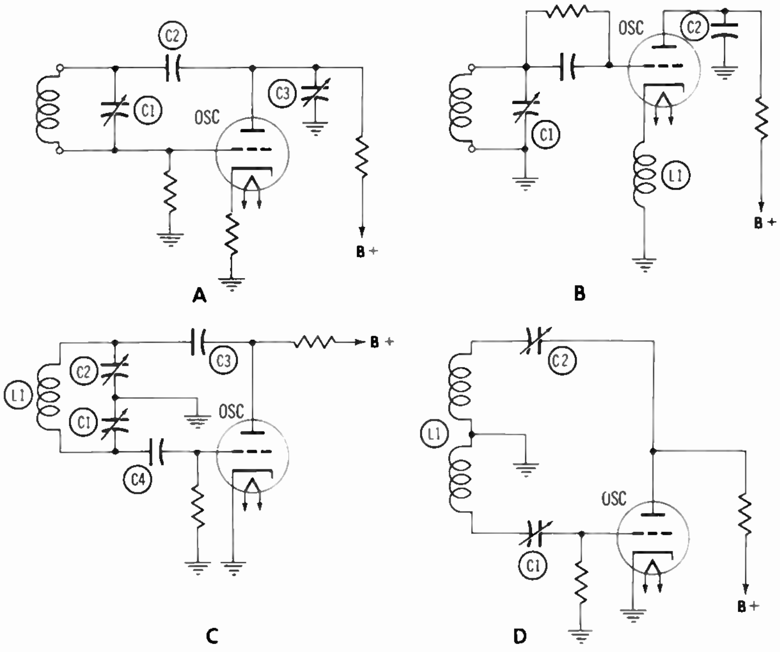

Fig. 10. Variation of the Colpitts Oscillator Circuits.

The connection method in Fig. 10C is the one commonly used. There is grounding of one side of each of the tuning capacitors C1 and C2 also of the tube cathode. In the much older method of connection shown in Fig. 10D, both sides of both capacitors are above ground potential.

The single coil L1 is tuned to resonance by varying both tuning capacitors in unison, for more capacitance in both or else for less capacitance in both. Oscillating voltage in the plate circuit is across capacitor C3. Capacitor C1 is in the grid circuit. Thus part of the energy put into the tuned circuit from the plate is fed back to the grid. Feedback is increased by increasing the ratio of capacitive reactance at C2 to capacitive reactance at C1.

Colpitts oscillators have less tendency than most other simple oscillators to produce harmonics of the tuned frequency.

2. The Push-Pull RF Oscillator

Fig. 11 shows circuit connections for a push-pull RF oscillator employing a twin triode tube and an oscillatory circuit consisting of capacitor C1 and coil L1 used as a parallel resonant circuit between the two plates. A different coil, L1, of suitable inductance for tuning is switched into position for each channel.

This oscillator operates so far as feedback is concerned like two resistance-coupled amplifiers with the output of each plate fed as the input to the opposite grid through coupling capacitors

C2 and C3. The reactance of these capacitors is very small in comparison with resistance of grid resistors R1 and R2. The oscillator output is of good frequency stability, and there is little tendency to produce harmonic frequencies.

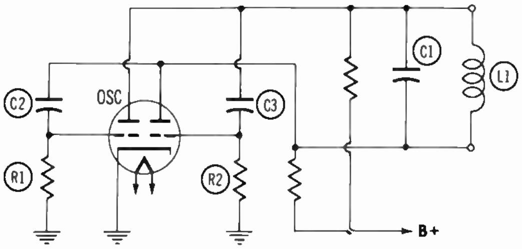

Fig. 11. Push-Pull RF Oscillator with Parallel Resonant Tuned Circuit.

Fig. 12 shows connections for a push-pull RF oscillator in which the tuned resonant circuit consisting of lumped capacitance and inductance elements is replaced with a quarter-wave shorted resonant line, which is the equivalent of a parallel resonant circuit so far as tuning is concerned. The left-hand end of this diagram is practically the same as the one in Fig. 11. Dual capacitor C1 is a variable fine tuning unit.

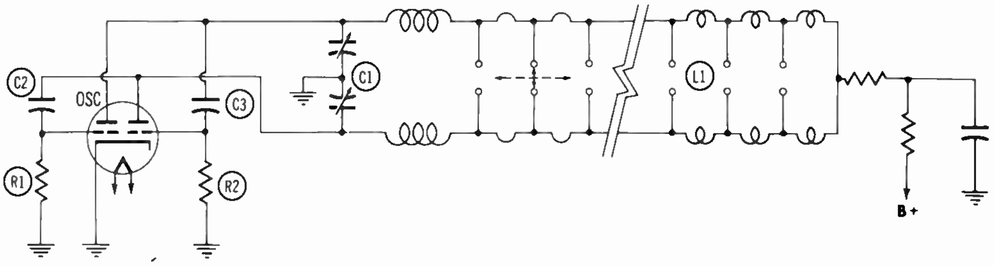

Fig. 12. Push-Pull RF Oscillator with a Shorted Quarter-Wave Resonant Line As the Tuned Circuit.

Opposite sides of the resonant line, shown toward the right in the diagram, consists of coils of a few turns, or small loops, or lengths of straight wire between the successive terminal points, depending on the amount which the resonant frequency must change between tuning positions. The movable shorting bar shown between opposite line terminals is shifted one way and the other to vary the effective length of line and provide resonance in the various channels. The shorting bar or connection usually is a conductor between movable contacts of a rotary switch, whose stationary contacts connect to or support the line inductors. The diagram would represent the circumference of the rotary switch spread out as a flat surface from left to right.

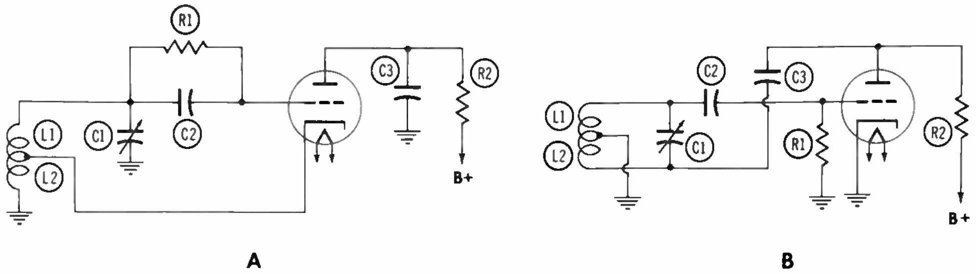

Fig. 13. Hartley Oscillator Circuits.

3. Hartley Oscillators

The Hartley oscillator circuit, shown in principle by Fig. 13, is used generally in both radio and television receivers for generation of low and intermediate radio frequencies, also in RF signal generators for service work and in some audio-frequency generators and audio modulating circuits.

Two coils, L1 and L2, or a single tapped coil, are tuned to resonance at the desired oscillator frequency by capacitor C1. The two coils or two parts of a coil usually are so mounted as to have inductive coupling, although such coupling is not essential for the reason that the same oscillating currents always must flow in both parts. Feedback is from coil L2, in the plate circuit, to coil L1 in the grid circuit. The two coils ordinarily are about alike, or a single coil is tapped near its center. Output amplitude is increased by more inductive reactance in the plate coil.

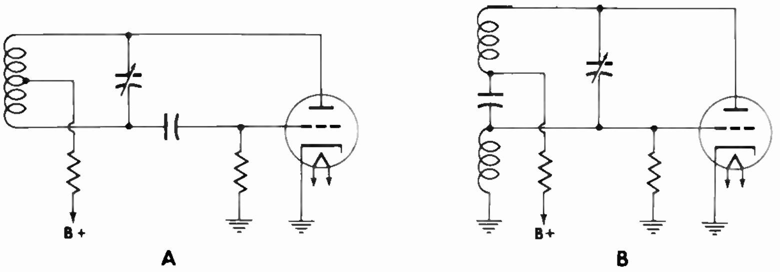

Fig. 14. Modifications of the Hartley Oscillator Circuit.

With connections shown in Fig. 13A one side of the tuning capacitor and one end of the tuned coil are grounded, an arrangement desirable for prevention of body capacitance effects if tuning is to be manually altered while the oscillator is operating. In Fig. 13B the cathode of the oscillator tube is grounded, with both ends of the tuned circuit at potentials above ground. The oscillatory circuit is connected to the tube plate through capacitor C3. Capacitance at C3, also at the grid capacitor C2, should be great enough to have small reactance at oscillator frequencies.

Hartley oscillator circuits are found with many modifications, two of which are shown by Fig. 14. The essential and easily recognized feature of this circuit is connection of the oscillator cathode to a tap on a single coil or to a point between two coils which are tuned to resonance by a single capacitor or by a principal capacitor paralleled by a trimmer or a fine tuning capacitor.

E. Other Types of Oscillators

1. Electron Coupled

An electron coupled oscillator is any radio-frequency oscillator with which the only intentional coupling between the tuned oscillating circuit and the output or load is by means of variations in the electron stream within the oscillator tube. The purpose is to prevent the capacitance and inductance of the load from reacting on the oscillator circuit to alter its tuned frequency.

Fig. 15 shows a Hartley oscillator arranged for electron coupling. Other types of oscillators may be used in a similar way. The tube is a pentode with its suppressor grounded to act as an RF shield between the screen and the plate. The portion of the tube used as an oscillator consists of the screen, the control grid, and the cathode, with the screen acting as the oscillator plate. The screen (oscillator plate) circuit is completed through capacitor C1, the ground connections, the lower part of the tuned coil at the left, and to the cathode of the tube.

The plate is operated at a higher voltage than the screen, electron flow from the cathode to plate, and through the output and load, must pass through the screen. The screen-to-cathode potential is varying at the oscillating frequency and this varying screen potential modulates the plate current or output current at the oscillating frequency. The load has little effect on oscillation frequency because, in any pentode, changes of plate voltage have little effect on plate current which is controlled almost entirely by screen voltage and control grid voltage.

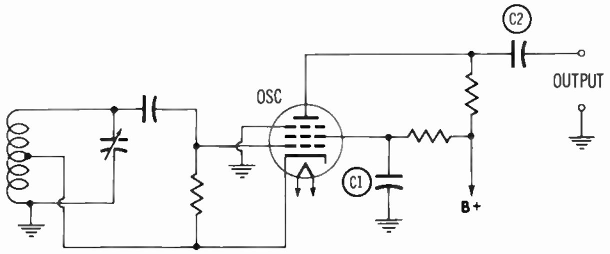

Fig. 15. An Electron Coupled Hartley Oscillator.

Electron coupled oscillators often are used in signal generators. The RF output of such a generator may be modulated with audio frequency by putting the AF voltage into the suppressor of the oscillator tube. That is, instead of connecting the suppressor to ground, as in the diagram, it is connected through some source of AF modulating voltage and thence to ground.

2. Feedback

Feedback oscillators include many types, but all are of the general class in which the tube acts as an amplifier of alternating voltages caused to appear in its grid circuit, and in which energy or power dissipated in the grid circuit is replaced by power fed back from the plate circuit of the oscillator tube. With circuit losses thus compensated for, oscillation will continue at the resonant frequency of capacitance and inductance in either the plate circuit or the grid circuit. Oscillation is begun in the first place by any change, however small, in plate current or voltage. Even the changes due to normal instantaneous variations of emission are enough to cause feedback and introduce a change of voltage into the grid circuit. Then oscillations build up to maximum value in a brief fraction of a second.

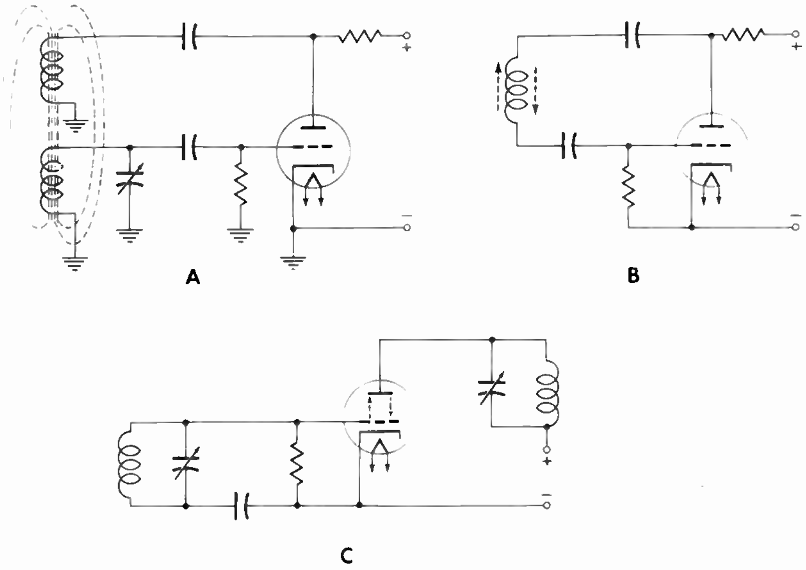

Fig. 16. The Three Principle Ways in Which Feedback Occurs in Oscillators.

Feedback from plate circuit to grid circuit may occur in any of the three principal ways illustrated in Fig. 16, by means of a common magnetic field, by means of a common inductance, or through tube capacitance or other capacitance between the plate and grid circuits.

When considering any type of feedback it will be helpful to keep in mind the phase relations of grid voltage, plate current, and plate voltage. When a grid becomes more positive or less negative there is increase of plate current, but because of increased voltage drop in the plate load there is a simultaneous decrease of plate voltage at the tube. When the grid becomes less positive or more negative there is a decrease of plate current, but an accompanying increase of plate voltage at the tube. Grid voltage and plate current are of like phase, but grid voltage and plate voltage are in opposite phase.

In Fig. 16A, there is feedback by means of inductive coupling through a single magnetic field common to one coil in the plate circuit and to another coil in the grid circuit. Relative directions of currents in the two coils must be such that the magnetic field of the plate coil aids the field of the grid coil, or so that north and south magnetic poles of both coils point the same direction at the same time. The phase relationship of voltages and currents in grid and plate circuits determines the relative directions of the magnetic fields, which must be in the same direction or polarity to have feedback such as will sustain oscillation.

If directions of currents in the coils happen to be such as produce opposite magnetic fields, and oppose rather than sustain oscillation, it is necessary only to turn either coil end for end, or else to interchange the circuit connections to the ends of either coil. Feedback voltage or current must be in correct phase no matter how it is accomplished.

In Fig. 16B the same coil is in both the plate circuit and the grid circuit for oscillatory currents. The opposite phase of voltages at plate and grid insures feedback which sustains oscillation. That is, with the coil a continuous winding in the same direction throughout its length, the positive voltage polarity of the grid at one end acts to cause electron flow in the same direction as does negative voltage polarity of the plate at the other end, or vice versa.

In Fig. 16C the feedback from plate to grid acts through the grid-plate capacitance of the oscillator tube. In order that feedback may reach the grid in such phase as to aid changes of grid voltage, the plate circuit must act as an inductive reactance rather than as a pure resistance. This is accomplished by connecting in the plate circuit a resonate circuit of a frequency slightly higher than the oscillating frequency, which is controlled by resonant frequency of the grid circuit.

With feedbacks such as have been described, every increase or decrease of plate voltage acts through the feedback to cause still further change of grid voltage in the direction that is responsible for the increase or decrease of plate voltage. This further change of grid voltage causes an even greater increase or decrease of plate voltage, and so the interaction continues until plate current reaches saturation value if it is increasing, or drops to zero at plate current cutoff if it is decreasing.

At either saturation or cutoff, the feedback can have no more increase, and the momentary loss of energy causes grid voltage to commence a reversal. This grid voltage sets immediately to start a reversal of the previous change of plate current and voltage, thus beginning a feedback in the opposite direction or alternation. This opposite feedback continues until plate current again must cease its changing as it comes to either saturation or cutoff. Here the grid voltage is again caused to reverse, and the whole process repeats over and over.

The result of this repeated process is continual rise and fall of plate current between cutoff and saturation, and corresponding changes of voltage across the load in the plate circuit. These changes are the alternating components of plate current and voltage, having the frequency of oscillation or of resonance in the tuned circuit which controls the oscillating system.

3. Tickler Feedbacks

With the oscillator circuits of Fig. 17 energy from the plate circuit is fed back to the tuned grid circuit by inductive coupling between the "tickler" coil L1 in the plate circuit and coil L2 in the grid circuit. Feedback is varied by changing the position or the angle of coil L1 in relation to coil L2. The tuned-grid tickler-feedback circuit is used in radio-frequency oscillators operating at frequencies up to 10 or 15 megacycles, and occasionally in audio-frequency oscillators. This circuit, operated with feedback just below that for oscillation, was used in most of the regenerative detectors for early radio broadcast receivers.

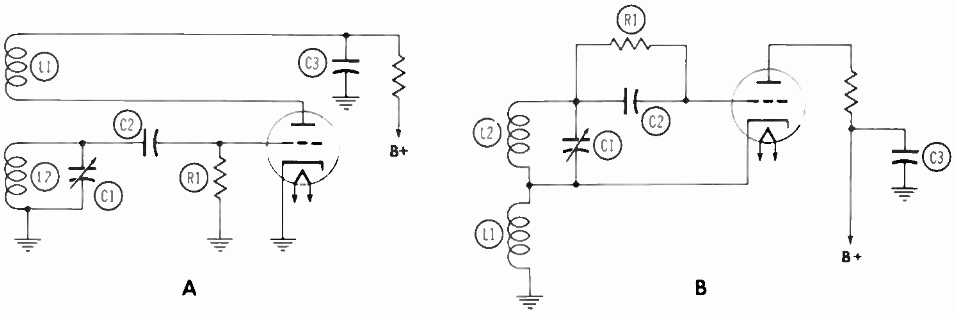

Fig. 17. Tuned Grid Oscillators with Tickler Feedbacks.

In Fig. 18 the plate circuit rather than the grid circuit is tuned to resonance, and to the coil in this tuned plate circuit is inductively coupled a tickler coil which is connected into the grid circuit. Such tuned-plate tickler-feedback circuits are used in RF signal generators operating at frequencies as high as 15 to 20 megacycles and sometimes in audio-frequency generators. With the connection scheme shown in Fig. 18A, one side of the tuning capacitor C1 is grounded. Although neither side of the tuning capacitor is grounded in Fig. 18B, the one which connects to B+ may be grounded for radio frequencies through a bypass capacitor.

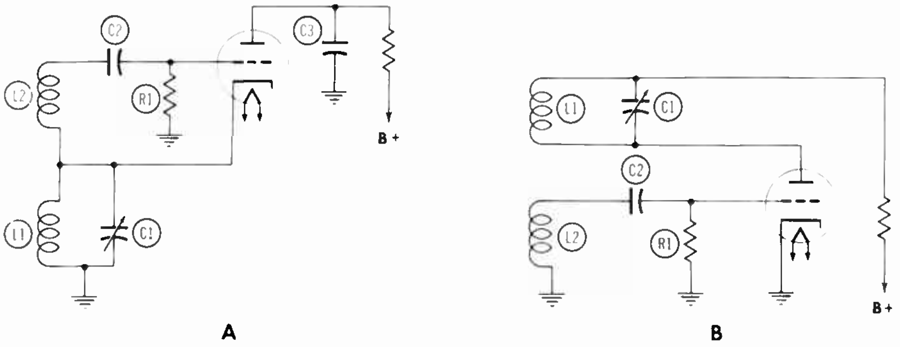

Fig. 18. Tuned Plate Oscillators with Tickler Feedbacks.

4. Other Feedback Oscillators

In Fig. 16C are shown the essential features of what is called a tuned-grid tuned-plate oscillator. There is no inductive coupling between the tuned coils in plate and grid circuits. Feedback current flows in the capacitance between plate and grid of the oscillator tube, which is a triode because triodes have greater grid-plate capacitance than pentodes.

In Fig. 19 is illustrated the usual form of ultraudion oscillator circuit. Feedback is through the magnetic field of tuned coil L1 which is common to both the plate circuit and the grid circuit. The amount of feedback may be controlled by connecting a variable bypass capacitor from plate to cathode or plate to ground, through which part of the feedback energy is shunted.

Fig. 20A shows an Arco-Meissner oscillator circuit in which there is a tuned plate circuit consisting of a series connected variable capacitor and coil which are paralleled by another coil. To the series plate coil is inductively coupled an untuned coil in the grid circuit to which is transferred the feedback energy.

Fig. 20B shows an oscillator circuit usually associated with the name Meissner. Neither the plate circuit nor the grid circuit is tuned, but coils in both these circuits are inductively coupled to coils which are in a tuned link circuit. Feedback is from coil L1 in the plate circuit through the link to coil L2 in the grid. The Meissner oscillators are not in common use for present radio and television receivers, but sometimes are referred to.

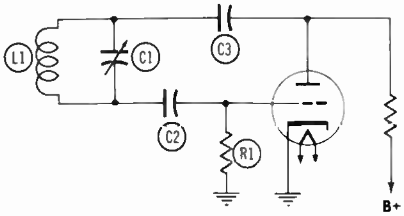

Fig. 19. An Ultraudion Oscillator Circuit.

5. Negative Resistance Oscillators

In negative resistance oscillators there is no feedback from the plate circuit to compensate for loss of energy in the grid circuit; rather there is utilized an effect called negative resistance to compensate for losses in a tuned circuit connected between plate or screen and cathode of the oscillator tube.

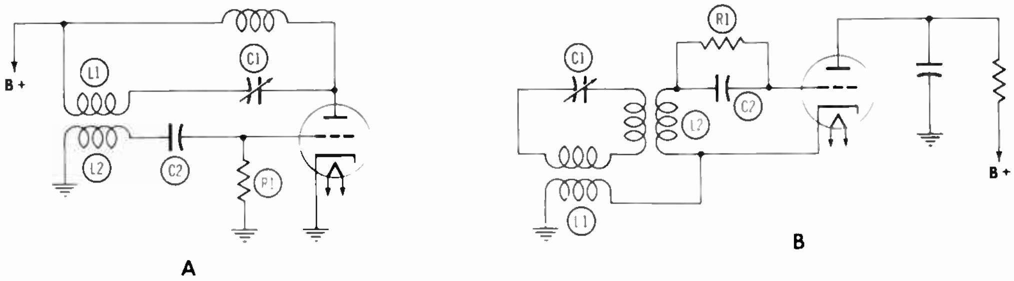

Fig. 20. Two Variations of the Meissner Oscillator Circuit.

Connections for a dynatron type negative resistance oscillator are shown by Fig. 21. The tube is represented as a tetrode or screen grid tube, but might be a pentode connected as a tetrode or might be a triode. The essential feature for dynatron operation is that the element between plate and cathode, which may be either a screen or a control grid, shall be at a potential higher than that on the plate.

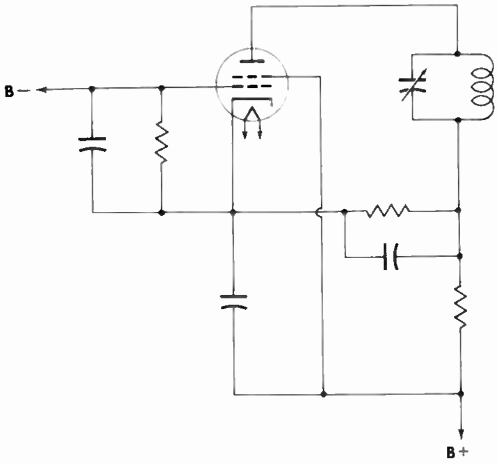

Fig. 21. A Dynatron Oscillator Circuit.

Fig. 22 shows variation of dynatron plate current, screen current, and total or cathode current when the screen is maintained at constant voltage while there are increases and decreases of plate current and voltage at the oscillating frequency. With zero plate voltage all emission goes to the screen, and screen current is total current. With increasing plate voltage, more and more electrons are drawn through the screen to strike the plate. These primary electrons cause emission of secondary electrons from the plate. The secondary electrons then are drawn to the more positive screen and add themselves to the screen current.

Continued rise of plate voltage increases the velocity of electrons striking the plate, which increases the rate of secondary emission. Soon there are more secondary electrons leaving the plate than primary electrons coming to the plate from the cathode. The result is a decrease of electrons remaining in the plate and flowing out to the external circuit in the form of plate current. If plate voltage rises above screen voltage there is no further dynatron action, and, as at the right in Fig. 22, there are rapid rises of plate current and total current with rapid drop of screen current. The grid of the tube is maintained negative enough to limit emission to a suitable rate and help maintain a constant emission rate.

With a tube operated in the ordinary manner (plate voltage higher than screen voltage) every increase of plate current in the tube and the plate load means more voltage drop between plate and cathode. Consequently, plate current soon is limited by lack of voltage applied from the B supply through the load. But when the tube is operated as a dynatron the increase of plate current means less voltage drop between plate and cathode, and more B supply voltage becomes available to the tuned-load circuit connected between plate and cathode. Any increase of current through the tuned circuit now is accompanied by an increase of voltage applied across it, while decrease of current is accompanied by decrease of applied voltage. Consequently, once the load current commences to either increase or decrease, there is a change of voltage across the load (plate to cathode) tending to accelerate the increase or decrease. This effect is equivalent to that obtained with any form of feedback.

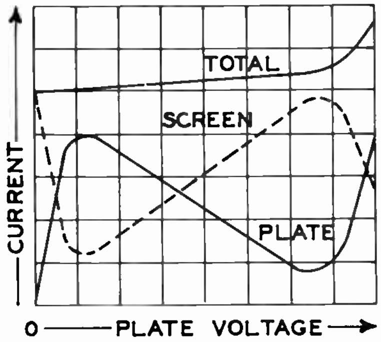

Fig. 22. Currents in a Dynatron Oscillator Tube.

Dynatron oscillators are used chiefly in test equipment, where they provide fair frequency stability and good waveform, but usually require considerable recalibration when the oscillator tube is replaced. Among other negative-resistance oscillator circuits is the negative transconductance type employing a pentode tube with the tuned oscillatory circuit connected between screen and cathode. A modulating voltage may be applied between grid and cathode of a negative-resistance oscillator.

F. Frequency Change in Oscillators

Frequency stability and constancy are necessary in any oscillator which is calibrated, as are the oscillators of signal generators, and are highly desirable where oscillator output is combined with other frequencies, as in superheterodyne tuners and controls for television sweep frequency. Frequency stability in test instruments is best secured by crystal control where crystal frequencies or their harmonics can be made to cover enough points in the operating band.

Automatic frequency control is generally used for horizontal sweep oscillators, sometimes for vertical sweep oscillators, and occasionally for RF oscillators in tuners.

Slow drift of oscillator frequency during possibly the first half hour of operation usually is due to temperature effects which alter the positions and dimensions of parts to change the inductance of coils and the capacitance of capacitors and tubes. Naturally, anything that lessens the production of heat will help. This will include the use of tubes requiring relatively small plate current, and of circuits and parts having least possible resistance. High-wattage resistors may allow improvement by reducing their own temperature, although this will not lessen the total production of heat. Temperature rise is lessened by good ventilation, absence of crowding, and by keeping parts free from dust and other dirt. Heat may be carried away and also distributed more uniformly by chassis metal and shielding of heavy gauge and of good thermal conductivity, as found in copper and aluminum.

When all practicable changes have been made in design and construction, the remaining temperature drift may be balanced out by connecting across the tuned oscillator circuits temperature-compensating ceramic capacitors having negative-temperature coefficients. These compensating capacitors must, of course, become active parts of the circuits and replace all or part of non-compensating types of capacitance which would be connected into the same positions. As temperature rises there is a decrease of the compensating capacitance with a tendency to raise the oscillator frequency to the same extent it would be lowered by heating of the various other parts.

More rapid changes of oscillator frequency may result from changes of load unless the tuned oscillating circuits are well isolated from the output. Such isolation usually is provided in test instruments by using electron-coupled oscillators or by using untuned buffer amplifiers between the oscillator itself and the output to the load.

Fluctuations of plate and screen voltage will alter the frequency of oscillation by changing plate resistance and transconductance of the oscillator tube. The best preventive is use of standard regulating tubes or voltage-regulating transformers or both. Effects of voltage variation are minimized by using oscillator tubes of fairly high plate resistance and by working with strongly negative grid bias and the required high plate-supply voltage. The use of insulation and other parts having minimum high-frequency resistance and losses helps maintain frequency stability.

Very rapid changes of oscillator frequency may be due to parts which are loose or which vibrate, or to loose electrical connections. Very slow changes which do not correct themselves usually are due to capacitors which have developed some leakage or which have changed their capacitance, or to resistors which have changed their resistance with aging. Gradual aging of tubes will alter the oscillating frequency. If no parts prove actually defective, it is best not to make replacements but to make readjustments or recalibrations after the first one or two hundred hours of use. Apparatus then should operate for long periods without enough additional change to cause any difficulty.

G. Oscillator Frequency Effects

Fig. 23 illustrates the effects of oscillator tuning or alignment in changing the intermediate frequencies which are produced in the mixer and applied to the input of the IF amplifier. The curve, which is the same at the left and right, represents the frequency response or gain versus frequency in the IF amplifier. It is assumed that the sound intermediate frequency applied to this amplifier should come low down on the left-hand or low-frequency skirt of the response, and that the video intermediate frequency should come at the point of 50 per cent gain on the right-hand side of the response curve. The two intermediate frequencies always will be separated by 4.5 megacycles, as marked on the diagram.

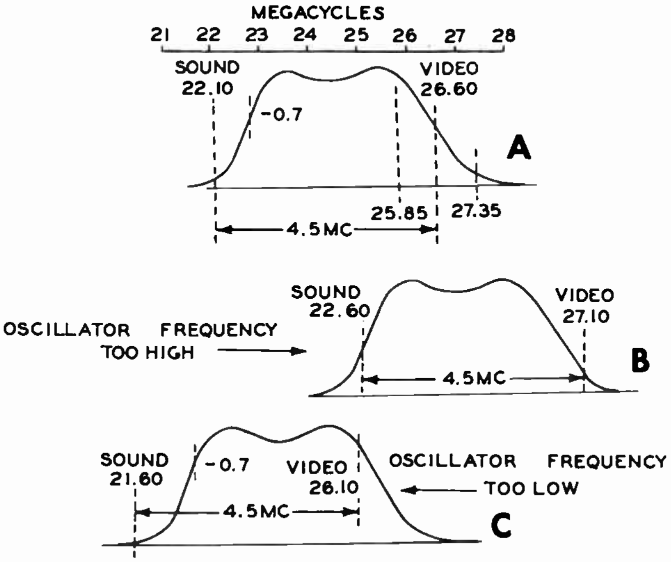

Fig. 23. How Video and Sound Intermediate Frequencies are Shifted on the IF Response Curve By Changes of RF Oscillator Frequency.

If the oscillator is mistuned or misaligned, both the sound and the video intermediate frequencies will be made too low or too high. Their separation, however, will remain 4.5 mc because separation of sound and video carriers in any channel always is 4.5 mc, and both intermediate frequencies are produced by beating of a single oscillator frequency with the two carriers.

With the oscillator tuned to a frequency which is too high, the results will be as shown in Fig. 23B. The sound intermediate frequency now moves up on the gain curve while the video intermediate frequency moves down. With an intercarrier sound system the amplification for sound will be so great as to cause possible overloading of the sound amplifiers, usually also the effect called intercarrier buzz, and it is quite probable that sound bars will appear on the picture or pattern. With a dual carrier sound system the intermediate frequency passed on to the sound amplifier will be nearly or wholly outside the band pass of this amplifier, and there will be distorted sound or none at all. The video carrier will move down on the gain curve. Low video frequencies will receive too little amplification, and there is probability of trailers and black "speckling" in pictures and patterns. Excessive reduction of low-frequency gain also may make it difficult to obtain satisfactory adjustment of the hold controls.

With the oscillator tuned or aligned for a frequency which is too low, both intermediate frequencies will be too low by the same number of megacycles or fraction of a megacycle. This is shown in Fig. 23C. If the receiver employs the intercarrier sound system the gain or response at the actual sound intermediate frequency will be so low as to allow practically no sound reproduction while if the sound system is of the dual carrier type the center frequency fed to the sound amplifier will be nearly or completely outside the bandpass of this amplifier, and there will be distorted sound or no sound at all. The video intermediate frequency will move up on the response curve. There will be too much gain at low video frequencies, while the highest video frequencies will be moved down on the opposite side of the curve, to give them too little amplification. This will prevent reproduction of fine details in the pictures.

If oscillator frequency is not too far out of alignment, and if there is a fine tuning control accessible to the operator, this control may have enough range to make correction in the various channels. With receivers having dual channel sound systems the fine tuning control may bring either satisfactory pictures or satisfactory sound, but not both at the same setting.

H. Mixers

The frequencies of the carrier signals and the RF oscillator combine to produce the intermediate frequency in the mixer or converter stage. Although the mixer in radio receivers usually is combined with the RF oscillator in the converter tube, in television receivers it most often is a separate tube or a separate section of a twin tube. The mixer sometimes is called the first detector, because it acts to rectify or partially rectify the frequencies applied to it.

The output of the RF oscillator consists of a single sharply-tuned frequency for each channel. This oscillator frequency beats with the amplitude-modulated video carrier frequency to produce a video intermediate frequency having the same signal modulation and extending over the same bandwidth in megacycles as covered by the video carrier. The same oscillator frequency beats with the frequency-modulated sound carrier in the same channel to produce a sound intermediate frequency having the same signal frequency modulation and covering the same bandwidth as the sound carrier.

It is a general rule that the RF oscillator frequency shall be higher than the carrier frequencies in the same channel. There are a few television receivers in which the oscillator frequency is lower than the carrier frequencies, but they are the exceptions. The difference between oscillator frequency and sound carrier frequency is the sound intermediate frequency of the receiver. The following tabulation shows these relations in a few channels for a receiver having video intermediate frequency of 26.60 mc and sound intermediate frequency of 22.10 mc. All the listed frequencies are in megacycles.

	Carriers		Intermediates		
Channel	Video	Sound	Video	Sound	Oscillator
2	55.25	59.75	26.60	22.10	81.85
6	83.25	87.75	26.60	22.10	109.85
7	175.25	179.75	26.60	22.10	201.85
13	211.25	215.75	26.60	22.10	237.85

I. Summary Questions

1. What are the three parts of the RF section of a television receiver?
2. What types of tubes are used as RF amplifier?
3. Explain briefly the cascode RF amplifier.
4. What type of oscillator is used most for television RF oscillator?
5. Explain briefly the push-pull RF oscillator.
6. What is necessary in order to sustain oscillations in an oscillator?
7. Explain briefly the effect of mistuning the oscillator.
8. What is the purpose of the mixer?

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THE RF TUNER OF A TV RECEIVER

Objective

To determine the type of tuner circuits used in television receivers.

References

Lesson Content

A. General

Each television program is carried through space from transmitter to receiver by two independent radio waves at very-high or ultra-high frequencies. One carrier is for the sound and will be frequency modulated while the other carrier is for the video and will be amplitude modulated. These carriers are transmitted from the television station simultaneously and therefore must be received simultaneously. For this reason it is necessary to pass both of these signals through the receiver simultaneously in order to see the picture and to hear the associated sound.

To properly select and tune to these carrier frequencies, the tuner is used. The tuner permits the operator to change the resonant frequency of the RF amplifier, mixer, or converter, and the oscillator, thus permitting selection of the channel in which reception is desired.

Signals at carrier frequencies come from the antenna through the transmission line and pass to the input of the RF amplifier through an antenna coupling. The antenna coupling may or may not be tuned for resonance at the signal frequency, or to match the impedance of the antenna at the signal frequency to be received. The RF amplifier may consist of one stage or of two stages, employing either sharp cut-off pentodes or twin triodes, or, more rarely, the remote cut-off pentode.

Strengthened carrier-frequency signals from the RF amplifier go through a tuned coupling to the input of the mixer tube. To the input of the mixer comes also a high-frequency voltage from the RF oscillator. The carrier and oscillator frequencies beat together in the mixer tube to produce in the output from this tube the intermediate frequency which is applied to the IF amplifier.

The RF oscillator and its tuned grid-plate circuit produce frequencies which, in nearly all television receivers, are higher than the carrier frequencies for the channel being received.

B. Tuners

A rather wide variety of mechanical principles are employed in TV tuners. The resonant frequency of the tuned circuit is changed by varying either the inductance or the capacitance. The tuned circuits are usually found in the RF amplifier plates, mixer grid circuit, and the oscillator grid-plate circuit.

1. Incremental Tuners

In the general type of tuner, often called an incremental-inductance type, the grid and plate circuits of the RF amplifier, mixer, and oscillator are tuned for channel selection by a number of inductors connected in series. Between adjacent inductors are switch connections that allow selecting a portion of the total inductance suitable for tuning each channel. These connections are contacted one after another by rotor tongues of a multi-section rotary selector switch. The switch and inductor compartment of a tuner of this type may be seen in Fig. 1.

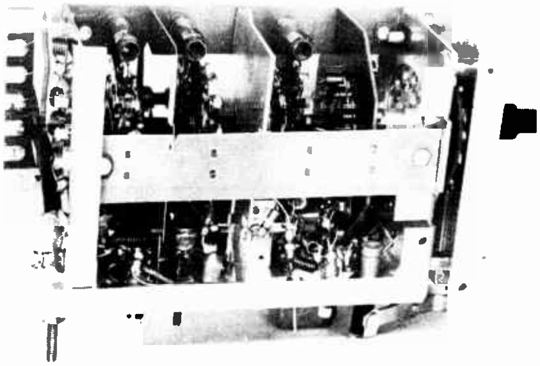


Fig. 1. An Incremental Tuner.

The principle of channel tuning by means of incremental inductance is illustrated by Fig. 2. In Fig. 2A are shown inductor sections on a switch that has a shorting segment on its rotor. In Fig. 2B is represented the same switch as it may be drawn on some service diagrams. On other diagrams the switch sections are shown by symbols which look much like the wafers themselves. The switch in the figure has its shorting segment in position for reception of channel 8. All of the inductors used for reception of channels 2 through 7 are shorted to ground. All inductors which are not thus shorted remain in series between a grid or plate and ground.

As the shorting segment is rotated clockwise it brings into the grid or plate circuit additional inductance in small steps or small increments. Inductors for high-band channels 7 through 13 consist of short, nearly straight pieces of wire between switch points. Inductance between the switch points for channel 13 and the grid or plate connection is sufficient for tuning this channel.

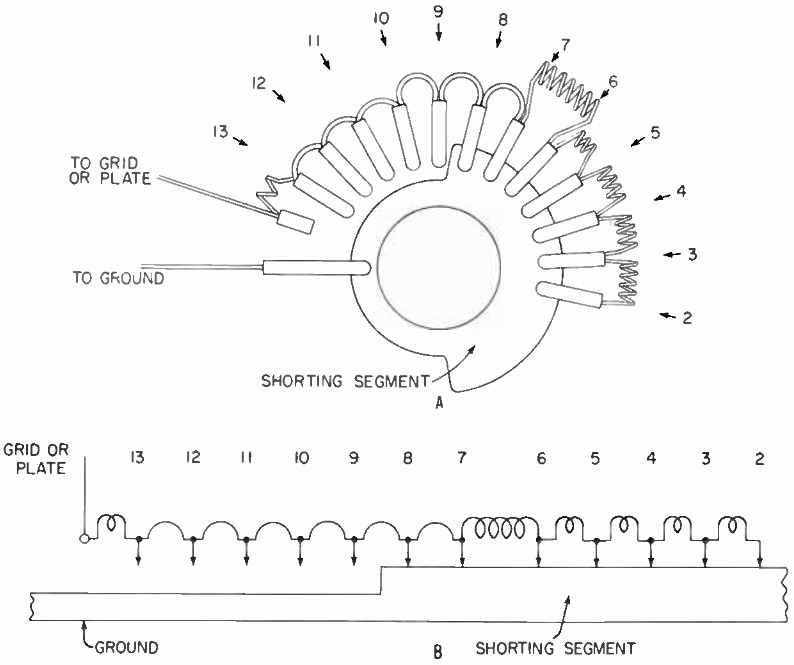


Fig. 2. The Principle of Tuning an Incremental Tuner.

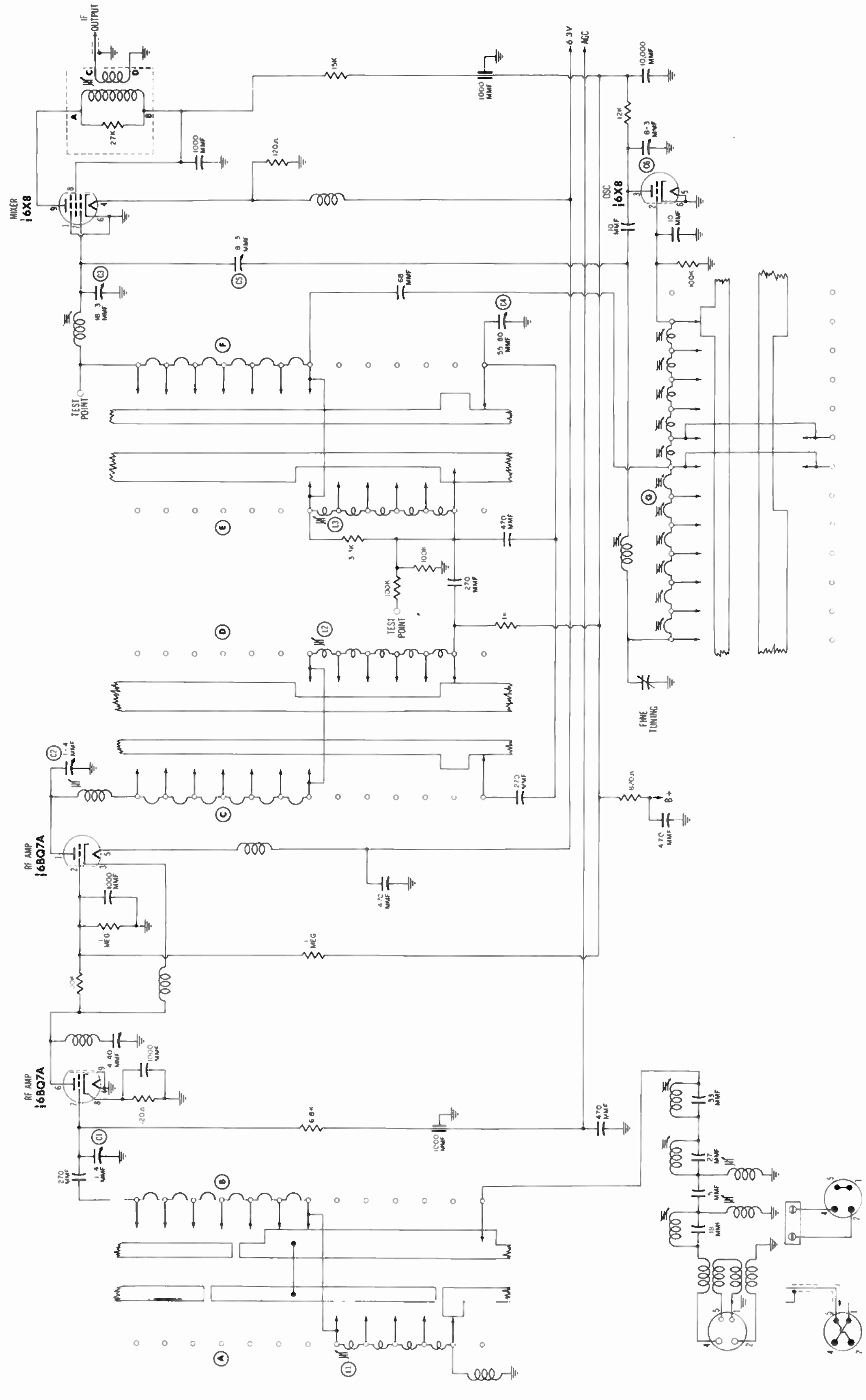


Fig. 3. Schematic Diagram of an Incremental Type Cascode Tuner.

If the total circuit capacitance is 15 mmf, total inductance for tuning to the center of channel 13 would be about 0.0372 microhenry which would be the value of the inductance between switch points 13 and the grid or plate connection. Then to tune all the way from channel 13 to channel 7 would require only 0.0167 microhenry additional inductance, which would be the combined value of all the small inductors between positions 13 and 7 on the switch.

Tuning to channel 6 with 15 mmf of circuit capacitance requires total inductance of 0.2337 microhenry. Therefore, almost 0.1800 microhenry must be added by the large coiled inductor between positions 7 and 6. The remaining smaller coiled inductors bring total inductance to about 0.5200 microhenry for tuning channel 2, all when total circuit capacitance for tuning is 15 mmf.

In Fig. 3 you find circuit connections for an incremental tuner having a twin-triode, cascode RF amplifier and a pentode mixer and triode oscillator. Switch sections A and B for antenna and RF amplifier grid are on opposite sides of the same wafer. This is true also of sections C and D for the RF amplifier plate and of sections E and F for the mixer grid. Shorting segments and tongues on opposite sides of each wafer move together. The switch is shown in position for reception of channel 2.

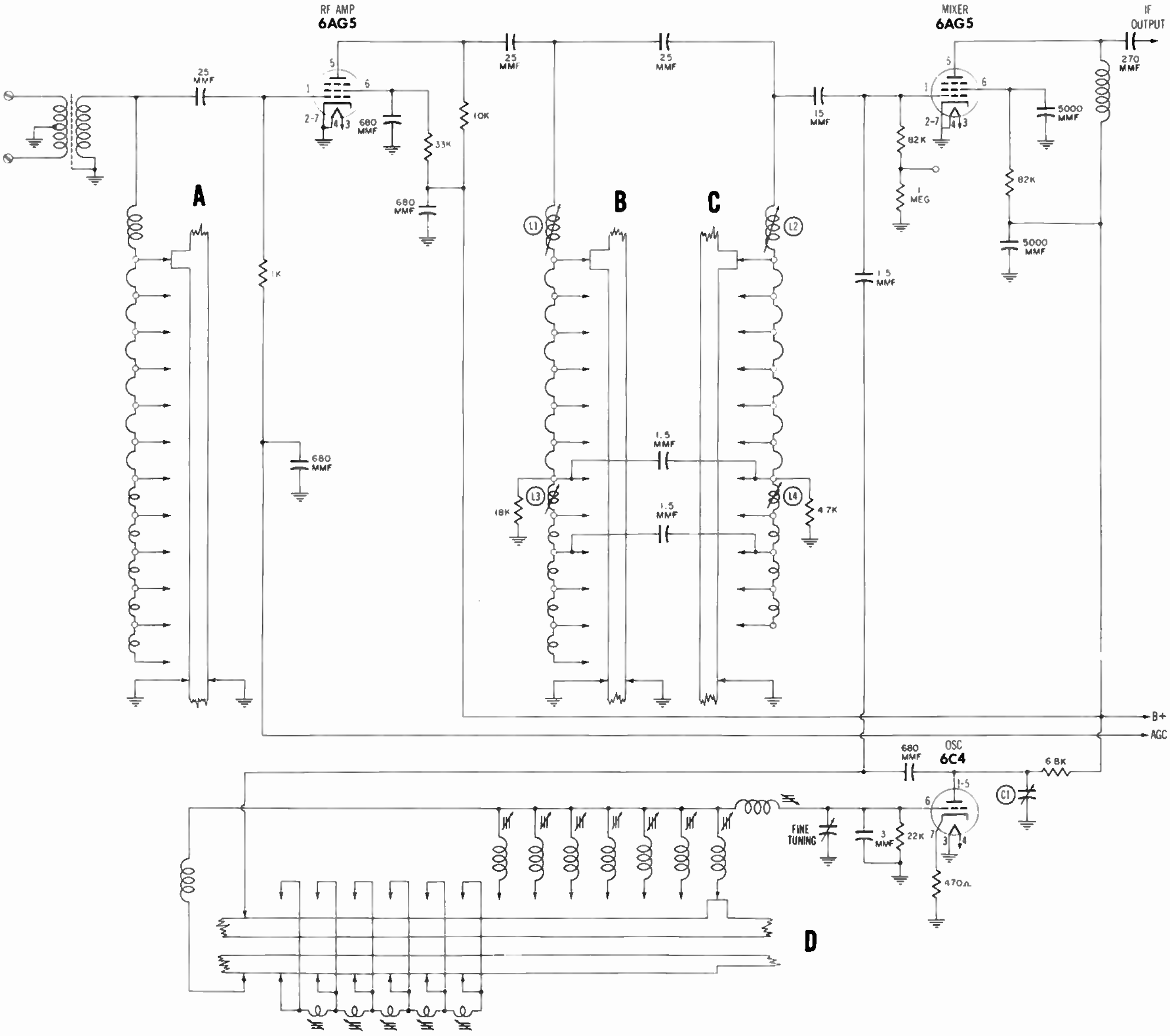


Fig. 4. Schematic Diagram of an Incremental Type Pentode Tuner.

Inductors at L1, L2,and L3 are adjustments for alignment of the low-band. High-band alignment is made with adjustable trimmer capacitors C1, C2,and C3. Capacitor C4 also an alignment adjustment, varies the degree of coupling between the RF amplifier plate and the mixer grid. At C5 is an adjustable alignment capacitor for varying injection voltage from the oscillator to the mixer grid.

The RF oscillator is a Colpitts type tuned by switch section G. Each small inductor on this section is individually adjustable for alignment of each channel. Trimmer capacitor C6 is for overall alignment of the oscillator.

In Fig. 4 is a circuit diagram for an incremental tuner having a pentode RF amplifier, a pentode mixer, and a triode RF oscillator. Switch section A tunes the RF amplifier grid circuit, B tunes the RF amplifier plate, C the mixer grid, and D the oscillator. Inductors L1 and L2, between the RF amplifier and mixer, are adjustable for alignment of high-band channels. Adjustment is made by spreading or squeezing the coil turns. Inductors L3 and L4 are adjustable in the same manner for alignment of low-band channels. Other than these inductors and a trimmer capacitor on the oscillator plate (C1) there are no service adjustments.

Fig. 5 shows circuits for a tuner employing incremental inductances for the RF amplifier plate and the mixer grid, with shorting of unused inductor sections by means of rotor tongues instead of segments on the selector switch. The oscillator is tuned by separate inductors for each channel with connections to the two ends of each inductor through contact tongues on rotors of two wafers in the selector switch. The switch and inductor compartment of a tuner of this type is pictured in Fig. 6. The RF oscillator used in tuners of Figs. 5 and 6 is a twin-triode push-pull type.

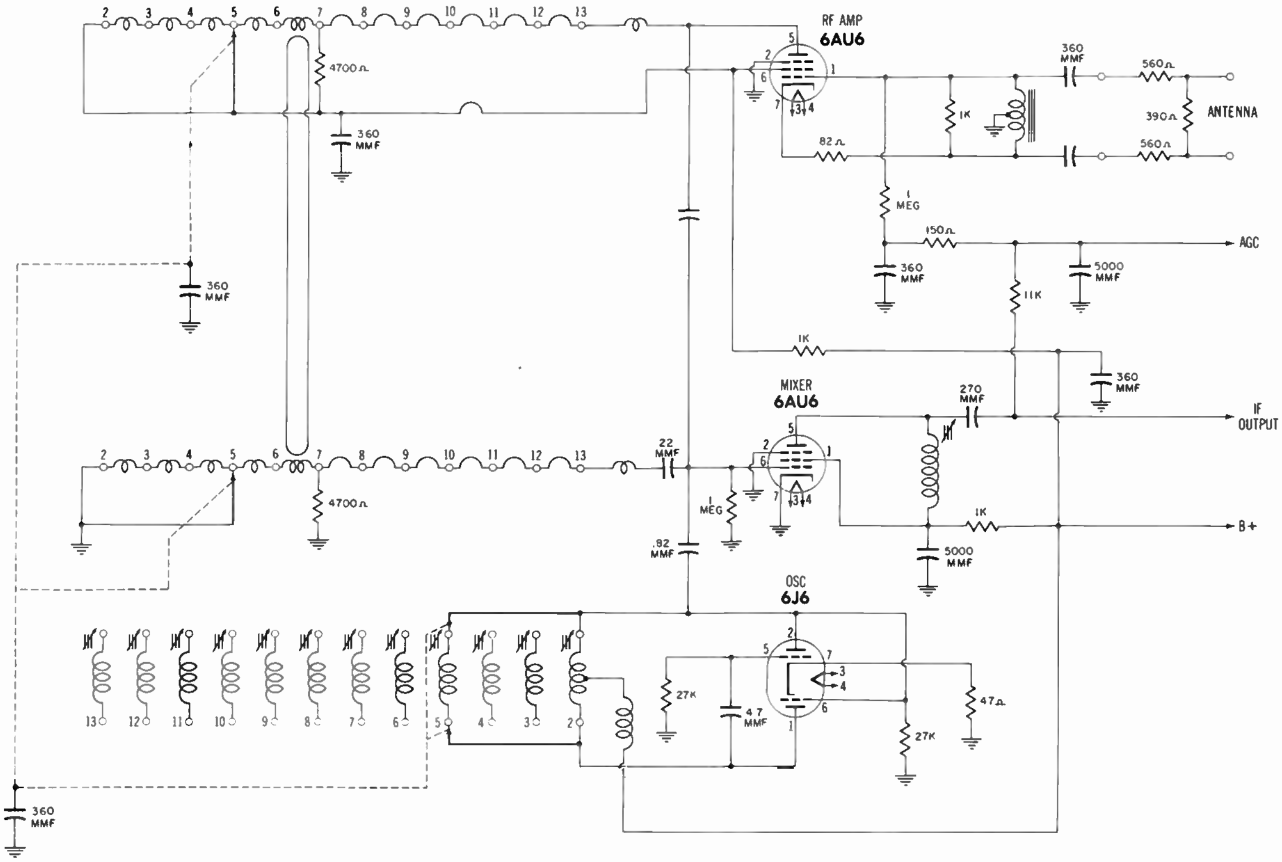


Fig. 5. Schematic Diagram of an Incremental Type Tuner Having a Pentode RF Amplifier and Mixer and a Twin Triode Push-Pull Oscillator.

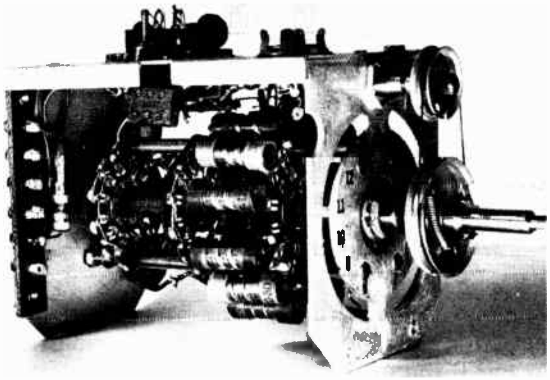


Fig. 6. Photo of the Tuner Shown in Fig. 5.

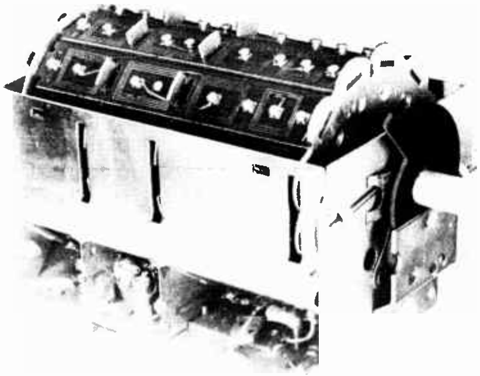


Fig. 7. A Turret Tuner Which has Printed Circuit Coils.

2. Turret Tuners:

The turret-type tuner, an example of which is pictured in Fig. 7, carries on a revolving drum a separate set of tuning inductors for each channel to be received. Inductors are on the inside of strips of insulation and connect to small metal buttons on the outside of the strips. As the drum is revolved from one position to another by the channel selector knob the buttons engage stationary spring contacts from which connections lead to the tube sockets and to the various circuit components in the tuner. In Fig. 8 you see a turret drum from which a few channel strips have been removed to expose inductors or remaining strips. The contact springs can be seen in the upper part of the frame. As shown by Fig. 9, the drum is removable from the frame after removing parts of the fine tuning control and retaining springs. Strips may be removed with the drum still mounted in the frame.

Fig. 10 is a circuit diagram for one style of turret tuner. Inductors for one channel are shown within the broken line boxes. Inductors for other channels are brought into these broken-line positions by rotating the drum. Contact buttons and springs are indicated by arrowheads to which connect the various circuits in stationary parts of the tuner.

Looking at the diagram in Fig. 10 the inductors are as follows: First, (on the left) a center tapped coil whose ends connect to the antenna through traps which help prevent interference in the range of the intermediate frequency. Second, the grid coil for the input section of the cascode RF amplifier. On this coil is a trimmer capacitor C1 and a series resonant trap adjustable to frequencies of local interference. Third, (in the center of the diagram) the plate coil

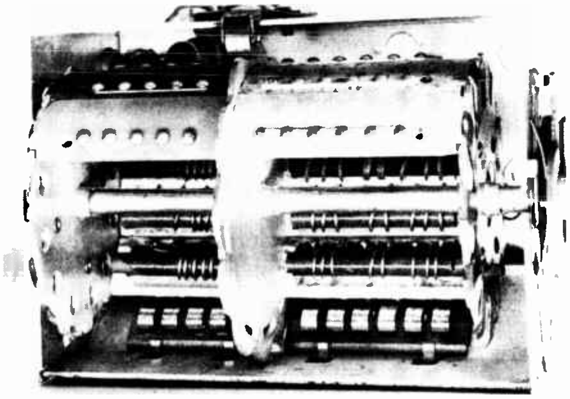


Fig. 8. A Turret Tuner with Part of the Channel Strips Removed.

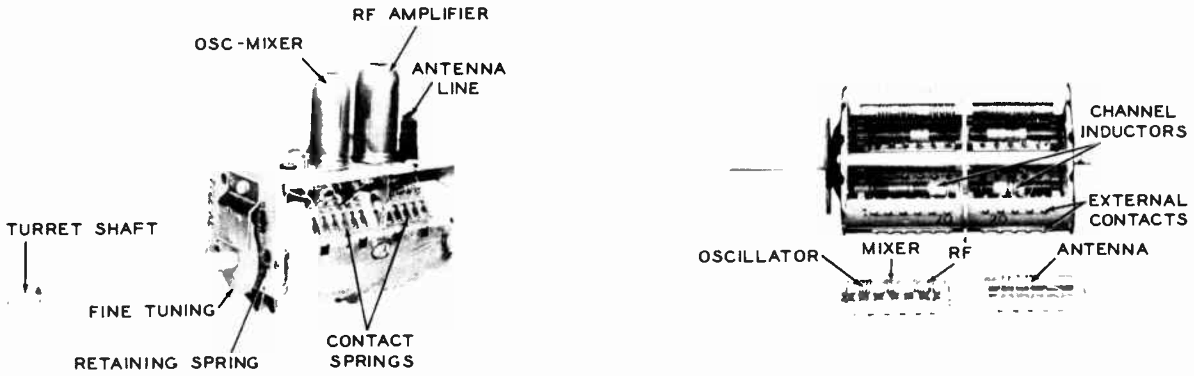


Fig. 9. A Turret Tuner with Drum Removed to Show Construction.

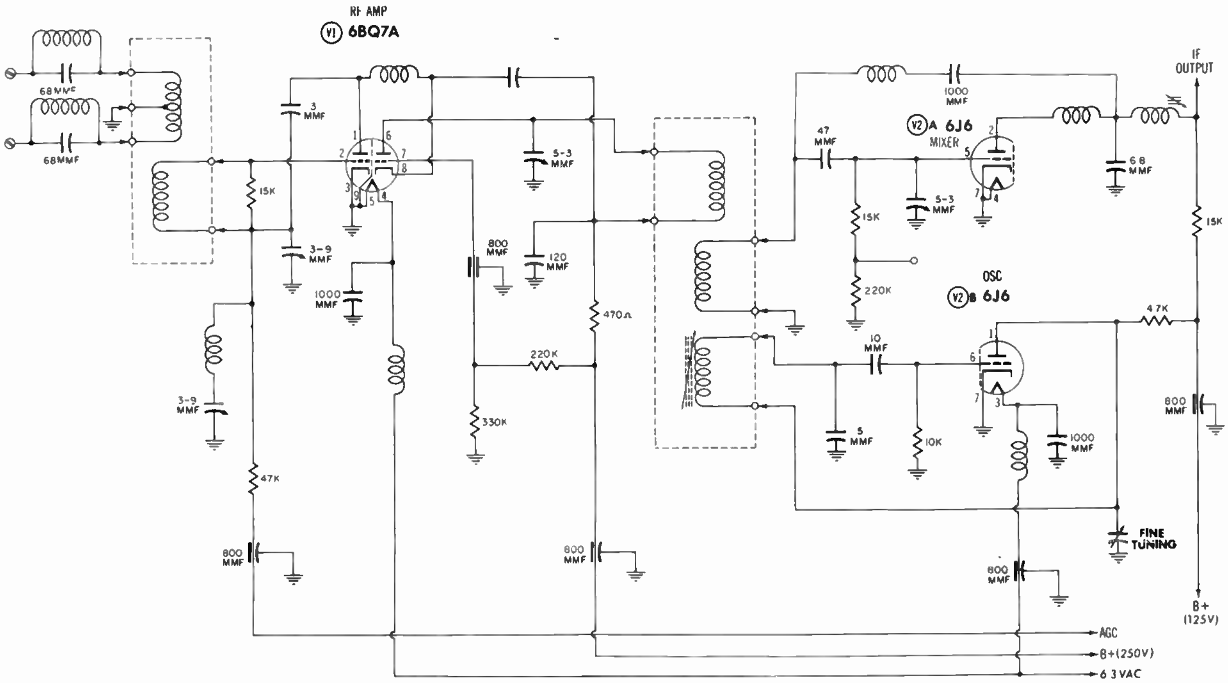


Fig. 10. Schematic Diagram of a Cascode Turret Tuner.

for the output section of the RF amplifier. Fourth, the grid coil for the mixer. There is degenerative feedback through a capacitor and inductor from the mixer plate to grid. Fifth, the coil in the tank circuit of the Colpitts type RF oscillator. Inside this oscillator coil is an adjustable core used for alignment. Connected to one side of the oscillator circuit is the fine tuning capacitor.

Fig. 11 is a circuit diagram for a turret tuner in which the RF amplifier is a pentode. The channel strip carrying the antenna coil and the RF grid coil is shown at the left of the RF amplifier while the strip carrying the other three coils is shown in the center of the diagram. Alignment trimmer capacitors are as follows: C1 for the RF amplifier grid, C2 for the RF amplifier plate, C3 for the mixer grid, C4 for the oscillator. The fine tuning is marked C5. The output of the mixer is coupled to the video IF amplifier section of the receiver.

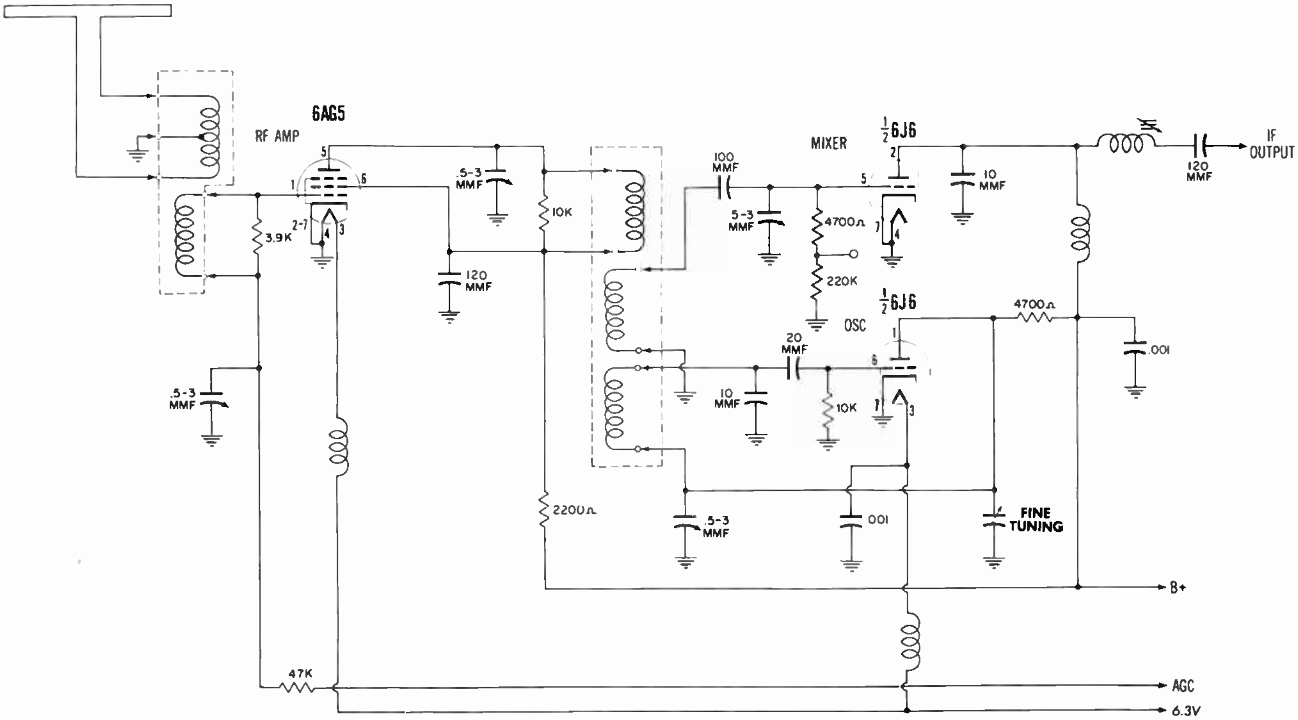


Fig. 11. Schematic Diagram of a Pentode Turret Tuner.

3. Continuous Tuning With Inductors

Many tuners are designed for changing their resonant frequencies only in steps. They tune to channel frequencies but not to any frequencies between channels or between bands. Other designs which may be called continuous tuners may be made resonant at any frequency in either the low or high bands of the very high frequency range and sometimes to frequencies between the top of the low band and the bottom of the high band.

A continuous variable inductance unit called an Inductuner is pictured in Fig. 12. There are three inductors, each consisting of a spiral of metal ribbon over which is rotated a contact arm operated through gearing from the channel selector knob. Similar units are made with four adjustable inductors.

One method of using three spiral inductors in a complete tuner is shown by Fig. 13. Between the RF amplifier plate and the mixer grid are three adjustable capacitors (C1, C2, and C3) used for low-band alignment. In series with each variable inductor is a loop or small coil (L1, L2, and L3) used for high band alignment by spreading or squeezing the turns or by moving the loop or coil toward or away from adjacent metal.

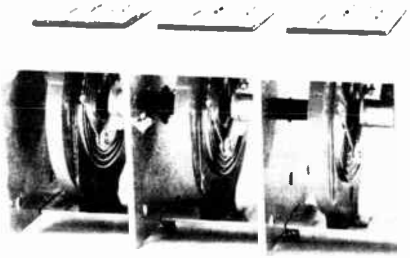


Fig. 12. The Inductuner.

External inductor L4, connected in parallel with the oscillator variable inductor, reduces effective oscillator tuning inductance to allow frequencies higher than received carrier frequencies to be generated. Capacitor C4 is an alignment adjustment for the oscillator. If the tuner is provided with fixed stops for each channel this capacitor may be used for fine tuning.

4. Variable Capacitance Tuner

Instead of varying the circuit ind··ctances a few tuners vary the capacitances which are connected across fixed inductors in several circuits. In one type of variable capacitance tuner there are three pairs of capacitors. One capacitor of each pair is used for low-band channels, the other for high-band channels. One of the pairs tunes the plate circuit of the RF amplifier, another tunes the mixer grid circuit, and the third tunes the oscillator. The capacitor rotor plates are moved by rotation of the tuning knob or dial.

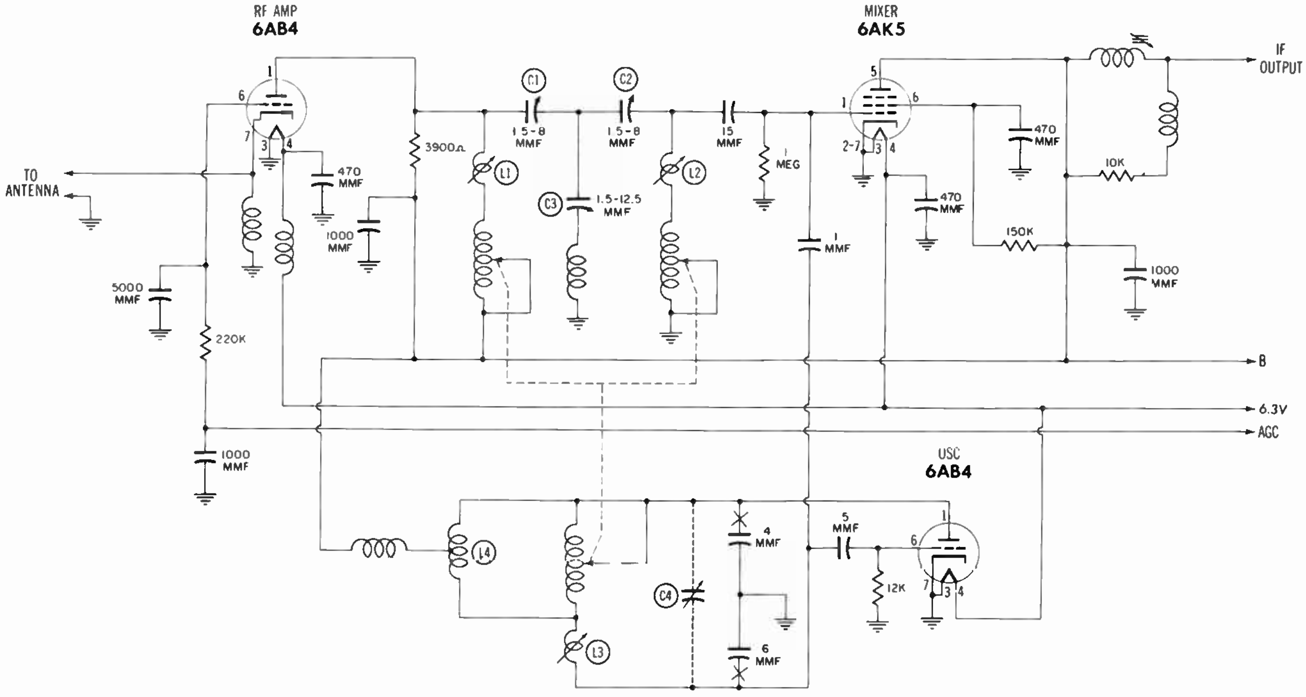


Fig. 13. Schematic Diagram of a Tuner Using the Inductuner.

In Fig. 14 may be seen the interior of a continuously variable tuner with which channel selection is by means of three air-dielectric capacitors at the lower right of the picture. A circuit diagram for such a tuner is given in Fig. 15. The three variable capacitors are operated by a single tuning shaft. There are two pentode RF amplifiers in the cascade. The first amplifier peaks at approximately the video carrier frequency of each received channel, while the second peaks at approximately the sound carrier frequency.

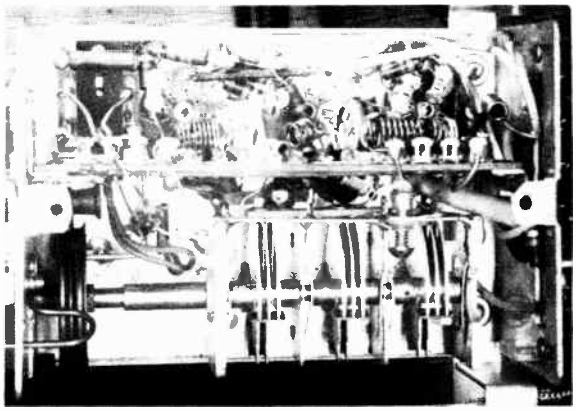


Fig. 14. Bottom View of a Variable Capacitance Tuner.

With still another method of capacitance tuning there are fixed inductors for each of the tuned circuits. Across each inductor may be connected any one of 12 separately adjustable trimmer capacitors. One of these capacitors acts for each channel to be tuned. The capacitors are connected to or disconnected from the inductors by push-button switches for each channel.

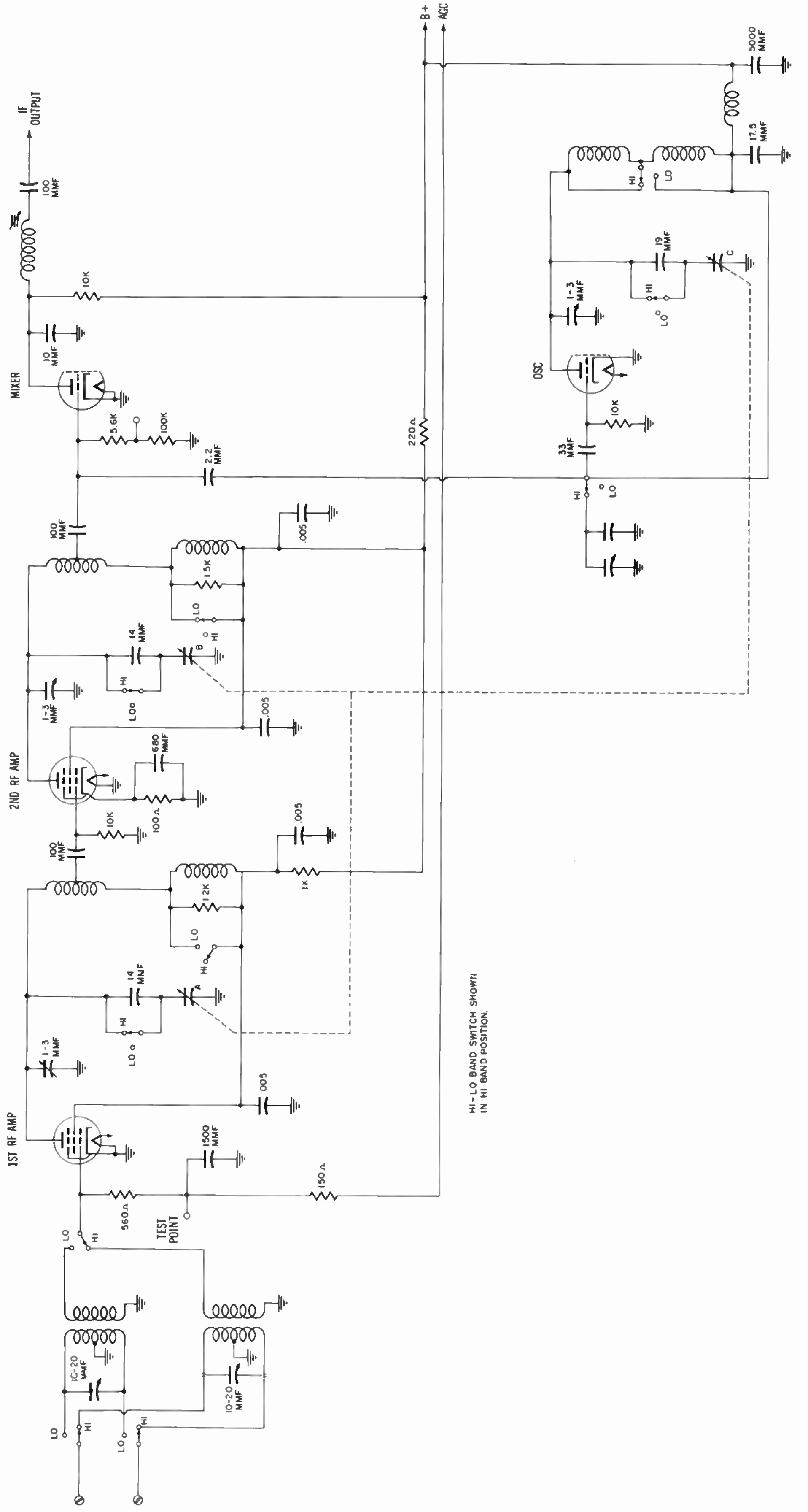


Fig. 15. Schematic Diagram of a Variable Capacitance Tuner.

C. Frequency Adjustments

Fig. 16 illustrates some of the methods of frequency adjustment employed in tuners, and shows the effects of alterations.

1. When a movable core, or slug, of powdered iron is turned farther into a coil the resonant frequency becomes lower. Turning this kind of core farther out of the coil will make the resonant frequency higher. (See Fig. 16A).

2. If a non-magnetic core, made of brass, copper, or aluminum, is turned farther into a coil the resonant frequency becomes higher, while turning this type of core farther out of the coil will lower the frequency. (See Fig. 16B).

3. With self-supporting coil, or one whose turns can be moved along the supporting form, squeezing the turns closer together will lower the resonant frequency. Spreading the turns farther apart will make the resonant frequency higher. (See Fig. 16C).

4. Frequency of resonance may be changed by moving a shorted turn toward or away from the end of a tuning coil, or by moving the shorted turn along the coil. As the shorted turn is moved toward the coil or toward the center of the coil the frequency is made higher. Moving the turn away from the coil makes the frequency lower. (See Fig. 16D).

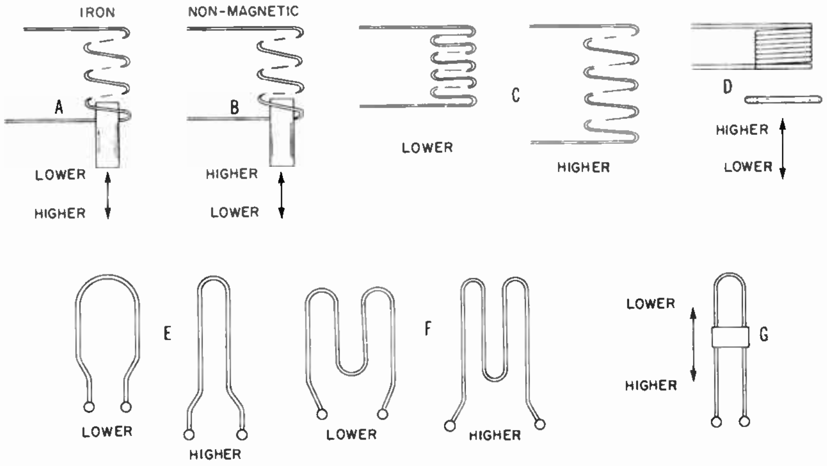


Fig. 16. Methods of Adjusting Tuner Inductances to Vary the Resonant Frequency. Reference Notes Are for Changes of Frequency.

5. When a tuning inductor consists of a single loop of wire, moving the sides of the loop farther apart will lower the resonant frequency of the circuit, while pressing the sides closer together will make the frequency higher. (See Fig. 16E).

6. If the tuning inductor consists of several flat loops of wire, the frequency will be lowered by spreading the loops wider, and will be made higher by moving the loops together or making them narrower from side to side. (See Fig. 16F).

7. Some tuning inductors are in the form of a wire loop on which is fitted a movable slider that makes a short circuit across the loop. Moving the slider toward the closed end of the loop will lower the resonant frequency, while moving the slider toward the terminals of the loop will make the frequency higher. (See Fig. 16G).

Any of these adjustments which lower the resonant frequency do so by increasing the effective inductance, while those which raise the frequency are such as to decrease the inductance.

Movable cores or slugs often are secured in position by a coating of wax over the end. The wax may be melted by bringing a hot soldering iron fairly close. When a new adjustment is completed the seal may be restored by warming the wax until it flows. If adjustable members are held in place with cement the fastening usually may be dissolved with lacquer thinner, methylbenzene spirits or some solvent made specially for dissolving radio cements. Movable cores in the tuner inductors should be adjusted only with alignment screw drivers or wrenches containing no metals at all. Tools used for bending or shaping wire inductors should contain no metal if adjustments are made while the circuits are in operation.

D. Summary Questions

1. What is the purpose of an RF tuner?
2. Explain briefly the rotary selector switch.
3. Explain briefly the turret tuner.
4. Explain briefly the variable inductance or capacitance tuners.
5. When a rotary selector switch is used the local oscillator may be tuned by what method?
6. What is the purpose of the fine tuning control?
7. What is the effect on resonant frequency when a powdered iron slug is turned farther into the coil?
8. What is the effect on resonant frequency when using brass slugs?
9. What are other methods of varying the resonant frequency of tuned circuits?
10. Why is it necessary to secure the slugs with wax when aligned?

TELEVISION SOUND

Objective

To study the sound section of a TV receiver.

References

Lesson Content

A. How the Sound is Carried Through the Intermediate Frequency Stages.

The type of sound amplifier affects not only the method of aligning the sound circuits, but also the design of the video IF amplifiers, the video amplifier, and the alignment procedures which is employed in these sections of the receiver. It is therefore necessary to consider the sound system first.

In order to have definite intermediate frequencies to illustrate the behavior of sound systems we shall consider what happens to certain carrier frequencies which come into the tuner. In channel 4, for example, the video carrier is 67.25 mc and the sound carrier 71.75 mc. We assume that when our RF oscillator is tuned for this channel,its frequency is 93.35 mc. The difference between the oscillator and video carrier frequencies (93.35 minus 67.25) is 26.1 mc. This is our video intermediate frequency. The difference between the oscillator and sound carrier frequencies (93.35 minus 71.75) is 21.6 mc. This is our sound intermediate frequency.

At this time we may make note of the relations between carrier and intermediate frequencies. The sound carrier frequency is higher than the video carrier frequency in the same channel. But in the different frequencies produced in heterodyning, the sound intermediate frequency is lower than the video intermediate frequency. This always is true on all channels and for any carrier and intermediate frequencies under consideration.

Two basic sound systems are used in television receivers. Most earlier receivers used the "split-sound" system and later receivers use the "intercarrier" system. The differences between these two systems is explained in the following paragraphs.

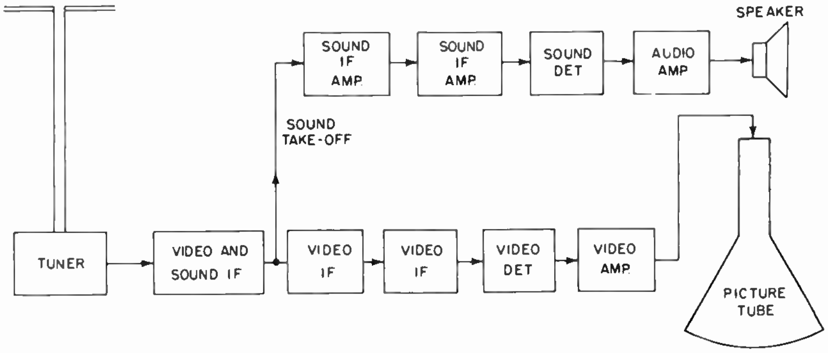


Fig. 1. Block Diagram of Split-Sound System.

The split-sound system may be represented as in Fig. 1. Continuing with our assumed intermediate frequencies, both of them pass from the mixer to the video and sound intermediate amplifying stage of this diagram. Both are amplified and both appear in the output of this stage. Then the sound intermediate frequency of 21.6 mc is taken off and applied to the first stage of the sound intermediate amplifier.

The sound intermediate frequency might be taken off immediately after the mixer without affecting the general principles of this system. Then there would be no amplifying stages handling both sound and video. Or the sound might be taken off after two or even three intermediate amplifying stages. Then there would be more stages handling both sound and video. The really important fact, regardless of point of takeoff, is that the frequency fed to the sound intermediate amplifier is the sound intermediate frequency of 21.6 mc.

This sound intermediate frequency is frequency-modulated with the audio signals. All of the sound IF stages operate at and pass the sound intermediate frequency. It then passes through the demodulator where the high frequencies are discarded and the audio signal passed on to the audio amplifier and speaker. The demodulator may be a discriminator or a ratio detector in its basic circuit.

The most widely used television receiver sound system is the intercarrier sound system. Signal travel in this system is shown in Fig. 2. The video and sound carriers beat together in the mixer to produce the same video and sound intermediate frequencies as with any other method. But instead of the sound intermediate being taken off at some point well ahead of the video detector, both the sound and the video intermediate frequencies continue together through all the IF stages, and both are applied to the video detector.

The two intermediate frequencies beat together in the video detector. The detector acts as a mixer for these frequencies. In its output is a new frequency, the difference between the incoming intermediates. The difference between any video intermediate frequency and the accompanying sound intermediate frequency is 4.5 mc. This is because the difference between the video carrier and sound carrier frequencies in any one channel always is 4.5 mc. Consequently the new beat frequency from the detector always must be 4.5 mc.

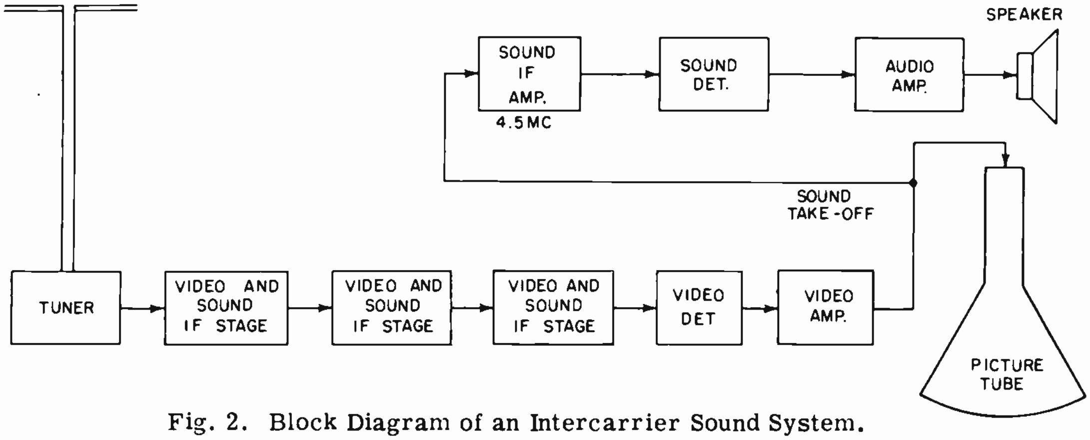


Fig. 2. Block Diagram of an Intercarrier Sound System.

Since the 4.5 mc frequency results primarily from the frequency difference between the two carriers it is called an intercarrier beat frequency. The 4.5 mc intercarrier beat or intercarrier sound goes through the video amplifier, where it is strengthened along with the video signal. The intercarrier sound frequency, with its modulation, is taken off at the output of the video amplifier and fed to the sound IF amplifier. From the sound IF amplifier the signal goes to the sound demodulator where the frequency deviations produce amplitude modulation which is the audio signal, just as in any other FM sound system. The sound take-off point is shown in Fig. 2 as being at the output of the video amplifier; however, the sound take-off in an intercarrier receiver may be at any point between the video detector and the picture tube grid.

The frequency response of the tuner does not vary, it may be the same with either sound system. A typical tuner response curve is shown by Fig. 3. Usually there are two peaks which are more or less pronounced. The video carrier frequency is at or near the peak of lower frequency, while the sound carrier frequency is at or near the peak of higher frequency. This latter peak sometimes is higher than the video-carrier peak, giving more amplitude on sound than on the video carrier in receivers using split-sound.

With the sound system operating at the sound intermediate frequency (split-sound) response curves for the IF amplifiers following the mixer are about as shown in Fig. 4. In stages before the sound takeoff, which carry both video intermediate and sound intermediate frequencies, the response of all such stages combined will be somewhat as shown in Fig. 4A. There will be enough gain at the sound intermediate to carry the sound signals through these stages in fair strength.

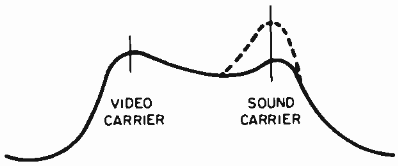


Fig. 3. Frequency Response of an RF Stage of a Tuner.

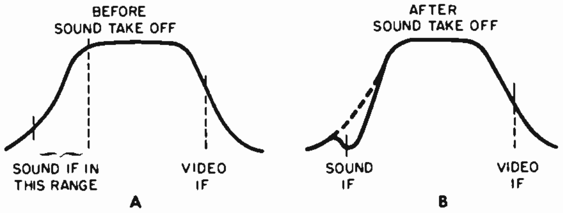


Fig. 4. Video IF Response in a Split-Sound Receiver.

The intermediate video frequency always is about half way down on the high-frequency side of the response. This provides a uniform output for all the frequencies which are transmitted in double strength with vestigial sideband transmission. We shall consider this feature at length in connection with video IF amplifiers.

In all video IF stages following the point of sound takeoff the response at the sound intermediate frequency is made as low as possible, as shown in Fig. 4B. This is because it is highly undesirable to have sound signals reach the picture tube. The reduction of sound IF response is accomplished by careful tuning of these video IF stages and by the use of wave traps which attenuate or absorb the intermediate sound frequency.

When the receiver uses an intercarrier sound system the overall response of the entire video-sound IF amplifier, from mixer to video detector, must be about as shown in Fig. 5. Now the position of the sound intermediate frequency on the response curve is critical. The gain at this point must be from 90% to 97 1/2% down from the peak gain. In many receivers this gain must be down at least 95%. This is a voltage attenuation of between 26 and 32 decibels.

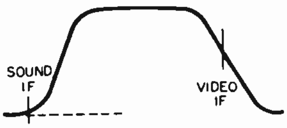


Fig. 5. Video IF Response in an Intercarrier Receiver.

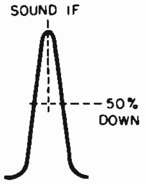


Fig. 6. Sound IF Amplifier Response Curve.

If the sound intermediate frequency is brought too high on the response curve the gain will be so great that sound signals will be forced on through the video amplifier and into the picture tube grid-cathode circuit. If the sound intermediate is too low on the response curve the gain will be too small for good sound reproduction from the loud speaker.

Fig. 6 shows a fairly typical response curve for the sound IF amplifier which follows the sound takeoff and precedes the sound demodulator. This amplifier is peaked at the sound intermediate frequency. The response is about 50% or 6 db down at frequencies only 0.15 to 0.20 mc either side of the peak. We have a useful response over a range only about 0.30 mc wide.

In every receiver the actual intermediate frequencies are determined by the frequency of the RF oscillator, since this frequency beats with the carrier frequencies to produce both intermediates. If the oscillator is tuned 1.0 mc too high it will raise both the video and the sound intermediate frequencies by 1.0 mc, and if the oscillator is 1.0 mc too low it will drop both intermediates by 1.0 mc. The amplifiers still will be tuned to the original intermediate frequencies, but the actual frequencies fed to the amplifiers will be too high or too low.

If the sound system is designed to operate on the split-sound principle and the oscillator frequency varies by as much as 1.0 mc, the actual IF frequency varies by as much as 1.0 mc, the actual frequency reaching the sound IF amplifier will be completely outside the effective range of that amplifier, as is evident from Fig. 6. There will be no reproduction of sound, although there still will be a picture of some sort. Actually, the frequency of the RF oscillator must be correct within less than 0.10 to 0.15 mc in order to have reproduction of sound signals.

In the intercarrier sound system, no matter how far from correct the RF oscillator frequency may be, it affects both the video and the sound intermediate frequencies equally. The video and sound IF always are separated by 4.5 mc, for that is the separation of the original carriers. Then there always will be a 4.5 mc beat frequency produced at the video detector, and this will be fed to the sound IF amplifier.

Do not conclude that tuning or alignment of the RF oscillator is not critical when we have intercarrier sound. Misalignment shifts the sound and video intermediate frequencies on the response curves of amplifiers between mixer and detector and causes much trouble. One of the really important conclusions in this: With a sound system operating at the regular sound intermediate frequency it is easy to align the RF oscillator by connecting an electronic voltmeter or an oscilloscope to the output of the sound demodulator. The output will be as sharp as indicated in Fig. 6 when oscillator frequency is exactly correct, and will fall off rapidly with very slight misalignment of the oscillator. With intercarrier sound we cannot align the RF oscillator by working through the sound system. No matter how far out of alignment the oscillator may be, we still have a 4.5 mc beat to which the sound IF amplifier is tuned.

B. How the Sound Carrier is Demodulated

Many sets still in operation use either a limiter stage and a discriminator or a ratio detector stage. These circuits were described in another lesson.

The latest system uses a single tube to combine the functions of limiting and demodulating. This tube is called a "Gated-Beam Tube". The gated beam tube has five active elements, but does not act like a pentode. The elements are, in order, a cathode, a control grid, a screen grid, a quadrature grid, and a plate. The most notable characteristic of this tube is the manner in which plate current is varied by changes of control grid voltage.

When the control grid is three to four volts negative with reference to the cathode there is plate current cutoff. As the control grid is made less negative there comes a point at which plate current begins to increase rapidly. Then, with a change of only about one volt on the control grid, plate current rises to its maximum value. Varying the control grid voltage back and forth through this range of approximately one volt will cause plate current to vary between zero and maximum. Even though the control grid is made positive by as much as 20 to 30 volts, plate current increases little if any above the value reached with the control grid still slightly negative.

Maximum plate current is determined chiefly by plate voltage or by B+ voltage applied to the plate load resistor. The maximum increases almost directly with this B+ voltage so long as screen voltage is held constant. The effect of screen voltage in the gated beam tube is much like that of plate voltage on a pentode. That is, plate current increases with screen voltage up to a certain value, after which further increase of screen voltage causes hardly any additional increase of plate current. Maximum plate current is determined also by voltage on the quadrature grid. With this grid a few volts negative there is plate-current cutoff. There is a gradual increase of maximum plate current as the quadrature grid voltage changes from negative through zero and to positive.

The gated-beam tube was designed primarily for use as a combined demodulator and limiter for FM sound, and is thus employed in television receivers. A typical circuit is shown by Fig. 7. There is limiting because plate current cannot exceed a predetermined maximum on positive alternations of input grid voltage. For demodulator action, pulses of electron flow pass through the screen, acting as an accelerator, and reach the quadrature grid. Connected to the quadrature grid is an inductor-capacitor circuit tuned to the FM center frequency. Resonant voltage in this tuned circuit lags signal voltage on the control grid by about 90 degrees. The combined effect of this lagging voltage and frequency-modulated voltage on the control grid vary the time duration of current pulses to the plate. Resulting variations of average plate current are proportional to frequency deviation of the FM signal. Consequently, plate current varies at audio frequency.

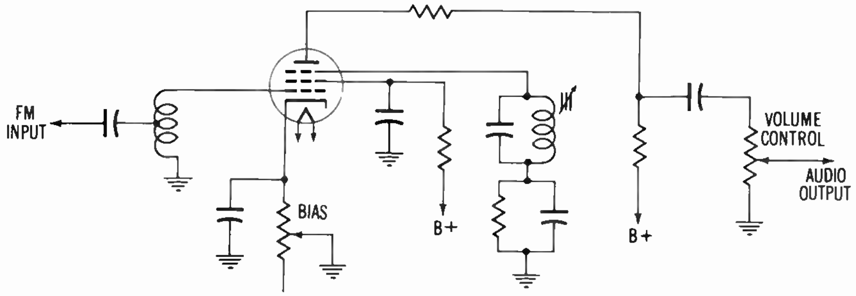


Fig. 7. The Gated-Beam Detector Circuit.

C. Summary Questions

1. What determines the video intermediate frequency?
2. What determines the sound intermediate frequency?
3. In the intercarrier sound systems what frequencies pass through a common IF strip?
4. In the intercarrier system, can we align the RF oscillator by working through the sound system?
5. What will happen to the intermediate frequencies when the oscillator is tuned too high?

VIDEO INTERMEDIATE FREQUENCY AMPLIFICATION

Objective

To study the intermediate frequency amplifier circuits used in the video section of a TV receiver.

References

Lesson Content

A. General

The television receiver video IF amplifier extends from the output of the mixer tube in the tuner section to the input side of the video detector. Fig. 1 shows fairly typical circuit connections from one of the simpler types of video IF amplifiers. Carrier and oscillator frequencies are applied to the control grid of the first IF amplifier tube, also their sum and difference frequencies from the mixer. Tuned circuits select the difference frequencies and reject the others, just as in the IF amplifier of the superheterodyne sound receiver. Whereas there may be only a single IF amplifier stage in a sound receiver, the relatively low gains possible in wide bandwidth circuits at high frequencies make it necessary to use two, three, or four such stages for television.

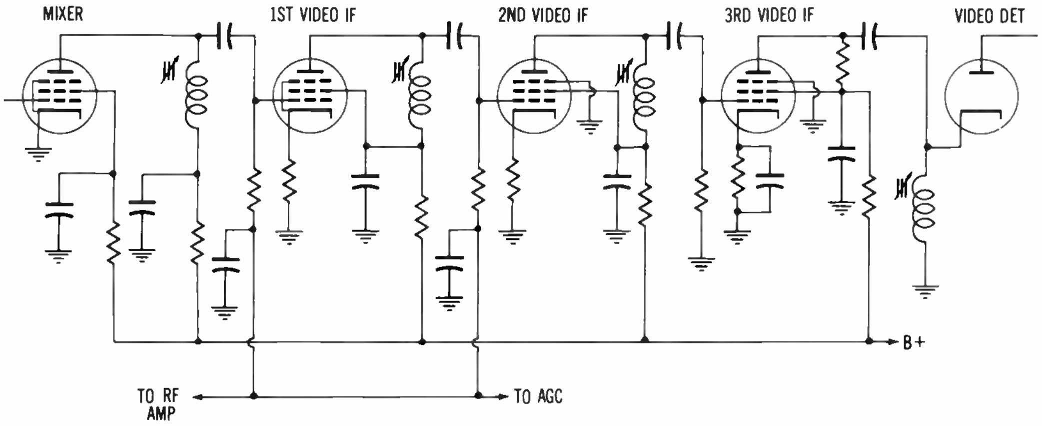


Fig. 1. Diagram of a Three - Stage Video IF Amplifier System.

B. The IF Stage

1. Characteristics

Video IF amplifier tubes are pentodes having high transconductance, usually of the miniature type. Tuning in Fig. 1 is by means of a single adjustable inductor in each interstage coupling. Tuning capacitance is furnished by the internal output and input capacitances of the tubes, by distributed capacitance of the inductors, and by stray capacitance in sockets, wiring, and other parts. Each stage is tuned to resonance at some certain frequency which is close to or in between the video intermediate and sound intermediate frequencies. The tuning shown here is "staggered" at different frequencies so that the overall response of the whole amplifier is satisfactory for the band of frequencies to be handled.

2. Frequency Response

The necessary wide frequency response in some receivers may be provided by transformers with two closely coupled windings, somewhat similar to IF transformers for sound receivers. In still others, some of the couplings are with transformers giving a double-peaked response, and other couplings in the same amplifier are single tuned inductors or may be loosely coupled transformers providing a single peak in their response. In any of these designs the IF amplifier must handle a frequency band three to four megacycles wide when it carries only picture and sync signals, or a band even wider in stages carrying the entire composite signal including sound.

3. The Suppressor Grid

Some types of video IF tubes have their suppressors internally connected to the cathodes. Suppressors provided with external connections or pins usually are connected directly to ground, as in the second and third IF stages in Fig. 1, but sometimes are connected externally to the cathode. Automatic gain control commonly is provided for all except the last video IF amplifier. Grid bias usually is by means of the AGC system and a cathode bias resistor for each tube. Grid resistors seldom have resistance greater than 10,000 ohms. Coupling capacitors between plates and following control grids ordinarily have capacitances somewhere between 50 and 300 mmf.

4. Traps

In many video IF amplifiers there are numerous features not shown by Fig. 1. These include traps for various interference frequencies and for the accompanying sound frequency, also sound take-off connections or couplings when the receiver does not operate with intercarrier sound. In such receivers the sound take-off may be anywhere between the mixer output coupling and the tuned circuits for the last video IF amplifier. All stages between the mixer and the sound take-off must carry signals for video, sync, and sound. Stages following the sound take-off carry only video and sync signals intentionally, with sound signals removed by means of traps.

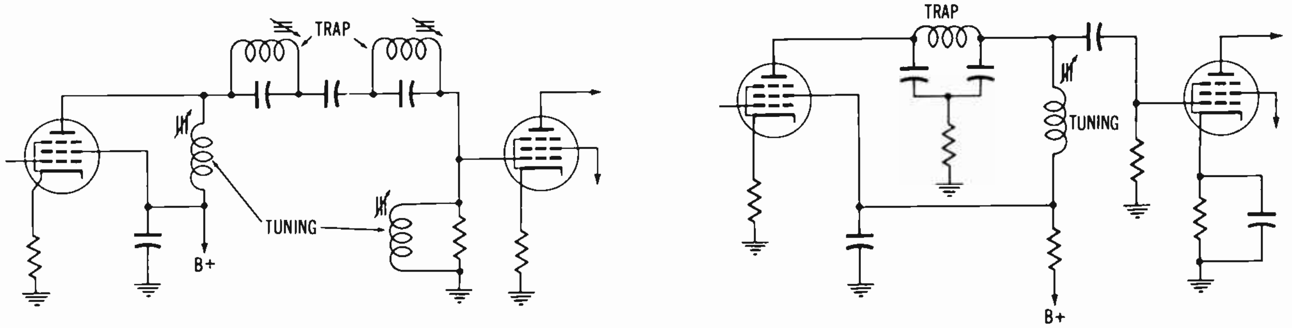


Fig. 2. Parallel Resonant Traps in Interstage Couplings of Video IF Amplifiers.

Parallel resonant types of traps often are found in the connection between the plate of one tube and the control grid of the following tube, in the line containing the coupling capacitor. Two such traps are illustrated by Fig. 2. The traps are tuned to the frequency which is to be reduced or eliminated; they then offer high impedance at this frequency. The traps are in addition to the usual inductors or transformers which are tuned to resonance at the frequency to be amplified.

5. The Plate Load

The plate load circuit for the last IF amplifier, Fig. 1, consists of a resistor between the plate and the B+ line. At the left in Fig. 3 this resistor is replaced by an untuned choke, L1, in the plate circuit, with tuning still on the detector side of the coupling. In the right-hand diagram the tuned inductor is in the plate circuit of the last IF amplifier, with an untuned choke on the detector side of the coupling capacitor. Not only in the coupling preceding the video detector, but in the coupling between any of the amplifier tubes, the tuned inductor may be on either the plate side or the grid side, either ahead of or following the coupling capacitor.

6. The Screen Grid

The screen always is bypassed directly to ground through the capacitor marked C2 in Fig. 3. There is a single voltage dropping resistor, R2, for both the screen and the plate. The bypass across the resistor carries the high-frequency currents for both elements to ground and the cathode return. If there is insufficient bypassing for the screen, high frequency signal potentials from this element reduce signal voltage variations at the plate and drop the gain of the stage.

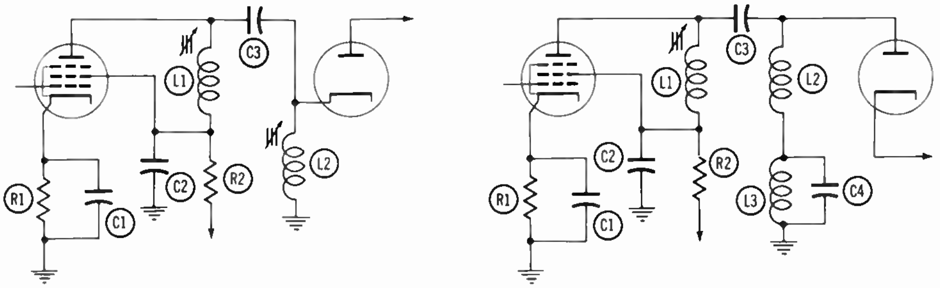


Fig. 3. Tuning Inductor Location in Video IF Amplifiers.

C. Video and Sound Intermediate Frequencies

The sound carrier for any television channel is at a frequency 4.5 mc higher than the video carrier. For example, in channel 4 the video carrier is at 67.25 mc and the sound carrier is at 71.75 mc, in channel 8 the video carrier is at 181.25 mc and the sound carrier at 185.75 mc, and so on.

The frequency to which the RF oscillator of the receiver is tuned for any channel is higher than the carrier frequencies in that channel. When the oscillator frequency and the video carrier frequency beat together in the mixer, the difference is amplified in the video IF system. When the oscillator frequency and the sound carrier beat together the difference frequency becomes the sound intermediate frequency.

We may assume that a receiver tuned for channel 4, as an example, operates with an RF oscillator frequency of 93.85 mc. The results are as follows:

	Video	Sound
Oscillator frequency	93.85	93.85
Carrier frequencies	67.25	71.75
Difference (intermediate frequencies)	26.6	22.1

Although the difference between the video and sound intermediate frequencies is 4.5 mc, the same as between the two carrier frequencies, the video intermediate frequency, is higher than the sound intermediate frequency, while the video carrier frequency is lower than the sound-carrier frequency. The same things are true in every channel; the video intermediate always is higher than the sound intermediate and their difference always is precisely 4.5 mc.

With signal input to the antenna, and markers injected for video and sound carrier frequencies, these frequencies will lie on the response curve at about the positions shown in Fig. 4A. When signal input is to the mixer tube, with markers injected for the video and sound intermediate frequencies, these frequencies will appear on the response curve in the positions shown in Fig. 4B.

Intermediate video frequencies range all the way from 25.75 mc up to 26.75 mc. The corresponding sound intermediate frequencies range from 21.25 mc up to 22.25 mc, with the sound intermediate frequency for any one receiver always just 4.5 mc lower than the video intermediate frequency for the same receiver. In some receivers the video intermediate frequencies are in the neighborhood of 35 to 38 mc, and the sound intermediates for the receivers would range from 31 to 33 mc, with the exact difference between these two always 4.5 mc. In many of the more recent designs the video intermediate frequencies range from 45.75 mc to 48.75 mc and the sound intermediate frequencies ranging from 41.25 mc to 44.25 mc, with the same 4.5 mc relationship between the two.

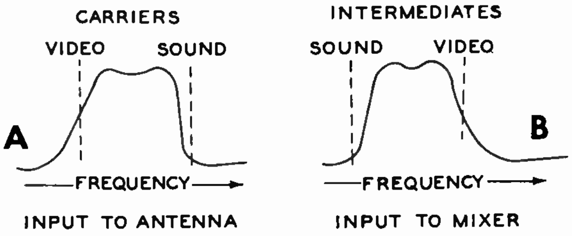


Fig. 4. Where Carrier Frequencies and Intermediate Frequencies Appear on the Frequency Response from the Video Detector.

D. Receiver Attenuation

When using vestigial sideband transmission of television signals all frequencies from 0.75 mc below the video carrier to 0.75 above this carrier are transmitted on both the lower and upper sidebands. The strength of all these frequencies thus is doubled in the transmitted signal. Frequencies still lower than 0.75 mc below the video carrier are cut off. All frequencies still higher than 0.75 mc above the video carrier than are transmitted in only the upper sideband, and have only half the strength of those which are transmitted in both sidebands. The unequal strengths of various frequencies in the transmitted signal must be evened out or equalized in the receiver. The double transmitted frequencies are attenuated by the video IF amplifier to make their strength equal to that of those singly transmitted. This process is known as receiver attenuation.

A curve representing relative strengths or amplitudes at various frequencies of signal brought to the video IF amplifier is shown in Fig. 5. This curve would correspond to the strength of the carrier signal at modulation frequencies measured both ways from the video-carrier frequency as a reference point. After passing through the mixer, the video-carrier frequency becomes the video intermediate frequency, so signal strengths shown by the upper cruve are those measured above and below the video intermediate frequency at the input to the video IF amplifier.

Modulation frequencies from zero up to 0.75 mc appear both above and below the video intermediate frequency. For example, with a video intermediate frequency of 26.25 mc these double-strength or double receiver modulation frequencies will be in the ranges from 25.50 mc (0.75 mc below the intermediate) up to 27.00 mc (0.75 mc above the intermediate). All greater modulation frequencies up to the limit of 4.00 mc appear on one side of the video intermediate frequency only.

In the video IF amplifier, there would be equal amplification or gain of all modulation frequencies if the amplifier response was of the ideal form shown by the upper curve of Fig. 5. At the video IF end of the response; however, the gain is not uniform, it drops steadily from 100 at a frequency 0.75 mc below the intermediate down to zero at a frequency 0.75 mc above the intermediate, and has a value of 50, or 50 per cent of maximum, at the video intermediate frequency.

A modulation frequency of 0.25 mc will be applied to the video IF amplifier on both sides of the intermediate frequency. On one side the gain will be 67 and on the other side the gain will be 33. The sum of the gains are the total gain at this modulation frequency then is 100 or 100 per cent. Another modulation frequency of 0.50 mc will be subjected in the video IF amplifier to gains of 83 and 17, so that this frequency too is subjected to a total gain of 100. Every other modulation frequency between zero and 0.75 mc is similarly subjected to a total gain of 100. All greater modulation frequencies, from 0.75 through to 4.00 mc act on the video IF response in a region where its gain is 100. Thus all modulation frequencies receive the same total gain.

It would be possible to construct a video IF amplifier system having a frequency response with the sharp changes illustrated at the bottom of Fig. 5, but it is not practical or necessary to do so. A video IF response of the general shape shown by Fig. 6 will give entirely acceptable results provided the video intermediate frequency is at or near the point of 50 per cent gain on the high-frequency side of the curve, and the sound intermediate frequency is far down on the low-frequency side.

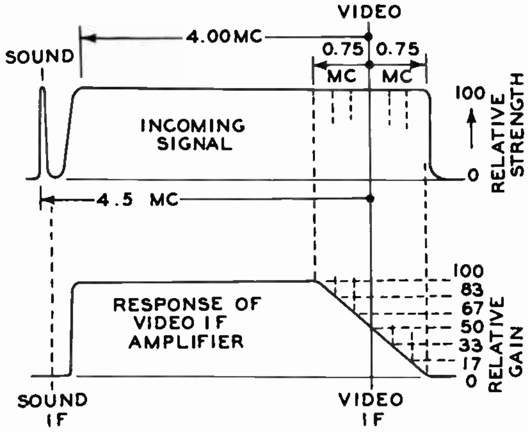


Fig. 5. How the Frequency Response of the Video Amplifier is Shaped to Equalize Total Amplification at All Applied Frequencies.

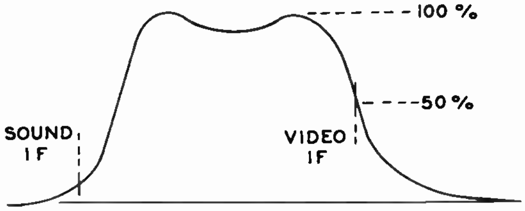


Fig. 6. Typical Frequency Response of a Video IF Amplifier System.

E. Positions of Intermediates on Amplifier Response

The shape of the frequency response curve for a video IF amplifier is determined by adjustment of the tuned inductors or transformers in the interstage couplings. Altering any one adjustment will change the shape of the whole response curve to some extent, and usually will affect some one portion of the curve more than other portions. That is, the entire curve or some parts of it may be raised or lowered or either side or both sides may be moved toward higher or lower frequencies. Adjustment ranges are limited, of course, but still it is possible to make variations of response and always it is possible to produce a response of a shape satisfactory for required amplification.

We shall assume that the video IF couplings have been adjusted or aligned to produce the frequency response shown in Fig. 7A. This response is well suited for video and sound intermediate frequencies used in an earlier example, 26.6 mc for video and 22.1 mc for sound.

Intermediate frequencies for video and sound depend on the frequency at which the RF oscillator operates for any channel. This is because the intermediates are beat frequencies resulting from mixing of oscillator and carrier frequencies, and the carrier frequencies are fixed in any one channel. In the earlier example, it was shown that an RF oscillator frequency of 93.85 mc for channel 4 produces a video intermediate of 26.60 mc and a sound intermediate of 22.10 mc.

The graph of Fig. 7B shows what happens when the RF oscillator frequency is higher than it should be. For purposes of illustration the oscillator frequency is assumed to be 0.50 mc high, which makes it 94.35 mc instead of the original 93.85 mc. Still using the carrier frequencies of channel 4, the intermediates now work out as follows.

	Video	Sound
Oscillator frequency	94.35	94.35
Carrier frequencies	67.25	71.75
Intermediate frequencies	27.10	22.60

Low frequencies of modulation—just above and below the video intermediate frequency, now are receiving too little amplification—they are too far down on the gain curve. The resulting picture will be of generally dull appearance, and there are likely to be trailers or bands on the right-hand edges of any large or wide black objects. Sync pulses are of low frequency, and the lack of gain at low frequencies may make it difficult to maintain horizontal synchronization, and especially difficult to maintain vertical synchronization of the picture.

While the video intermediate has been moved too far down on the gain curve, the sound intermediate has been moved up by the excessively high oscillator frequency. Sound signals will be much too strong, and they are likely to cause horizontal bars or dark bands across the picture. These are called sound bars. If there is a separate sound section in the receiver designed to operate for the intermediate frequency, the actual sound intermediate will have been moved too far from the narrow frequency band in which the sound IF amplifier has gain, and there will be no reproduction of sound from the loud speaker. If the receiver is designed to operate with intercarrier sound the result of the strong sound signal usually will be a loud buzz from the loudspeaker, a buzz which cannot be removed by adjustment of the sound detector or demodulator circuit.

We shall now assume that the RF oscillator frequency has been made 0.50 mc lower than its original value, or brought down to 93.35 mc. The resulting intermediates are arrived at as follows.

	Video	Sound
Oscillator frequency	93.35	93.35
Carrier frequencies	67.25	71.75
Intermediate frequencies	26.10	21.60

These intermediate frequencies will appear on the video IF amplifier gain curve as in Fig. 7C. Now the video intermediate is higher on the curve than originally and the sound intermediate is much farther down. Note that the frequency response of the video IF amplifier is not altered by these variations of oscillator frequency. The response of the amplifier is fixed by adjustments of its interstage couplings, and these are not being changed. Note also that the difference between video and sound intermediate frequencies always remains 4. 5 mc. This is fixed by the difference between video and sound carrier frequencies established at the transmitter, and never changes.

With the oscillator frequency too low the low modulation frequencies on either side of the video intermediate are receiving more than usual amplification. This may do no particular harm, in fact, it may be desirable when signal strength from the antenna is very weak. There may, however, be trouble due to lack of gain at the high video frequencies or high modulation frequencies. In Fig. 7A the band width from the video intermediate frequency to a point 0. 7 down from maximum gain is about 3. 75 mc. In Fig. 7C this band width is reduced at about 3. 25 mc. Frequencies farthest from the video intermediates, which are the highest modulation frequencies, are not so well amplified. This may cause poor definition or fuzzy appearance in the picture.

With the oscillator frequency low the sound intermediate frequency is so far down on the gain curve as to be out of the band which is passed by a sound IF amplifier in a separate sound receiver and there will be no reproduction of sound. With an intercarrier sound system the reproduction may be weak, but usually can be brought up to hearing level with the sound volume control.

Were it impossible to change the oscillator frequency to produce intermediates suited to the frequency gain response of the video IF amplifier, the amplifier might be realigned to make its gain curve suit the actual intermediate frequencies. With a sound system having an IF amplifier and demodulator designed to operate at the original sound intermediate frequency it would be necessary also to realign the sound IF system and demodulator input for the new intermediate frequency. This might be impossible due to limited adjustment range. With intercarrier sound the sound modulation always is carried with the beat frequency of 4. 5 mc which is the difference between video and sound carriers. This intercarrier beat, with its sound modulation, is not affected by changes of video and sound intermediates used in the video IF amplifier.

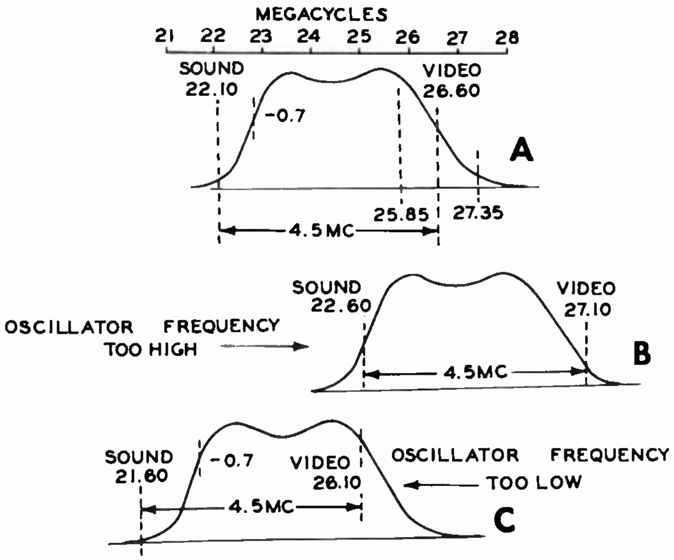


Fig. 7. How Video and Sound Intermediate Frequencies are Shifted on the IF Amplifier Response Curve by Changes of RF Oscillator Frequency.

F. Bandwidth and Gain

In the interstage coupling represented by Fig. 8 and in every other type of coupling it is necessary to consider the effects of capacitances of tube sockets, and of wiring. Output capacitance on the plate side of the first tube is represented as C1, and input capacitance on the grid side of the second tube is represented as C3. Output capacitance of tubes in general use as video IF amplifiers may be as low as 2 mmf, and input capacitances are as low as 5 or 6 mmf. Capacitances of sockets and wiring might be kept down to between 3 and 5 mmf with exceptionally good construction, but usually will be quite a bit more.

These tube and circuit capacitances add to the distributed capacitance of the tuning inductors and transformers and act with the inductance to tune the coupling to resonance. Adjustment for a desired resonant frequency nearly always is by means of movable powdered iron cores or slugs in the coils, although very small capacitors sometimes are connected across the coils.

While tube and circuit capacitances may be useful for tuning, they may also act as low reactance shunts across the tuned circuits. For example, if we consider the output capacitance C1 of Fig. 8, to be a tuning capacitance used with the inductor, the input C3 is in parallel with grid resistor R1 and forms part of the load impedance in the plate circuit. The reactance of coupling capacitors which would be at point C2 is much less than 100 ohms at video intermediate frequencies for capacitances in common use, and so may be neglected. The reactance of the input or output capacitances at video intermediate frequencies usually will be on the order of 500 to 1,000 ohms. The resulting small impedance of the effective plate load makes it impossible to obtain more than a small fraction of the gain which might be expected in view of high transconductance in the tubes. Transconductances of video IF pentodes usually are somewhere between 5,000 and 10,000 micromhos.

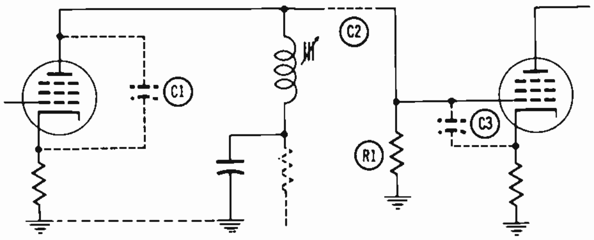


Fig. 8. Tube or Circuit Capacitances Which Affect High-Frequency Response of the Video IF Amplifier.

Improved gain is accomplished by doing everything possible to lessen stray capacitances. This raises the load impedance, also allows using more inductance and a higher Q-factor in the tuned circuits. Wiring in plate and control grid circuits must be of shortest possible length, and kept separated from chassis metal and from other wiring.

To obtain a frequency response sufficiently wide to cover the IF band there may be a fixed resistor connected across the ends of one or more of the tuning coils or windings. These broadening resistances usually are of some value between 3,000 and 20,000 ohms. Although these units are called broadening resistors, their effect is not so much to increase the range of frequencies at which there is gain but rather to flatten the gain curve to prevent resonant peaks which might cause feedback and undesirable regeneration or even oscillation in the video IF amplifier. Grid resistors commonly have values between 3,000 and 10,000 ohms. These resistors are in parallel with the tuned circuits and act in the same manner as do broadening resistors connected directly across the coils.

Uniformity of gain throughout the frequency band often is increased by using cathode bias resistors with no bypass capacitor. An unbypassed cathode resistor allows degeneration, or an effective negative feedback, from plate circuit to grid circuit of the tube. An unbypassed cathode resistor helps also to lessen variations of input capacitance which might occur on strong signals, especially with the first or second IF amplifiers.

The output of the last video IF stage feeds into the video detector. A diode acts as a low impedance load. Consequently, in the coupling from the last IF tube to the detector it is not necessary to use any other means for broadening the response, and usually the cathode-resistor of the last IF amplifier is bypassed to prevent degeneration and allow all possible gain.

There are several basic types of interstage couplings which are used alone or in combination to produce the broad band frequency response required from the video IF amplifier system. Three are shown in Fig. 9. At the left is a single tuned inductor or coil shown earlier in Figs. 1 and 3. Such a coupling provides a response which peaks at a single frequency, with gain decreasing both above and below this tuned frequency. At the center is a two-winding transformer with the windings very loosely coupled. With such coupling the transformer provides a single peaked frequency response of the same general form as the single tuned coil.

At the right is a transformer with closely coupled windings. As the coupling is increased in a transformer the single-peaked response will become broader and will develop two separate peaks. One peak is at a frequency lower than the frequency to which both windings are tuned and the other peak is at a higher frequency. The closer the coupling, the greater becomes the separation between peaks and the less the gain at either peak. At the same time the valley between the peaks becomes deeper and deeper.

None of the couplings illustrated will produce in a single amplifying stage a frequency response broad enough for the video IF system as a whole. In a great many receivers there are three, four, or five couplings of the type shown at the last in Fig. 9. The separate couplings are peaked at two or more different frequencies with the result that their overall gain or frequency response is satisfactory. This is called stagger tuning.

Other receivers have loosely coupled transformers in each stage, with the transformers peaked at different frequencies to produce the required broadness of overall response. Still other designs utilize two or more closely coupled transformers whose combined response is wider than shown at the right in Fig. 9. Some receivers have one stage with a closely coupled transformer, and in other stages have single-peaked couplers to fill in the valley between transformer peaks and sometimes to extend the overall frequency response in both directions as may be required.

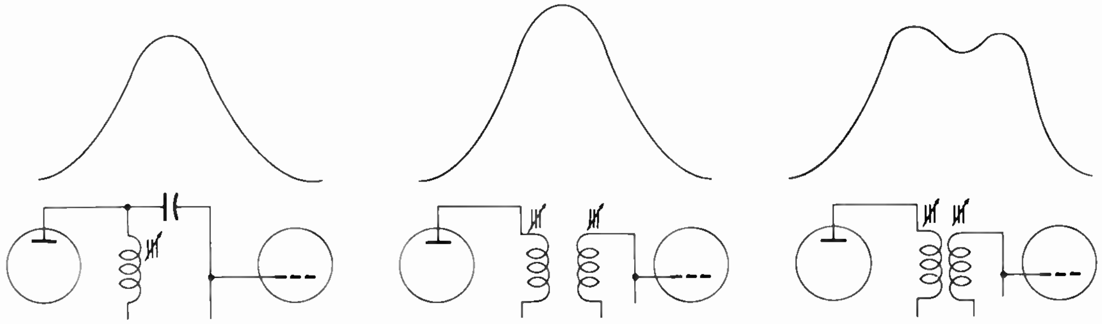


Fig. 9. Basic Types of Interstage Couplings and Their Frequency Responses.

G. Summary Questions

1. What type of tube is used for video IF amplification?
2. Draw a schematic of the IF amplifier stage.
3. Which of the two IF's, sound or video, has the high value? Why?
4. What is meant by the term Receiver Attenuation?
5. Draw a response curve of a video IF amplifier showing the position of the signals and their values.
6. What are the factors governing the bandwidth of the IF stage?
7. What type of coupling is usually employed in the video IF stage?

THE VIDEO DETECTOR AND AUTOMATIC GAIN CONTROL

Objective:

To consider the video detector circuits and the automatic gain control.

References

Lesson Content

A. The Video Detector

This detector, as shown in Fig. 1, is connected between the last video IF amplifier and the first video amplifier in order to recover from the amplitude modulated video intermediate frequency all the picture signal variations and all the sync pulses together with blanking level intervals, of the television signal. In most receivers the video detector is either one section of a twin diode whose other section may be used for automatic gain control, for DC restoration, or any other purpose.

1. Detector Circuits

The IF signal input may be to the plate of the detector with output from the cathode as in Fig. 1A, or the input may be to the cathode with output from the plate as in Fig. 1B. With input to the detector plate, picture signals are negative and sync pulses are positive in the output. With input to detector cathode, picture signals are positive and sync pulses negative in the output.

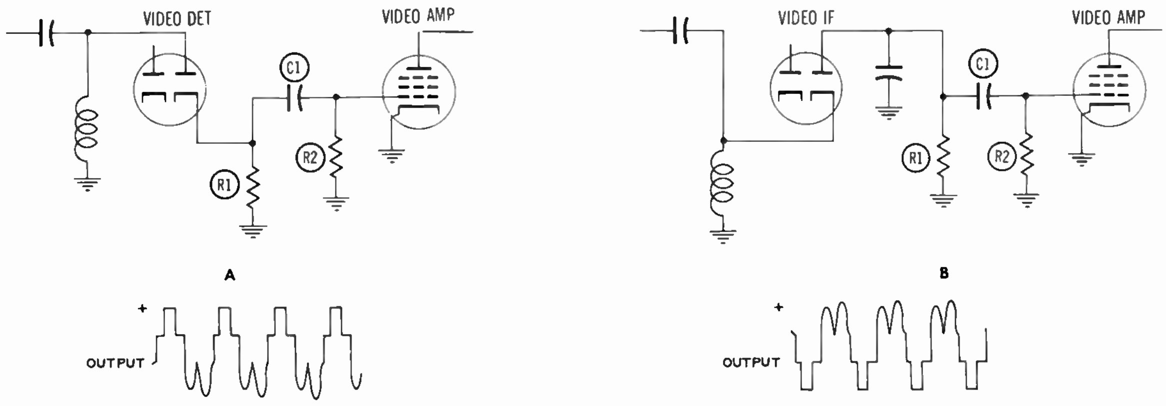


Fig. 1. Video Signal Polarity at the Output of the Video Detector.

The detector must handle the same wide range of frequencies as the video amplifier, consequently it is subject to the same difficulties due to wide band coverage as are encountered in the video amplifier. The detector load resistor, R1 in Fig. 1, is only 2,000 to 5,000 ohms in order to lessen the effects of shunting capacitances at high frequencies. Coupling capacitor C1 is from 0.05 to 0.10 mfd capacitance in order to keep its capacitive reactance reasonably small at the lowest video frequencies.

The small load resistance in the detector output and the rather small internal resistance of a diode have the effect of heavily loading the video IF stage which precedes the detector. This broadens the frequency response while reducing the gain of that stage.

Fig. 2, illustrates some features which may be found in circuits between the video detector and video amplifier. The series and shunt compensating coils are like those used in video amplifier couplings, and serve the same purpose of extending the response to higher frequencies. The small capacitor at C1, usually 5 to 10 mmf, bypasses the high video intermediate frequencies to ground and back to the IF coupler so that these frequencies do not go on into the video amplifier. This capacitor, in connection with the series compensating coil, form a low-pass filter which passes all frequencies up to the video limit of about 4.5 mc, while attenuating the much higher video intermediate frequencies.

2. Detector Output Polarity

When video IF input is to the detector plate, as in Fig. 1A, the positive side of the IF carrier is rectified and in the detector output the sync pulses are positive and the picture signals are negative. Signal polarity will be inverted in passing through each video amplifier between detector and picture tube. Consequently, if the signal is to reach the picture tube with the picture signals positive there must be one inversion and one video amplifier stage, or there might be any odd number. If the signal is to reach the picture tube with picture signals negative, there must be two inversions and two video amplifier stages, or any even number. The signal must reach the picture tube with picture signals positive when input is to the grid of the picture tube, and the picture signals must be negative when input is to the cathode of the picture tube. These polarity relations are shown in Fig. 3A and 3B.

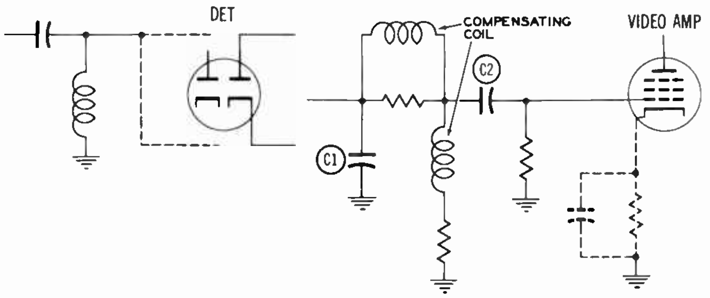


Fig. 2. Features Found in Couplings Between the Video Detector and the First Video Amplifier.

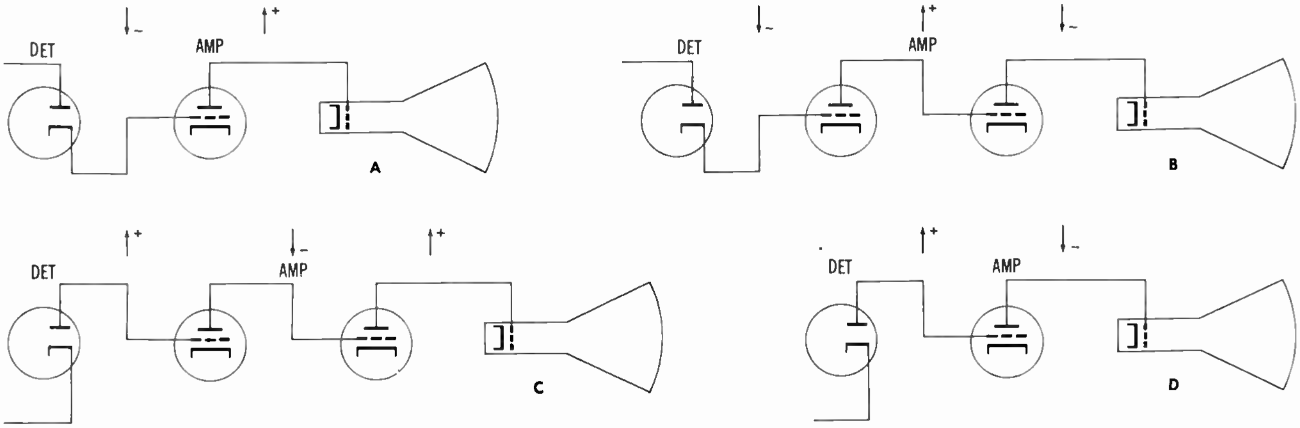


Fig. 3. Picture Signal Polarities with IF Input to Detector Plate or Cathode and With Picture Tube Input to Grid or Cathode.

In Fig. 3C and 3D are shown the stage polarities when video IF input is to the cathode of the detector. Two, or some even number of video amplifiers are needed to make the picture signals positive at the picture tube grid. One or any odd number of stages are needed to make the picture signals negative at the picture tube cathode.

The same general rules for signal polarity apply when considering the sync pulses which go through the sync section of the receiver and are used to trigger the sweep oscillators. The relations are clearly shown by Fig. 3, if we assume the sweep oscillator sync input to be the same as the picture tube input illustrated, and assume the amplifiers to be tubes in the sync section. Most sweep oscillators require a positive triggering pulse, although some use negative pulses. It must be kept in mind that there is polarity inversion in any tube where input is to a grid and output from a plate, but there is no inversion in cathode followers where input is to the grid and output from the cathode or in stages where the input is at the cathode and the output from this plate.

3. Crystal Detectors

A number of television receivers have germanium crystal diodes for their video detectors. Crystal rectifiers or crystal diodes depend for their action on unequal conductivity for currents flowing in opposite directions through the contact between a crystalline body and the tip of a fine wire which touches the crystal surface. The crystalline material in most common use is germanium employed in germanium crystal diodes. The contact point is the end of a fine wire of non-oxidizing metal such as tungsten or platinum. Germanium crystal diodes are used regularly at frequencies up to 100 megacycles, and in some applications up to 500 megacycles. Silicon crystal diodes are available for frequencies ranging from 3,000 to more than 30,000 megacycles.

Crystal diodes are used in television for video detectors, discriminators and ratio detectors, DC restorers, noise limiters and pulse limiters, rectifiers for high-frequency meters, and probe detectors for electronic voltmeters, oscilloscopes, and signal tracers. There are a number of special types, including matched pairs for use as discriminators or in any fullwave rectifier circuits, also single units which have been dynamically tested for use as video detectors.

The diode units are cylindrical, ranging in diameter from about 1/8 to 1/2 inch and, in length, from about 5/8 to 7/8 inch for different makes. Bodies are of ceramic, glass, and other insulating materials. Some types have exposed metal end caps, others are completely insulated. Circuit connections are made, and the crystal diodes may be supported, by means of wire pigtails built into the ends of the diodes, just as such pigtails are used on many fixed resistors and capacitors. The end of the diode marked "K", or "+" corresponds to the cathode of a vacuum tube rectifier.

The internal shunt capacitance of crystal diodes is on the order of 1 mmf. This shunt capacitance is increased somewhat by the wiring connections, but with care in mounting it need be only about 3 mmf. Different types of diodes are designed to withstand continual maximum peak inverse voltages from 50 to 200 volts. That is, they may be used in circuits where peak AC voltages are from 50 to 200, or where effective sine wave voltages are from 35 to 140 volts.

Compared with tube rectifiers the crystal diodes have advantages of requiring no heater power, of easier mounting, and sometimes of simpler wiring. The general purpose crystal diodes will carry more direct current without overheating than will commonly used miniature tube diodes. The forward resistance of these crystal diodes is considerably less than that of otherwise equivalent tube diodes. This is an advantage where the output load resistance must be small, since performance improves with a smaller ratio of rectifier internal resistance to load resistance. A disadvantage of crystal diodes in some applications is their inability to withstand as high inverse voltages as may safely be applied to tube rectifiers. Crystal diodes, except in special types, tend to be somewhat less uniform in operating characteristics than do tube diodes.

General purpose crystal diodes, such as the 1N34 and equivalent types, may be tested with an ohmmeter capable of indicating resistance all the way from hundreds of ohms up to hundreds of thousands of ohms. Back resistance must be many times greater than forward resistance. Indications will depend on the kind of ohmmeter and on the scale used, since apparent diode resistance varies with applied voltage. The most practical meter test is comparison of readings from a doubtful unit with readings from one known to be satisfactory, using the same ohmmeter scale. Substitution of a new diode for a doubtful one is even better. When making a replacement watch the diode polarity markings, and make new connections the same as the original. Do not solder onto pigtails closer than 1/4 inch to the diode, and make the heating time as brief as possible.

A fairly typical crystal detector circuit is shown by Fig. 4. The positive end of the crystal is equivalent to the cathode of a tube diode, and the other end corresponds to the plate of a tube diode. Whether the IF input is applied to the negative or positive end of the crystal determines the polarity of the output signal just as with tube diodes. Values of load resistance, R1, and of coupling and bypass capacitors are like those for tube diode detectors. Series and shunt compensating coils may or may not be used, just as with tube detectors.

Care must be exercised in making service tests on crystal detectors, since strong AC voltages from a signal generator may overload the crystal because of its low resistance to forward current. Neither end of the crystal should be connected to ground while making tests.

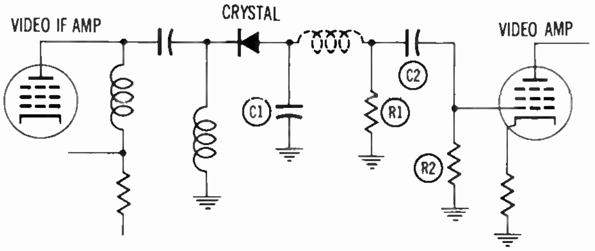


Fig. 4. A Crystal Diode Used as a Video Detector.

B. Gain Control, Automatic

1. General Characteristics.

Automatic gain control circuits in a television receiver increase the amplification in RF and IF amplifiers when weak signals reach the antenna, and reduce the amplification for strong signals. Inputs to video and sound detectors then remain nearly constant with changes of antenna signal strength.

Automatic gain control systems apply a variable negative-bias voltage to the control grids of one or more IF amplifiers, and in most cases to the RF amplifier or amplifiers. This bias voltage becomes more negative when the received signal becomes stronger, and less negative on weaker signals.

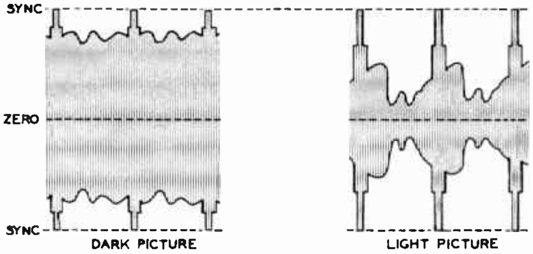


Fig. 5. Sync Pulse Amplitude Is Not Altered by Changes of Picture Tone or Shading.

An effective automatic gain control lessens the need for readjustment of contrast and brightness when changing from one station to another, and maintains uniform picture quality and sound volume when there are variations of antenna signal strength during a program. Many automatic gain controls reduce picture flicker such as caused by low flying airplanes, reduce the effects of outside electrical interference classed as "noise", and prevent picture and sound from being greatly affected by power line voltage fluctuations, swaying antennas, and other faults.

Gain control bias voltage must vary with some characteristic of the received signal which changes only with change of signal strength and not with changes of picture tone or shading. The characteristic which meets this requirement is the amplitude or voltage of the peaks of the sync pulses. This maximum pulse amplitude is maintained constant at the transmitter, and varies at the receiving antenna only when there is some variation in signal attenuation between transmitter and receiver. The sync pulse tips represents 100 per cent signal strength, while the black or blanking level represents 75 per cent, maximum white level represents 15 per cent, and picture modulation varies between 15 and 75 per cent.

As shown by Fig. 5, the sync pulse tips remain at the same amplitude with dark or light pictures and all intermediate shadings. Average amplitude varies, being high for dark pictures and low for light pictures. Were this average amplitude used for regulating the gain control, as it is used in automatic volume controls for sound receivers, the picture brightness would be maintained constant instead of showing changes which actually occur in brightness of televised scenes.

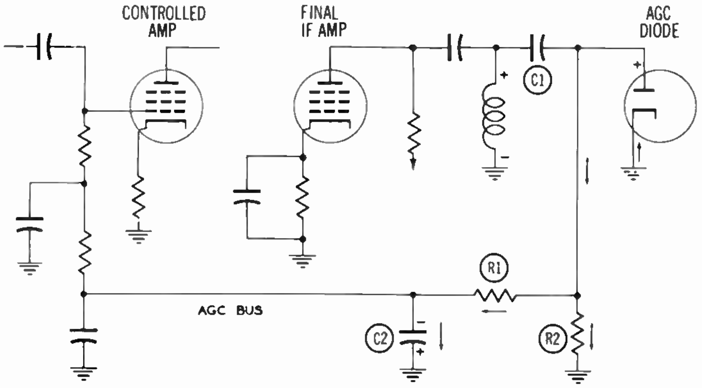


Fig. 6. Circuit of a Simple Type of AGC.

2. Automatic Gain Control Circuits

Circuits for one of the simplest automatic gain control systems are shown by Fig. 6. Connected to the output of the final IF amplifier, through capacitor C1, is the plate of the AGC (automatic gain control) diode. The cathode of this diode is connected to ground. During each half-cycle of intermediate frequency in which the top of the coupling coil becomes positive with reference to the lower end and ground, the plate of the diode is made positive with reference to its cathode and ground. During this half-cycle there is electron flow in the direction of the arrows, and capacitor C2 is given a small charge in the polarity marked.

During intervening half-cycles the diode plate is made negative with reference to the cathode, and this tube becomes non-conductive. Then the charge of capacitor C2 may escape through resistors R1 and R2 and the ground path. But because the rather large capacitance of C2 and high resistance of R1 and R2 produce a long time constant for discharge, only a little of the charge escapes before more is added during the following half-cycle in which the diode again is conductive.

The charge on capacitor C2 increases until the accompanying voltage reaches and remains at practically the voltage of the peak amplitude of the sync pulses. This voltage, negative at the top of capacitor C2, is applied as negative grid bias to the grid returns of whatever tubes are to have automatic gain control. One controlled tube is shown at the left in the diagram. The stronger the signal at the antenna and at the output of the IF amplifier the greater becomes the peak amplitude of the sync pulses, and the greater the charge and voltage on capacitor C2. The greater voltage then makes the controlled grids more negative and reduces amplification.

Weaker incoming signals reduce the amplitude of sync pulse peaks, allow reduction of charge and voltage of capacitor C2 and make the controlled grids less negative for an increase of amplification.

The method of obtaining a gain control voltage which is proportional to peak voltage of sync pulses, as illustrated in Fig. 6, is utilized in some manner or other for the majority of automatic gain control systems. There is great variety in details of AGC systems. Some are quite simple while others are complex. The principal variations will be examined.

3. Delayed Automatic Gain Control

With the simple AGC system of Fig. 6, the bias voltage, with no incoming signal, may allow fairly high amplification. As soon as a signal is applied, or as soon as there is any increase in strength of an applied signal, there is an immediate increase of negative bias voltage and a reduction of gain. Often it is desirable to have no reduction of gain on very weak signals, which need all the amplification possible. Controls which do not reduce amplification until the received signal exceeds some certain strength are called delayed automatic gain controls.

A simple method of obtaining delay is illustrated by Fig. 7. The cathode of the AGC diode is not connected to ground but to a tap on a voltage divider between B+ and ground. This tap usually is at a potential of 1 to 3 volts positive. Then, with no received signal, the cathode of the AGC diode is 1 to 3 volts positive with reference to the plate, which is the same as making the plate 1 to 3 volts negative with reference to the cathode. Until IF signal voltage applied to the AGC diode exceeds the value of positive voltage on the cathode of this diode there can be no conduction in the tube. With no conduction there will be no negative biasing voltage built up across capacitor C2, and there will be no reduction of amplification in the tubes connected to this AGC system.

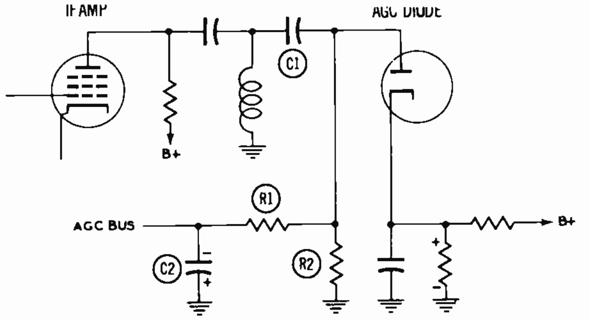


Fig. 7. Diagram of a Delayed AGC Circuit Where the Delay Results From a Positive Voltage Being Impressed on the Cathode of the AGC Tube.

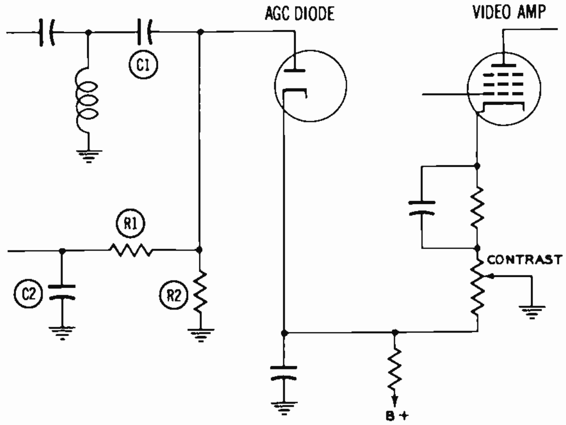


Fig. 8. A Delayed AGC Circuit Where the Delay is Controlled by the Contrast Control in the Cathode Circuit of the Video Amplifier.

In some receivers the positive delay voltage is adjustable. The cathode of the AGC diode is connected to the slider of a potentiometer in a voltage divider instead of to a fixed point on the divider as in Fig. 7. Making the cathode less positive allows automatic reduction of gain on weaker signals, as might be required in a locality of high signal strength. Making the cathode more positive delays the AGC action until stronger signals are received, as might be desirable in an area of low signal strength.

With the circuit connections of Fig. 8, the positive delay voltage is varied by the contrast control. This method of control is used in many receivers. The voltage divider between B+ and ground includes resistor R3 and the portion of the contrast-control potentiometer between its lower end and the grounded slider. Adjustment of the contrast control varies the grid bias and gain of the video-amplifier tube in whose cathode circuit this control is located. At the same time, the adjustment varies the amount of positive delay voltage on the cathode of the AGC diode.

When the contrast control is adjusted for maximum gain in the video amplifier, or for minimum bias in this tube, there is the greatest positive delay voltage. Thus, when the contrast control is set for maximum gain, the AGC system is prevented from reducing the gain on weak received signals. When the contrast control is set for less gain or less contrast the AGC system will act on weaker signals.

Fig. 9 Shows another method of adjusting a positive delay voltage by means of a contrast control in the cathode circuit of a video amplifier. The variable positive delay voltage appears at the junction between resistor R3 and the lower end of the contrast control potentiometer. Instead of applying this delay voltage to the cathode of the AGC diode it is fed through about one megohm resistance at R4 to the AGC bus, where the positive voltage opposes the negative voltage produced across capacitor C2.

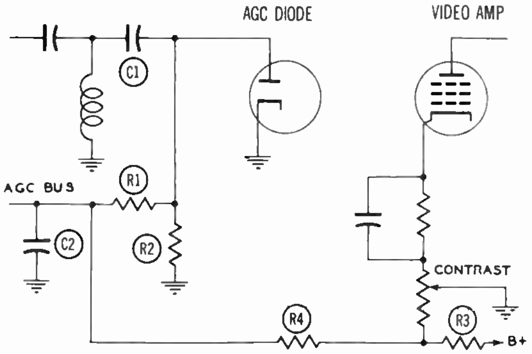


Fig. 9. A Delayed AGC Circuit in which the Positive Delay Voltage is Applied Directly to the AGC Bus.

When the contrast control is adjusted for more contrast or more gain in the video amplifier there is increase of the positive delay voltage at the junction of R3 and the contrast control. This increased positive voltage reduces the effect of negative biasing voltage from capacitor C2, and tubes which are automatically controlled then operate with full gain until there is a stronger received signal.

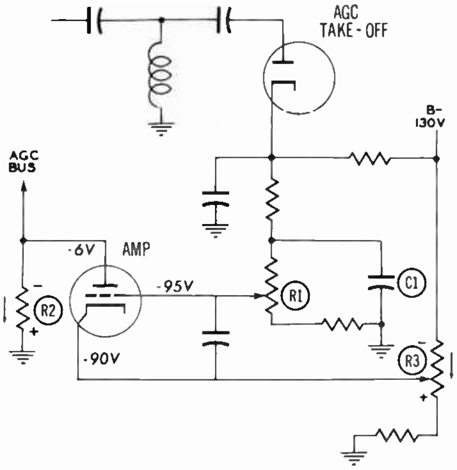


Fig. 10. An Amplifier for Increasing the Automatic Biasing Voltage and Inverting Its Polarity.

4. Amplifiers in AGC Systems

In many receivers there are AGC systems which incorporate an amplifier tube in addition to the tube which furnishes a voltage proportionate to peak amplitude of the sync pulses. Some of the principles employed in circuits using an amplifier are illustrated by Fig. 10. As in AGC circuits examined earlier, the video signal is rectified by a diode tube used for the AGC take-off.

The cathode of this take-off tube is connected to ground through a series of resistors in which is the potentiometer R1, whose slider is connected to the grid of the amplifier tube. Increase of signal strength increases the electron flow in the diode. This flow will be upward in the resistance at R1, tending to make the top of R1 more positive with reference to the ground end, and making the amplifier grid less negative with reference to the amplifier cathode. Thus an increase of signal strength causes an increase of amplifier plate current. Time constants in the diode cathode circuit are such that capacitor R1 remains charged to a voltage proportional to the peak amplitude of the sync pulses.

The entire amplifier system of Fig. 10 is connected between B- and ground. Voltage divider action in the various resistances, combined with potential drops which accompany the electron flows, may be assumed to place the elements of the amplifier tube at the voltages marked, which are with reference to ground. The grid (-95v) is more negative than the cathode (-90v) so is negatively biased. The plate (-6v) is much less negative than the cathode and, in effect, is 84 volts positive with reference to the cathode. All the negative potentials shown on the diagram are purely for illustration of principles. Actual receiver voltages might differ widely from these and still have the same general relations at the amplifier.

When a stronger incoming signal increases plate current in the amplifier there is increased flow in resistor R2 and the top of R2 becomes more negative with reference to ground. The potential at the top of R2 and at the amplifier plate, is that for the AGC bus which connects to the grid returns of all tubes whose gain is automatically controlled. Thus the automatic bias voltage is made more negative by increased signal strength and amplification of the controlled tubes is reduced.

Shown in Fig. 10 are two adjustments which affect the strength of signal necessary to cause any given automatic bias voltage at the amplifier plate. The adjustment of R1 alters the steady negative grid voltage which exists in the absence of current in the AGC take-off diode. This is a grid bias voltage for the amplifier. The adjustment of R3 alters the steady negative potential of the cathode with reference to ground. Change of cathode potential alters both the grid-cathode and the plate-cathode potential differences in the amplifier tube, changing the amplifier plate current, and the automatic bias voltage for any given signal amplitude or signal strength. Ordinarily only one or the other of these adjustments will be found in the same receiver.

5. Limited Control for RF Stages

The prime purpose of automatic gain control is to provide constant signal strength at the video detector and thus reduce the need for readjustment of brightness and contrast controls. This purpose is satisfied by making the automatic negative bias increase uniformly with signal strength. It is found, however, that an improved signal-to-noise ratio may be secured by allowing the RF amplifier or amplifiers to operate at full gain on all signals which won't cause overloading of the following IF stages. With full automatic control on RF amplifiers the highly negative bias may cause cross modulation, which allows strong signals to ride through with weak ones and produce an effect of poor selectivity.

In some receivers, only some definite fraction of the automatic negative bias is connected to grid returns of RF amplifiers while the full AGC voltage or a greater fraction of it is connected to grid returns of IF amplifiers. Voltage divider circuits such as those in Fig. 11, are used for this division. In other receivers there is a switch for cutting off the action when receiving weak signals. If AGC action is cut off when receiving strong signals the resulting overloading of IF stages may cause excessive control on these stages, and a picture which appears weak or allover gray.

By using two separate diode take-off tubes, one for IF biasing and the other for RF biasing, it is possible to use different delay voltages on the two tubes. Then the greater delay is applied to the RF amplifier or amplifiers and the lesser delay to the IF amplifiers. The same general method may be used with two separate amplifiers, whose steady grid or cathode voltages may be adjusted for different delays, or for different signal strengths required for production of equally negative bias voltages. The same general idea is utilized by having a single take-off diode feeding a single amplifier, with the AGC voltage output of this amplifier applied to two separate diodes. One of these diodes may be cathode-biased for a delay suited to IF amplifiers and the other diode may be cathode-biased for a delay to RF amplifiers.

6. Time Constants and Noise Limiters

In order that the automatic negative bias voltage may remain proportional to input signal strength the time constant of the gain control system must be longer than the period of one horizontal line. This time constant is the discharge time constant of the capacitor which has been marked C2 and the resistors marked R1 and R2 in Figs. 6, 7, 8, and 9. This time constant must be long enough to prevent any great loss of charge and bias voltage between successive horizontal sync pulses.

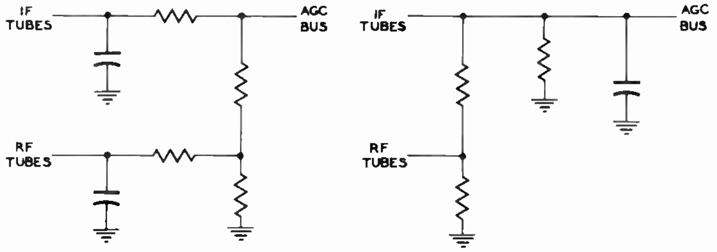


Fig. 11. Methods of Lessening the AGC Action on RF Amplifiers.

Should any external electrical interference be of a type causing brief voltage peaks to come through the RF and IF amplifiers these peaks may act on the AGC system in the same manner as the sync pulses. These interference voltages usually called noise, may establish a negative biasing voltage of their own if the interference is stronger than the sync pulses. This false AGC will reduce amplification for desired signals, possibly to the extent that program reception is impossible when or where the noise interference level is high.

Many expedients are employed for making the AGC system more or less independent of noise interference. Referring to Figs. 6 and 7, the time constant of capacitor C1 and resistor R2 may be made relatively short. Then, even though C1 is charged by noise to a voltage higher than the sync pulse peaks, this capacitor discharges so quickly as to add but little to the biasing voltage maintained on capacitor C2.

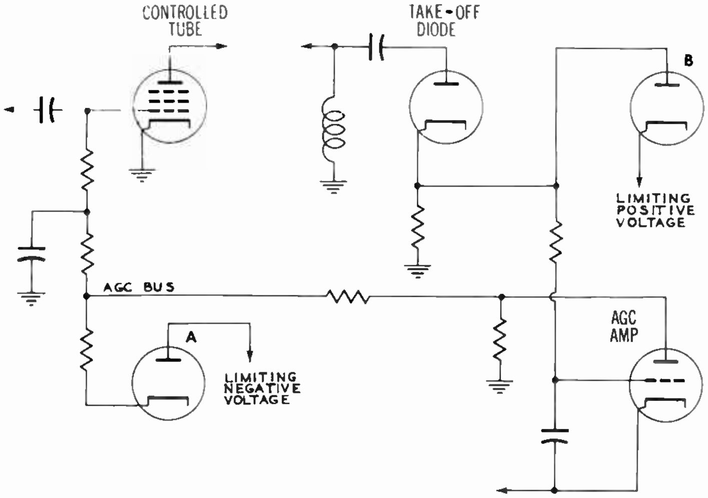


Fig. 12. Two Ways in Which Diodes May Be Used as Noise Limiters.

Fig. 12 illustrates the principles of two methods of using diodes as noise limiters in connection with an AGC amplifier. At A the cathode of the diode limiter is connected to the negative AGC bus on the plate side of the amplifier. The plate of the diode limiter is connected to a negative voltage equal approximately to the maximum automatic bias which is to be allowed. That is, this limiting negative voltage would correspond to maximum peak amplitude of sync pulses.

Noise peaks whose voltage exceeds that of the signal sync pulses will make the amplifier plate and diode-limiter cathode more negative. Then the cathode of the diode will be more negative than its plate, which is equivalent to making the plate positive with reference to the cathode. This will cause the diode to conduct and load the circuit sufficiently to prevent excessively negative voltage on the AGC bus.

Diode B of Fig. 12 is connected to the input or grid side of the AGC amplifier, with the plate of this limited diode to the line between the take-off diode and the amplifier. In this line the potential becomes more positive with reference to ground when there is increase of signal strength. This positive potential acts on the plate of the limiter diode. The cathode of this limiter diode is connected to a positive voltage which prevents conduction in the diode so long as voltage on the diode plate does not exceed that corresponding to peak amplitude of the sync pulses.

Noise peaks which would cause more current in the take-off diode and a more positive voltage at the amplifier grid also make the plate of the limiter diode more positive. Then this diode conducts and loads the amplifier grid circuit to keep the grid from becoming sufficiently positive to make a material increase of negative bias voltage in the plate circuit of the amplifier. Only one or the other of the diode limiters ordinarily would be used in an AGC system.

7. Keyed or Gated Automatic Gain Control

In keyed or gated methods of automatic gain control, the tube is conductive during only the periods of horizontal sync pulses. Unless noise peaks occur simultaneously with the sync pulses, the noise voltages can neither add to nor subtract from the automatic biasing voltage which is developed by direct or indirect action of the horizontal sync pulses. In between successive horizontal sync pulses the control tube is made non-conductive either by holding its plate at a voltage less positive than necessary for conduction or else by holding its grid more negative than required for plate-current cutoff.

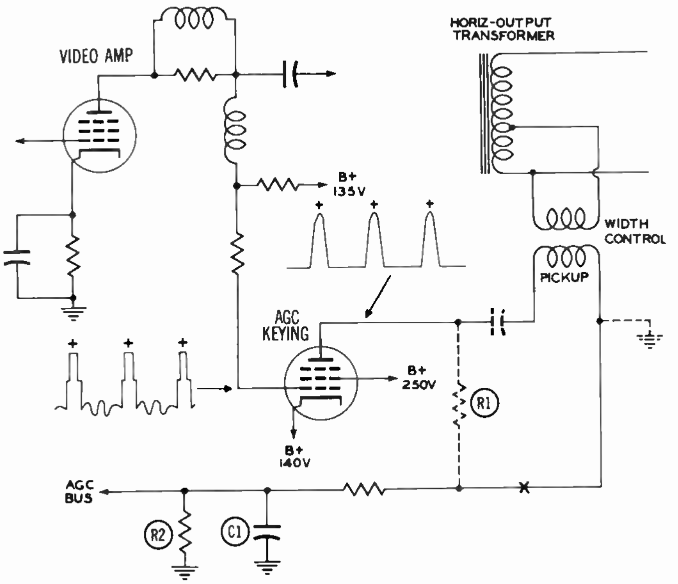


Fig. 13. Diagram of a Keyed AGC System is Which Keying Pulses are Taken From the Horizontal Output Transformer.

Principles employed in one method of keyed automatic gain control are illustrated by Fig. 13. To the grid of the AGC tube is applied the entire composite video signal as taken from the output of a video amplifier. Average voltage on the AGC grid is highly positive, shown here for purposes of explanation as 135 volts. The cathode is connected to a voltage slightly more positive, which makes the grid negative with reference to the cathode. Screen voltage is relatively high.

In the system illustrated the pick-up coil in the plate circuit is coupled to the width control inductor on the secondary of the sweep transformer in a flyback type of high-voltage power supply. In this secondary winding there is sudden reversal of current during each horizontal retrace period. The change of magnetic field due to current reversal induces a strong voltage pulse in the coil and a brief highly-positive voltage on the plate of the AGC tube. This happens while the grid of the AGC tube is being driven more positive by a sync pulse.

There are various ways of introducing positive voltage peaks from the sweep circuit into the plate circuit of the AGC tube. With one method the conductor from the tube plate extends unbroken through the pickup coil and to the AGC bus. With another method, indicated by broken lines in Fig. 13, the pickup coil is connected to the plate circuit through a capacitor and ground, with a conductive connection from the plate through resistor R1 to the AGC bus. In any case, the average potential of the plate in the AGC tube is practically ground potential except when the positive voltage peaks occur, and is so highly negative with reference to the cathode as to prevent conduction except during those voltage peaks.

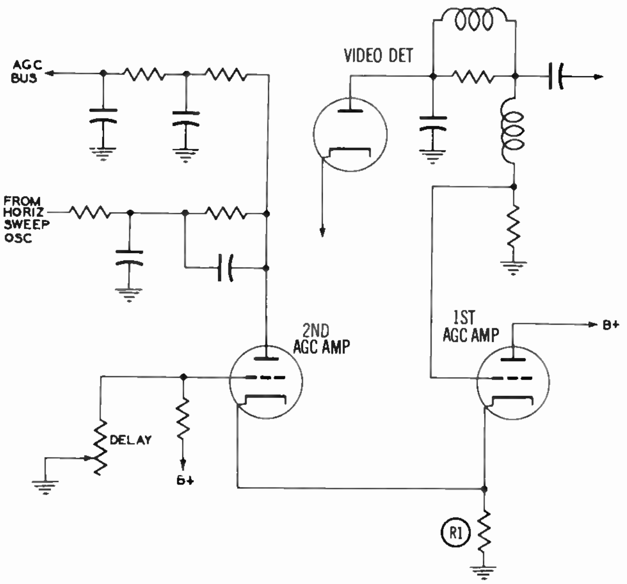


Fig. 14. Diagram of a Keyed System in Which Voltage Peaks for Making an Amplifier Conductive are Taken From the Horizontal-Oscillator Circuit.

While the plate of the AGC tube is positive, the positive sync pulses on the grid cause conduction. The plate current charges capacitor C1 to build up a negative biasing voltage at the AGC bus in the usual way. Since the tube is conductive only while sync pulses act on the grid, any voltage pulses due to noise interference occurring between sync pulses cannot affect the negative AGC voltage. Strength of negative biasing voltage is proportional to plate current of the AGC tube. Plate current is proportional to strength of sync pulses on the grid, and sync pulse amplitude is proportional to strength of the received signal. Consequently, the AGC bias is proportional to signal strength.

In the gated AGC system of Fig. 14, the video signal with negative sync pulses is taken from the output of the video detector and applied to the grid of the first AGC amplifier. Stronger incoming signals make the grid more negative and reduce the plate current. This plate current of the first AGC amplifier flows in cathode resistor R1, which is also in the cathode circuit of the second AGC amplifier. When stronger signals reduce plate current in resistor R1 there is less voltage drop across this resistor, which makes the grid bias of the second amplifier less negative and increases plate current in the second amplifier making its plate more negative, due to inversion of grid and plate voltages which occurs in any amplifier. Thus the automatic biasing voltage from the plate of the second amplifier becomes more negative when there is increase of signal strength.

The gated effect in the system of Fig. 14, results from the fact that plate current can flow in the second AGC amplifier only when its plate is made positive with reference to its cathode by a positive voltage pulse taken from the circuit of the horizontal sweep oscillator. This voltage is positive at the plate of the second amplifier only while a horizontal sync pulse is reaching the grid of the first amplifier. Noise voltages occurring at other times have no effect on the automatic biasing voltage.

The elementary principle of another keyed AGC system is shown by Fig. 15. The video signal with sync pulses negative is taken from the output of a video amplifier and applied to the cathode of AGC tube A, also to the plate of AGC tube B. A stronger signal tends to increase conduction in tube A, because the cathode is made more negative, and at the same time tends to decrease or stop conduction in tube B, because its plate is made more negative.

To the grids of both AGC tubes are applied positive sync pulses taken from a point in the sync section where picture signals have been removed and only the uniform sync pulses remain. The AGC tubes can conduct only while these positive pulses from the sync section are acting on the AGC grids. This happens only while negative sync pulses from the video amplifier are acting on the cathode of tube A and on the plate of tube B. Noise voltages occurring between the sync pulses find the tubes nonconductive, and have no effect on AGC voltage.

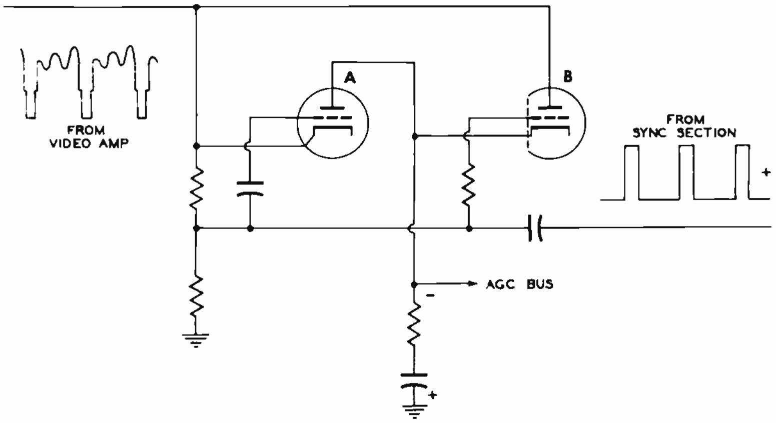


Fig. 15. Circuit for a Keyed AGC System Where Positive Keying Pulses for Control Grids Are Taken From the Sync Section of the Receiver.

In the system of Fig. 15, the automatic negative bias is maintained proportional to strength of received signals by the following actions. Conduction in AGC tube A, charges capacitor C1 to make its upper end, connected to the AGC bus, of negative polarity with reference to ground. Since conduction in tube A increases with a stronger signal, the stronger signal acts to increase the charge on capacitor C1; which makes the automatic bias more negative and lessens amplification in the controlled amplifiers.

The plate of tube B, is being maintained negative with reference to the tube cathode by the negative peaks of the video signal which are applied to this plate. At the same time, since the cathode of tube B is connected to the top of capacitor C1, increase of negative biasing voltage makes this cathode more and more negative. Finally, the increase of biasing voltage makes the cathode negative with reference to the plate, and the tube becomes conductive. Then current which would cause additional charging of C1 flows instead through tube B. Biasing voltage increases no further, but is held at a value proportional to strength of the received signal.

Should strength of the received signal decrease, the plate of tube B becomes less negative, and through this tube there is discharge of capacitor C1 to reduce the biasing voltage. If there is an increase in signal strength the plate of tube B is made more negative, stopping discharge of capacitor C1 until its biasing voltage builds up to a value corresponding to the stronger signal.

C. Summary Questions

1. What is the purpose of the video detector?
2. What is the effect of having a small diode load resistor?
3. How can you identify the picture polarity or phase?
4. Explain briefly the operation of a crystal detector.
5. Explain briefly the operation of the AGC.
6. Explain briefly the operation of the DAGC.
7. Explain briefly the operation of the AGC Amplifier.
8. Explain briefly the operation of the Keyed AGC or Gated AGC.

VIDEO AMPLIFIERS

Objective

To study the operation and construction of the video amplifier.

References

Lesson Content

A. General

Receiver video amplifiers consist of one or more tubes and interstage couplings between the video detector and the grid-cathode input circuit of the picture tube. The video amplifier receives composite television signals from the video detector output and delivers these signals, amplified, to the picture tube. Take-off for pulses which go to the sync section of the receiver often is at some point along the video amplifier.

The composite signals in the video amplifier may be observed by connecting an oscilloscope to any control grid or plate between the detector output and the picture tube input. The vertical input of the scope might be connected first to the detector plate or cathode, whichever serves as output. The following connections might be to the control grid of the first video amplifier, then to the plate of this tube, then to the control grid of the second video amplifier, and so on until the connection finally is made to either the control grid or the cathode of the picture tube according to which of these elements acts as the input for this tube.

With the internal sweep of the scope synchronized for 60 cycles, 30 cycles, or other submultiple of 60 cycles, the vertical sync pulses and vertical blanking intervals will appear about as shown by Fig. 1. To observe a pulse and blanking interval on such a large scale as in the figure it is necessary to increase the horizontal gain of the scope while operating its horizontal centering control to bring a single blanking interval onto the screen.

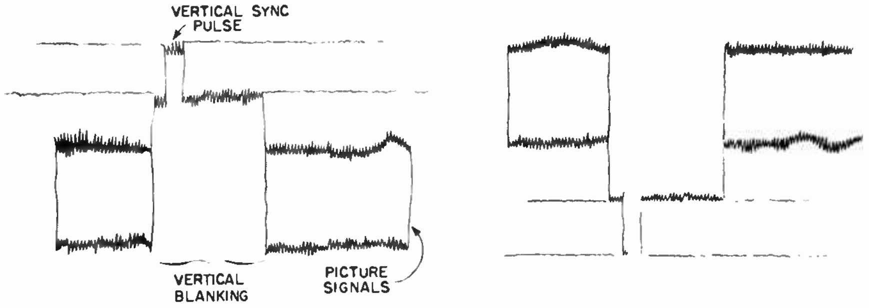


Fig. 1. Vertical Sync Pulses and Blanking Intervals of the Composite Signal in the Video Amplifier.

The trace may be upright as at the left or inverted as at the right. If it is upright at the control grid of an amplifier the trace will be inverted at the plate of the same tube, and if the trace is inverted at the control grid it will be upright at the plate.

If the internal sweep of the oscilloscope is synchronized for 7,875 cycles per second, which is just half the line frequency of 15,750 cycles, it will be possible to observe the horizontal sync pulses and blanking intervals in about the form illustrated by Fig. 2. Again the signal may appear upright as at the left or inverted as at the right, depending on the point in the amplifier system to which the oscilloscope is connected. Because of the higher frequency it is more difficult to obtain clear traces of horizontal pulses than of vertical pulses. By connecting the oscilloscope successively to the inputs and outputs of the video amplifier tubes between the detector and picture tube, it is possible to follow the composite signal all the way through this portion of the receiver. The effect of various controls is easily observed by watching for changes in the signal trace.

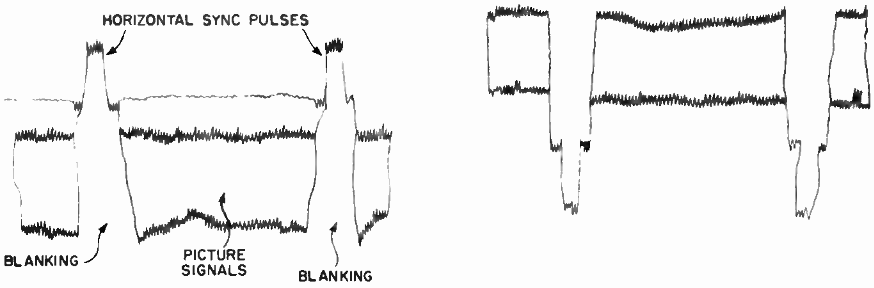


Fig. 2. Horizontal Sync Pulses and Blanking Intervals of the Composite Signal in the Video Amplifier.

B. Frequency Response

Video amplifiers are resistance-capacitance coupled, with features which compensate in greater or less degree for the natural tendency of such amplifiers to drop off in gain at both very low and very high frequencies. If the gain of an amplifier decreases materially at low frequencies, any changes of picture tone or shading which occur only at relatively long intervals will not be well reproduced, instead of distinct changes there will be a tendency to merge all the shadings into a single tone or single degree of illumination. It is entirely possible for a certain shade to last throughout an entire frame of the picture, or for even more than a whole frame. This makes it necessary that the video amplifier have fairly good response at frequencies as low as 30 cycles per second.

The highest frequency the video amplifier must pass will be at least as high as the bandwidth of the IF stages. In the highest quality receivers, this will require a full 4 megacycles for "split-sound" receivers and 6 mc for intercarrier sets. Some competitively priced intercarrier sets have a total IF bandwidth of as low as 3. 9 mc. In this case, the video stages will have to pass a higher frequency than the total bandwidth of the IF stages since the sound IF frequency is always 4. 5 mc in intercarrier sets and the sound take-off point in these sets is usually after the video amplifier.

There is, of course, some sacrifice of detail and picture sharpness when the bandwidth of the IF stages is compromised. These deficiencies will be much more apparent on larger picture tubes.

The video amplifier must have good high-frequency response in order to have sharply defined pictures. The low-frequency response must be good in order to reproduce slow changes in light and shade, to avoid trailers at the right-hand edges of large black objects or large white ones, and to prevent distortion of sync pulses. It is necessary also to avoid excessive differences between phase shifts at the two limits of frequency. Phase shift means a delay in the passage of signals through the amplifier. It is related to changes of voltage gain, also to time constants in the circuits. If some frequencies are delayed more than others the picture will become distorted. On top of all the other requirements, it is desirable to have the highest practical gain.

C. Video Amplifier Tubes

The picture signal voltage amplitude as applied at the grid-cathode input of the picture tube must reach peak values which will produce white tones. That is, the picture tube input signal for white tones must overcome enough of the negative bias to cause maximum required intensity of the electron beam. This peak signal voltage depends on the type of picture tube and on the anode voltages applied to that tube, but in general the peak will be something between 40 and 80 volts.

The voltage output of the detector will depend on the maximum peak-to-peak video IF input to the detector, which varies greatly in different receivers and with the strength of signal from the antenna. Maximum signal output voltage from the video detector usually will be at least 2 volts, but seldom more than 4 volts. To bring this 2 to 4 volts detector output up to the 40 to 80 volts input for the picture tube calls for an overall gain of 10 to 40 times. To provide this gain there may be one, two, or sometimes three video amplifier stages.

When there is only a single video amplifier it most often is one of the high-frequency broad-band pentodes designed especially for television service. When there is more than one stage the output amplifier most often is a power pentode or a beam power tube, and the preceding video amplifiers are voltage amplifying pentodes of types suited to high-frequency operation. In some receivers the video-output amplifier is a triode.

The two features which are essential in video-amplifier tubes are high transconductance or high mutual conductance, and small internal capacitances. The effectiveness of a video amplifier is very nearly proportional to the ratio of transconductance to its input and output capacitances, or, at least, this is the case at the high-frequency end of the band.

D. Amplifier Elements

Typical circuit connections for a two stage video amplifier circuit are shown in Fig. 3. The inductors L2, L4, and L6 in series with the plate load resistors R1, R4, and R8; and inductors L1, L3, and L5 in series with coupling capacitors C1, C3, and C5; are used only in wideband high-frequency amplifiers such as video amplifiers. The functions of these inductors will be discussed a little later. All other elements in the circuit diagram might be found in any resistance-capacitance coupled amplifier designed to have resonable gain at low audio frequencies.

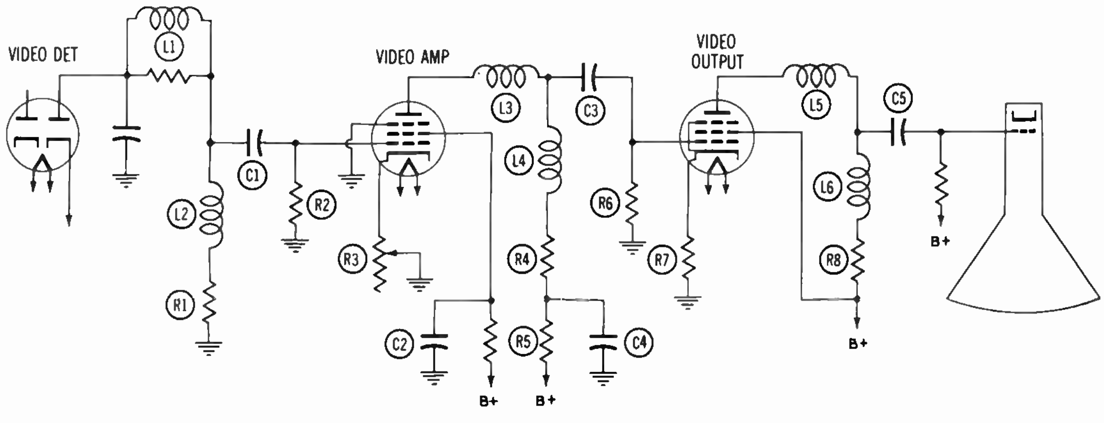


Fig. 3. Two Stage Video Amplifier Circuit.

Some of the features to be noted are as follows: there is a decoupling capacitor C2 connected from the screen grid to ground or B-. This capacitor bypasses variations of signal voltage which appear on the screen, and prevents interstage coupling which might otherwise occur because of the impedance of the voltage-dropping resistor in the screen line. There is a decoupling capacitor C4 to ground from a point below load resistor R4 in the plate circuit. This capacitor keeps signal voltage variations in the plate circuit from causing interstage coupling or feed-back due to impedance of the plate voltage dropping resistor R5. Capacitor C4 and resistor R5 may have such values as will help to maintain good gain at the very low frequencies to be amplified, as will be explained later.

The suppressor grid of the first amplifier is connected directly to ground rather than to the cathode of this tube. The suppressor of the output amplifier is internally connected to the cathode of that tube, as is usual practice in power pentodes and some other types.

Cathode bias resistors R3 and R7 are shown as having no bypass capacitors in Fig. 3. With no bypassing there is degeneration, which lessens the gain of the stage but makes for a more uniform gain throughout a wider range of frequencies. If a bypass capacitor is used on the cathode there will be a rather pronounced drop in gain at and near the frequency for which the capacitive reactance of the capacitors becomes equal to the resistance of R3 and R7. To keep this frequency low enough to be out of the amplified range requires very large capacitance in the bypass. A small bypass capacitance on the cathode will allow some degeneration at low frequencies, where the capacitive reactance becomes large, but at high frequencies this reactance becomes so small as to allow practically full gain.

E. Low Frequency Compensation

Fig. 4 shows the parts of the interstage coupling which chiefly affect how low the frequency may be while still obtaining necessary gain. For any given transconductance in the tube, gain is directly proportional to impedance of the load in the plate circuit. With high resistance at R3, and capacitance at C2 great enough to offer only small reactance, the plate load is approximately the resistance of R1 and R2 in parallel. It will be shown that, to have uniform gain over a wide band of frequencies, the resistance at R1 has to be small, only a few thousand ohms at most. Then the parallel resistance of R1 and R3 depends almost wholly on the resistance of R1, the plate load resistor.

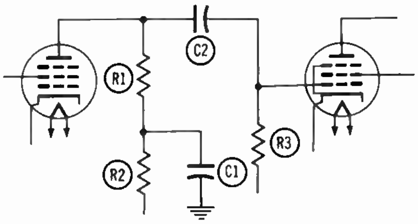


Fig. 4. Components of the Video Amplifier Coupling Which Affect Low-Frequency Response.

The signal voltage developed across the load resistor R1 is applied through the reactance of coupling capacitor C2 to the grid resistor R3, and the signal voltage across the grid resistor is applied to the control grid of the second tube. The signal voltage divides between C2 and R3 proportionately to their impedances, or practically in proportion to the capacitive reactance of C2 and the resistance of R3. The reactance of the coupling capacitor is inversely proportional to frequency. For example, the reactance of an 0.05 mfd capacitor at 60 cycles is about 53,000 ohms, at 30 cycles it is about 106,000 ohms, at 20 cycles it is about 160,000 ohms and so on.

If the resistance of R3 were 500,000 ohms the percentages of signal voltage appearing across this resistor when using the 0.05 mfd coupling capacitor would be approximately 90.4 per cent at 60 cycles, 82.5 per cent at 30 cycles, and 75.9 per cent at 20 cycles. If the resistance of R3 were greater, the percentages of signal voltage across it and at the grid of the second tube would be greater.

In view of all this, it is desirable to use the highest resistance for R3 that is permissible for the type of tube and the kind of grid biasing employed. The actual resistance usually is something between 0.5 and 1.0 megohm. At the same time the capacitance of the coupling capacitor should be as great as permissible, and its reactance low. Maximum capacitance usually is limited by the physical size of the capacitor, for the greater its size the larger is the capacitance to ground and the greater the bypassing effect at high frequencies. Capacitance of 0.1 mfd is the usual high limit, although greater capacitances are used in some receivers.

At frequencies for which the reactance of bypass capacitor C1 is small compared to the resistance of dropping resistor R2, most of the AC signal voltage in the plate circuit returns to the cathode of the first amplifier by way of the bypass capacitor. The plate load impedance in the path of the signal includes the resistance of R1 and the reactance of C1. The reactance of capacitor C1 rises as signal frequency drops, and there is some increase of load impedance to retard the loss of gain at the lower frequencies. For this effect to be of much importance the capacitance of C1 would have to be smaller than ordinarily needed for decoupling, and the voltage dropping resistance would have to be greater than usually found in practice.

F. High Frequency Compensation

Fig. 5 shows those portions of the interstage coupling which have greatest effect on how high the frequency may be at which the gain remains satisfactory. First to be noted are the capacitances C1 and C2, which do not appear in usual circuit diagrams. C1 represents the output capacitance of the first amplifier tube, and C2 represents the input capacitance of the following tube. Although these internal capacitances are of only a few micromicrofarads, their reactances drop to such low values at the higher frequencies as to have important effects on gain. It may be noted also that the coupling capacitor is not shown. This is because the reactance of this rather large capacitance becomes so very small at the high frequencies as to have no effect on circuit behavior or on gain.

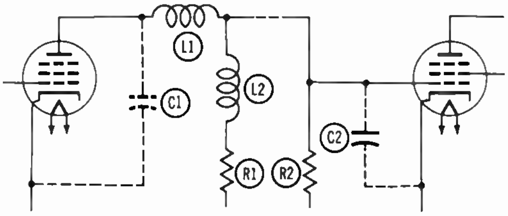


Fig. 5. Components Which Chiefly Affect the High-Frequency Response of the Video Amplifier.

The output capacitance of video-amplifier tubes in general use, ranges from 2 to 9 or 10 mmf. Input capacitances of these tubes range from about 5 to 12 or 13 mmf. There are also the capacitances of sockets and wiring which usually are, at the very least, from 3 to 5 mmf at each end of the circuit. All these capacitances are effectively in parallel with the load impedance, and are called shunting capacitances. A low value for total shunting capacitance on the plate side of the circuit might be 10 mmf, and the total on the grid side might be about 13 mmf. The total capacitance in parallel with the plate load then would be about 23 mmf if design and construction were first class in every respect.

The capacitive reactance of 23 mmf at a frequency of 4 mc is about 1,730 ohms, at 3 mc is about 2,310 ohms, and even at 2 mc still is only about 3,460 ohms. The impedance of elements in parallel always must be less than the impedance of any one of them alone. Therefore, the plate load impedance can be no greater than the capacitive reactances mentioned at the respective frequencies so long as the two shunting capacitances remain in parallel with each other.

The two shunting capacitances can be partially isolated from each other by inserting the series compensating inductor L1 anywhere in the line from plate to coupling capacitor. The inductance of L1 often is somewhere around 100 to 150 microhenrys. The inductive reactance of L1 increases with rise of frequency, while the reactances of the shunting capacitances become less. The inductive reactance of 100 microhenrys at 2 mc is 1,255 ohms, at 3 mc it is 1,885 ohms, and at 4 mc this reactance rises to 2,510 ohms. The reactance of 150 microhenrys would be just 50 per cent greater at each frequency.

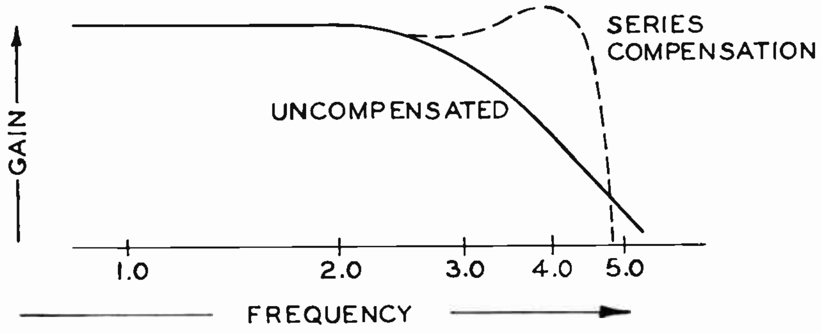


Fig. 6. Series Compensating Inductance Extends the Range to Higher Frequencies.

With the shunting capacitances thus separated by L1 their total effective reactance is raised, and the plate load impedance is raised accordingly, for improvement of gain at the higher frequencies. The highest frequency at which the gain remains fairly good is that for which the capacitive reactance of the total effective shunting capacitance becomes equal to the impedance of the plate load. High frequency cutoff is extended by first doing everything economically possible to decrease the shunting capacitances. This is done by choosing tubes with small internal capacitances, using sockets whose insulation has a low dielectric constant, using short wires of small diameter in the plate and grid circuit, keeping these wires away from each other and from chassis metal, and by careful assembly in general.

Then the impedance of the plate load must be decreased until the high frequency cutoff reaches the required value. Dropping the plate load impedance decreases the stage gain while extending the frequency cutoff. Gain is approximately proportional to the product of tube transconductance and ohms of impedance in the plate load. Whereas the stage gain of an uncompensated resistance-coupled amplifier would drop at high frequencies, as shown by the solid line curve of Fig. 6. Adding series compensation will extend the gain as shown by the broken line curve.

It will be found that the inductance of the series compensating coil L1 and total input capacitance at the second tube are resonant at about the cutoff frequency. For example, with total input capacitance of 12 mmf and cutoff around 4.2 mc the inductance at L1 would be 120 microhenrys.

As mentioned before, it is necessary to use a rather small resistance for load resistor R1 in order to extend the video range into high frequencies. Where this range is to be extended to approximately 4 mc the resistance of R1 is normally between 2,000 and 6,000 ohms. Where the video frequency is to extend only to about 3 mc, this resistance may be about 8,000 ohms. Values mentioned represent common practice, but there may be wide variations.

In series with this load resistance is the shunt compensating inductor L2 of Figs. 3 and 5. The inductive reactance of L2 increases with rise of frequency, and this action tends to maintain the effective plate load impedance at higher values in spite of the reduction in reactance of the shunting capacitances as frequency rises. The result is an extension of frequency at which there is satisfactory gain.

The inductance of this shunt compensating coil is resonant with the total effective shunting capacitance in the tube circuit at a frequency near the high cutoff value. Because this resonating capacitance is more than in the grid side of the circuit, the inductance of the shunt compensating coil is smaller than that of the series compensating coil.

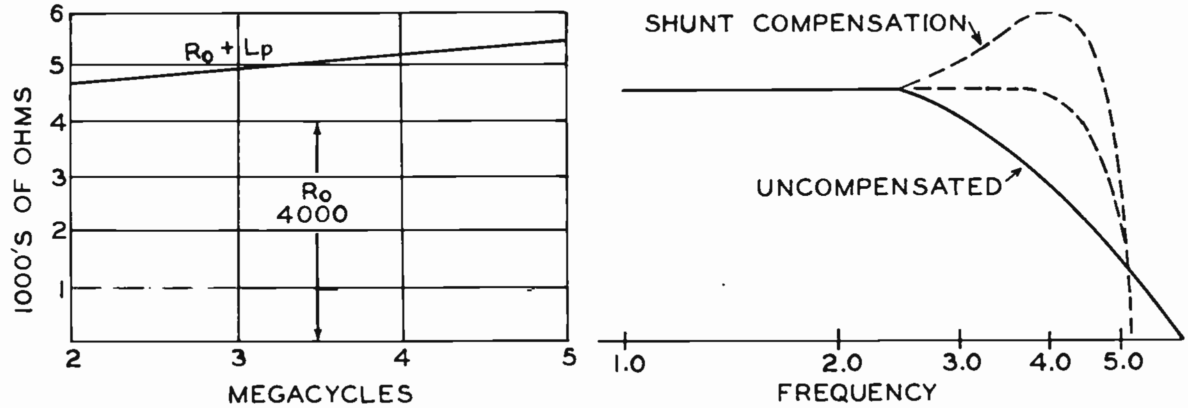


Fig. 7. Effects of Using a Shunt Compensating Inductance.

Taking for an example a plate load resistor R1 of 4,000 ohms and shunt coil L2 of 50 microhenrys, the rise of total impedance with frequency would be only as shown at the left in Fig. 7. But as the inductance of L2 and the shunting capacitance approach resonance there is the effect on gain as shown at the right. By suitable choice of values, the gain curve may be extended in almost a straight line well beyond where it would drop with uncompensated coupling, or the curve may be made to rise through a peak before the gain commences to drop rather sharply. The peak will be at a frequency somewhat lower than that at which the coil and the shunting capacitance would be resonant.

The load resistance which is part of the resonant circuit reduces the Q-factor and broadens whatever peaking may occur. To further reduce the peaking while still extending the frequency response, a resistor sometimes is connected across the ends of shunt compensating coil L2. In a few cases, there will be connected across the ends of the shunt compensating coil a capacitor whose capacitance is about one-third the shunting capacitance. The effect is to further extend the high frequency limit, but there may be decided peaking near the high end.

Either series or shunt compensation used alone will extend the frequency range of the video amplifier and allow a more uniform gain through the high-frequency region. The greatest band width and most uniform gain may be had by using both series and shunt compensation in the same coupling. Using both kinds of compensation makes the phase shift or time delay for certain frequencies less than with shunt compensation alone, but this shift is somewhat greater than with only series compensation.

It should be mentioned that the value of grid resistor R2 has little effect on high-frequency gain. This resistor is paralleled by the input capacitance of the second tube, whose reactance becomes so low at high frequencies that no permissible value of grid resistance would appreciably affect the total load impedance.

Video amplifier frequency response is not easy to measure with instruments such as usually are available. It would be necessary to apply at the input of the amplifier, or output of the video detector, a signal voltage of constant or accurately measured amplitude at frequencies all the way from below 30 cycles per second to about 5 megacycles per second. Output could be measured with an electronic voltmeter responding to alternating voltages, but the indications of usual voltmeters would vary so greatly in this range of frequencies as to require use of correction factors known to be correct for each frequency.

G. Number of Video Amplifier Stages

There are definite relations between the number of stages or tubes in the video amplifier, the element from which detector output is taken, and the element of the picture tube at which there is signal input.

In Fig. 8 the modulated signal from the output of the video IF amplifier is applied to the cathode element of the diode-type detector, and detector output is from the diode plate. For the detector to be conductive its cathode must be negative with reference to its plate. With the connections shown here the cathode becomes negative only on the negative swings of the modulated signal. Consequently, only the negative side of the incoming signal envelope causes current in the detector output and this output reproduces the negative envelope. In the DC output of the detector the picture portion of the signal is most positive and the sync pulses least positive, and when this output passes through any coupling capacitor to become an alternating voltage the picture signals are on the positive side and the sync pulses on the negative side of the wave.

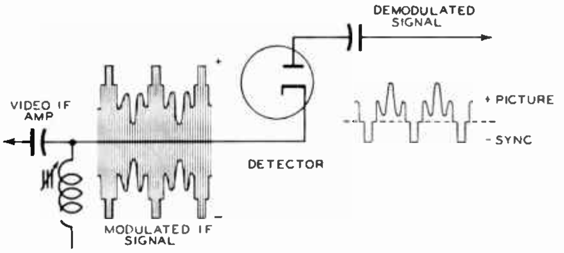


Fig. 8. Picture Signals are Positive When the Detector Output is From the Diode Plate.

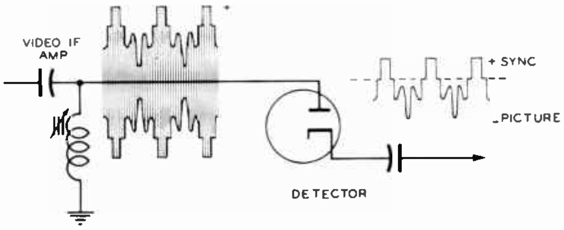


Fig. 9. Sync Pulses Are Positive if the Output is From the Cathode of a Diode Detector.

In Fig. 9 we have the same modulated IF signals as before, but now this signal is applied to the plate of the diode detector. For conduction to occur in the detector its plate must be made positive. The plate is made positive by the positive swings of the incoming signal, and the DC output of the detector consists of the positive envelope of the IF signal. Now the negative side of the modulated signal has been cut off by the detector, just as the positive side is cut off in Fig. 8. When the detector output passes through a capacitor and becomes alternating, the sync pulses are positive and the picture signals are negative.

The diagram in Fig. 10A shows the signal output from the video amplifier applied to the cathode of the picture tube. In order that picture variations in the signal which are to produce bright areas may cause an increase of beam current and brighter traces on the picture tube screen, the control grid of this tube must become more positive or less negative with reference to the cathode. This is the same as saying that the cathode must become less positive or more negative, with reference to the grid, to have brighter traces. Then, for increasing the beam current, it is necessary that the picture signal make the cathode of the picture tube more negative. In order for this to happen, the picture side of the applied signal must be negative, and the sync pulses positive, just as shown in the diagram. For input to the picture tube cathode, the sync pulses must be positive and the picture signal negative.

In Fig. 10B the signal from the video amplifier is applied to the control grid of the picture tube. In order that increases of picture signal amplitude increase the beam current and brightness on the screen, these increases must make the control grid more positive or less negative with reference to the cathode. For this to happen, the picture side of the applied signal must be positive, and the sync pulses negative, as shown in the diagram. For input to the picture tube grid, the picture signals must be positive and the sync pulses negative.

The detector connection shown in either Fig. 8 or in Fig. 9 may be used in a receiver where signal input is to either the control grid or the cathode of the picture tube. If the detector output is of such polarity that it must be inverted before reaching the picture tube input, a single video amplifier stage and tube will perform this inversion. Any odd number of video amplifiers would do the same thing, because any signal voltage applied to the control grid of a tube having a grid and a plate is inverted in the plate circuit of that tube.

If the detector output polarity is the same as the polarity required at the picture tube input this much of the problem could be handled by using no video amplifier, only a direct connection from detector to picture tube. But the detector output requires amplification. One video amplifier stage will invert the signal, and a second amplifier will bring the polarity back to its original form. Consequently, to have no inversion between detector and picture tube it is necessary to have at least two video amplifier stages. Any even number of video amplifiers would accomplish the same thing so far as maintaining signal polarity is concerned.

If output from one of the tubes in the video amplifier is from the cathode rather than from the plate of that tube, there is no inversion by that one tube. Then any tube used as a cathode follower in the video-amplifier system may be ignored when considering signal inversion or lack of inversion. There is, however, no gain in the cathode follower stage.

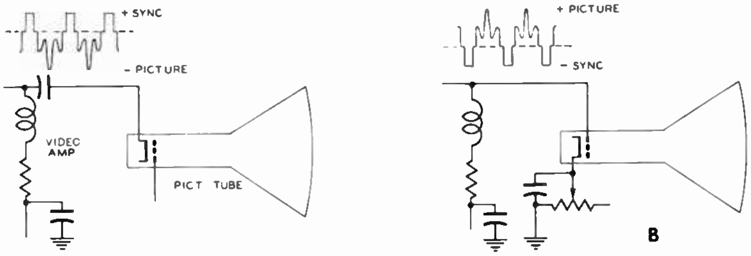


Fig. 10. Polarities Required in Signal Inputs to the Cathode and to the Control Grid of the Picture Tube.

H. Summary Questions

1. What signals will be found at the output of the video amplifier?
2. What is the normal frequency response of the video amplifier? Why must it be these values?
3. What type of tube is used for video amplification?
4. How are low frequencies compensated for in video amplifiers?
5. How are high frequencies compensated for in video amplifiers?
6. What factors determine the number of video amplifier stages?

DC RESTORATION – SYNC SEPARATION

Objective

To study circuits pertaining to DC reinsertion, sync clipper, and separators.

References

Lesson Content

A. General

The brightness control will be manually adjusted for correct reproduction at the beginning of a period of reception from a certain station, but unless we provide additional automatic means of varying the point on the curve of Fig. 1 at which the average signal potential is applied, the background illumination will not change when there are changes in the televised scene.

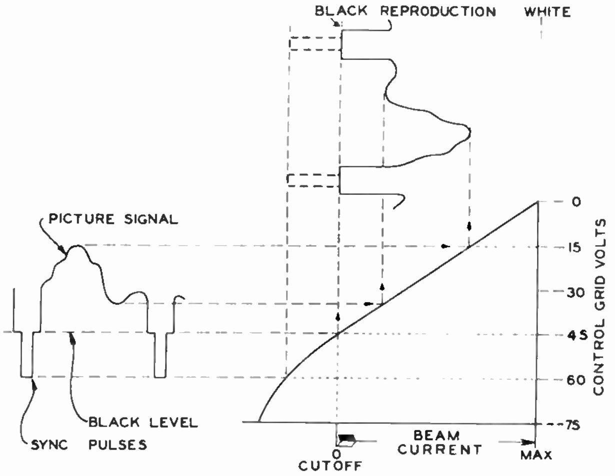


Fig. 1. Biasing the Picture Tube Control Grid for Beam Cutoff at the Black Level of the Signal Eliminates the Sync Pulses.

B. DC Reinsertion

Fig. 2 represents picture signals for three different lines. All three signal variations are alike, all have the same contrast. But variations for the bright picture are up toward the white level, those for the medium picture are about midway between white and black levels, and those for the dark picture are down near the black level. Across resistor R1 of Fig. 3 we would have variations or changes of potential difference corresponding to signal variations such as shown by Fig. 2. Across R1, however, we would have at the same time an average potential difference which is shown as 100 volts in Fig. 3. The changes of potential which represent the picture and the sync pulses would vary the potential drop across R1 above and below the average potential drop across R1.

From left to right through each of the signals in Fig. 2 is a dashed line representing the average potential of all the momentary variations above and below this line. Were the three signals applied between grid and cathode of the picture tube, with the grid bias fixed at some certain value by the brightness control, the average potentials of all the signals would come on the value of grid bias.

This is just the same as when we apply an AC signal to the control grid of an amplifier tube whose grid is biased to some certain potential; the average of the signal appears on the bias value, and changes of the signal vary the grid potential above and below the bias value.

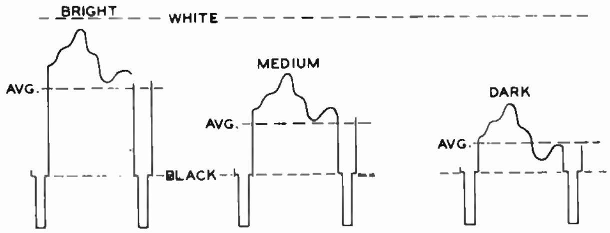


Fig. 2. Picture Signals for Backgrounds Which are Bright, Medium, and Dark.

To correctly distinguish between bright, medium, and dark backgrounds we do not want the average signal potential to appear on the picture tube grid bias; rather, we want the black level of the signal to stay on the grid bias voltage. Then the picture variations will be raised to their correct values above the black level. If the signals are considered with reference to their average potentials, as divided above and below the average lines of Fig. 2, the signals are, in effect, alternating potentials or currents. If the signals are considered with reference to the black level, the picture portions of the signal are direct (one-way) potentials or currents with all of their values on the positive side of the black level. For this reason we speak of "DC reinsertion" or "DC restoration" when making the black level rather than the average potential act as our reference level for the picture tube grid.

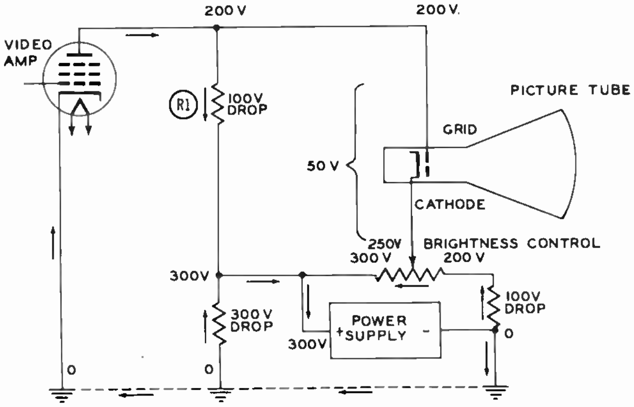


Fig. 3. A Picture Tube Control Grid Circuit.

To employ the picture tube input circuit shown in principle by Fig. 3, we must decrease the average potential drop across R1, as from 100 to say 85 volts, for a picture with a bright background. This will make the average potential of the picture tube grid more positive, or less negative, will increase the average beam current, and will make the picture appear brighter on the screen. Conversely, for a picture with dark background we must increase the average potential drop across R1, making the average grid potential of the picture tube more negative than before, decreasing the average beam current, and darkening the reproduction.

To vary automatically, the potential drop across R1, we change the average plate current of the video amplifier tube. To change the average plate current we may automatically vary the grid bias of this tube in accordance with picture brightness.

The video amplifier grid bias may be automatically varied by using grid rectification in the control grid circuit. This means a biasing capacitor in series with the control grid, and a biasing resistor between control grid and cathode. When an AC signal is applied to a tube thus biased, the greater the amplitude of the applied signal the more negative becomes the grid bias, and the average plate current becomes less.

Part of the circuit of Fig. 3 is shown in Fig. 4 and in addition, a biasing capacitor C1 and a biasing resistor R2 in the control-grid circuit of the video amplifier. We shall assume that a "bright" signal of large amplitude comes to the video amplifier grid circuit. The grid bias becomes more negative than before, and there is a decrease of average plate current. Should the plate current decrease to a value which is accompanied by an 80-volt drop in R1 instead of the 100-volt drop of Fig. 3, the average potential of the picture tube grid would change to 220 volts. With the picture cathode still at 250 volts the grid now is only 30 volts negative with reference to the cathode, whereas in Fig. 3 it is 50 volts negative. Thus the average beam current is increased to show the bright picture correctly.

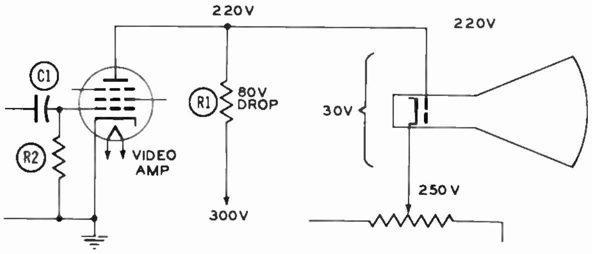


Fig. 4. DC Reinsertion with Automatic (Grid Rectification) Bias on the Video-Amplifier Tube.

A signal for a "dark" picture of small amplitude applied to the video amplifier grid would make the grid bias less negative, would allow an increase of average plate current, would increase the drop across R1, would lower the picture tube average grid potential, and make the grid more negative with reference to the cathode. Then we would have less average beam current and a darker reproduction.

The method described is not the only way of accomplishing DC restoration. Another way is to use a rectifier tube in the video amplifier plate circuit, and apply the rectified DC potential to the grid circuit of the picture tube to change its bias. The biasing potential varies with amplitude of the signal, and is applied to the picture tube grid circuit in such polarity as to make the grid less negative for large amplitudes (bright pictures) and more negative for small amplitudes (dark pictures.)

C. Separation

The sync (synchronizing) signal can be taken off immediately after the video detector or after the video amplifier (at the plate of the video amplifier).

Fig. 5A, shows the signal taken from the detector output. The sync pulses are more positive than the picture variations. We wish to retain the positive sync pulses and get rid of the negative picture signal. One of the simplest methods is to feed the signal to the grid circuit of a tube biased to

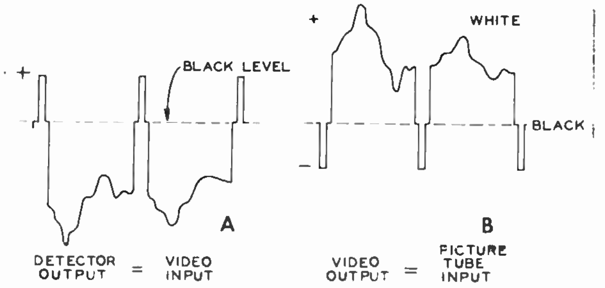


Fig. 5. Phase Inversion Makes the Picture Signal Positive, with Maximum Amplitude Corresponding to White.

cut off its plate current at the potential of the black level in the signal. Then everything more negative than the black level, which includes all of the picture signal, causes no plate current. Everything more positive than the black level, which means the sync signals, causes pulses of plate current which correspond to sync pulses of the signal. The necessary negative bias is conveniently produced by grid rectification with a grid capacitor and grid resistor such as shown for the video amplifier in Fig. 4.

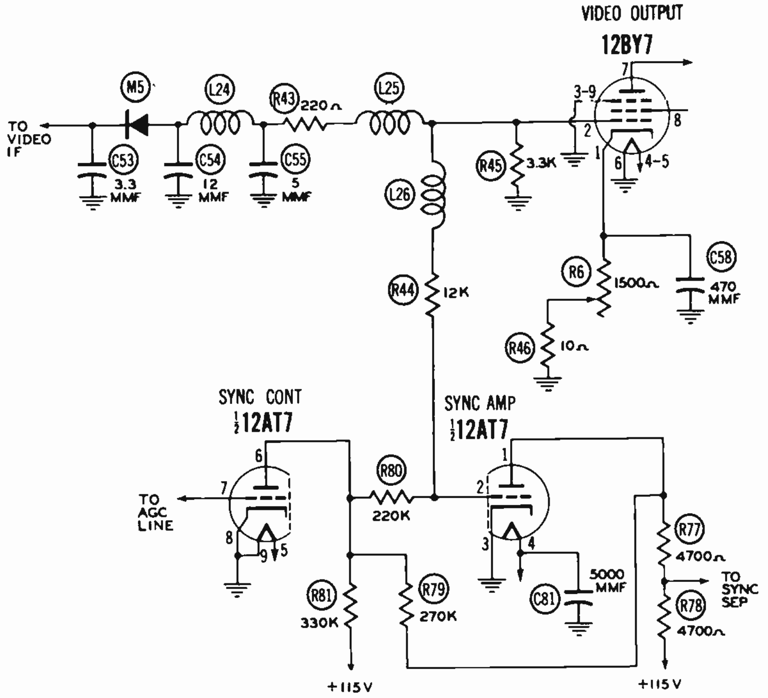


Fig. 6. Schematic Diagram of a Sync Control System Used in a Typical Receiver.

A system is designed to provide better synchronization under conditions of varying signal strength is shown schematically in Fig. 6.

The output of the video detector (in this case a germanium diode) is directly coupled to the grid of the sync amplifier. The DC level of this output signal is negative by an amount proportional to the strength of the incoming signal. Note that a small positive DC voltage is applied to the grid of the sync amplifier through the voltage-dividing network composed of resistors R81, R80, R44, R45, and inductance L26. The action of the circuit is such that the two DC voltages of opposite polarity vary with change in signal strength so that the voltage of the sync-pulse tips is maintained at slightly above the cut-off level of the sync amplifier.

Let us assume that a strong signal is being received. The negative voltage developed across resistor R45 in the video detector is applied as bias to the grid of the sync amplifier. If it were not for the positive DC voltage which is also applied to the grid, the negative sync pulses would tend to drive the tube well beyond cutoff and the sync pulses would be lost in the output of the sync amplifier. The contribution of positive DC voltage from the voltage-dividing network increases when a strong signal is received, and this action tends to oppose the increase in negative bias from the detector. The sync control tube in Fig. 6 causes the increase in positive voltage. Note that the grid voltage on the sync control tube is established by the voltage on the AGC line. When a strong signal is received, the AGC voltage becomes increasingly negative; conduction in the sync control tube decreases; and the voltage at the junction of resistors R81 and R80 goes in a positive direction. These operations result in an increase in positive voltage applied to the sync-amplifier grid.

Under weak signal conditions, the events mentioned in the foregoing paragraph occur in the same sequence; but the voltage changes are in the opposite direction. A decrease in negative voltage from the video detector is counteracted by a decrease in positive voltage from the voltage-divider network.

Hence, grid conduction in the sync-amplifier tube and an undesirable reduction in the input impedance of this tube are prevented.

It may be seen from the fore-going explanation that the sync control tube acts as a variable impedance in the voltage-divider network. The end effect is to regulate the amount of bias applied to the sync-amplifier tube in accordance with the strength of the received signal. Such regulation insures that proper sync amplification is maintained.

Vertical and Horizontal Sync Separation — The sync pulses consist of those which are to control timing of the active horizontal lines and the horizontal retraces, also these which are to control downward travel of the beam and the vertical retraces.

Fig. 7 shows the synchronizing signals which occur during a vertical blanking period. There are shown also, at the extreme left, the picture signals during the last two active lines of the second field, with their intervening horizontal sync pulses. At the extreme right are shown the picture signal for the first line of the following field, and the horizontal sync signal following the active line.

At the end of the last line on the left of the graph the signal potential rises to the black level. Then follow six very brief positive pulses marked Equalizing. These equalizing pulses are spaced apart, in time, by only half the interval for a scanned line. Line intervals, which are continued by suitable divisions of the pulses throughout the whole time represented on this graph, are indicated by the short vertical dashes at the top of the graph. Note that there is a rise of potential, or there is the beginning of a positive pulse, at the beginning of every line period of time. Thus the timing for horizontal synchronization is carried without interruption through the whole period of vertical blanking. Were this not done, the horizontal sync generator would get quite a ways out of correct timing and control would be difficult.

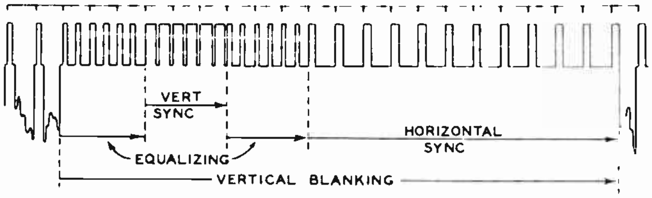


Fig. 7. Synchronizing Pulses which Occur in the Television Signal During One Period of Vertical Blanking.

Following the first series of equalizing pulses there are six relatively long pulses which, taken together, occupy the same time as three lines. These pulses are interrupted by such brief dips of potential that they act about like a single continuous pulse which is three line periods in duration. These six long pulses form the vertical synchronizing signal. They are followed by six more brief equalizing pulses, and then the remainder of the time during the vertical blanking is filled with regular horizontal sync pulses between which there are no picture signals, but which have the same timing as though there were picture signals.

It is not very difficult to separate the horizontal and vertical lines, because the frequency of occurence of the horizontal pulses is 15,750 per second (with 525 lines in each of 30 frames per second), while the vertical sync pulses occur only 60 times per second for the two fields which make up one frame during 1/30 second.

One type of frequency separator circuit, and output, is shown by Fig. 8. The sync signals, horizontal and vertical, enter from the left. Capacitor Ch is of small capacitance. It is charged by the high-frequency horizontal sync pulses and discharges across grid resistor Rh. The pulses of potential applied between grid and cathode of the horizontal sync amplifier tube, produce sharp positive peaks in the output occurring at the horizontal sync frequency. These positive peaks go to the horizontal sync generator. This particular circuit uses negative sync pulses at the input.

The capacitance of Ch is small enough to offer high reactance at the relatively low frequency of the vertical sync pulses, but these vertical pulses are fed through resistor Rv to charge capacitor Cv. The time constant of Rv and Cv is long enough so that the voltage across Cv increases and decreases as shown at the right of the vertical sync amplifier tube. The equalizing pulses are so brief that most of the charge leaks off through Rg every time it is accumulated. But with the long vertical sync pulses, shown by Fig. 7, the charge accumulates faster than it can leak off through Rg, and there is a continued rise of capacitor voltage and of grid-cathode voltage across Rg. Thus, there is fed to the vertical sync generator a relatively long pulse of potential, from the output of the vertical sync amplifier, for each vertical sync signal.

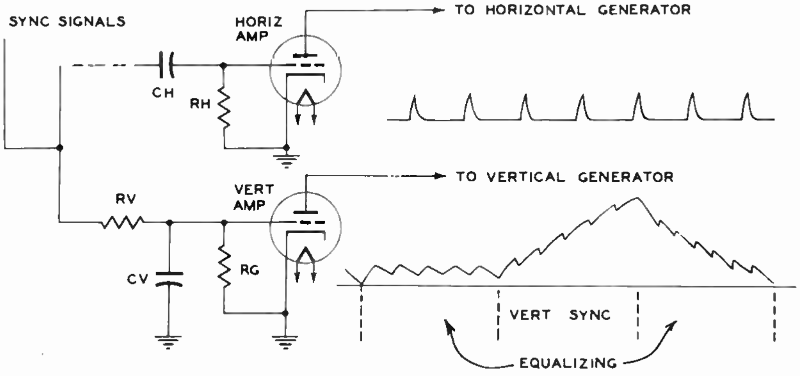


Fig. 8. A Circuit for Separating the Horizontal and Vertical Sync Pulses, with the Effects of the Pulses Shown at the Right.

The potentials sent to the sync generators must be positive in order to time or trigger the generators. Video detector output or load polarity and the number of amplifying stages always must be so related with respect to phase inversions as to deliver signals of correct polarity both to the picture tube grid and to the sync generators. The two triode amplifiers of Fig. 8 usually would be replaced by a twin-triode tube.

D. Clippers or Limiters

In television receivers the name clipper may be applied to a tube whose purpose is to retain and sometimes to amplify the sync pulses of a signal while reducing or eliminating the picture variations of the signal. This would be one of the tubes in the sync section of the receiver. A tube performing this function may be called also a sync separator.

The name limiter may be applied to a tube whose chief purpose is to reduce all sync pulses of a signal to the same amplitude or same voltage strength, or to limit the amplitude to some certain maximum value which prevents passage of extra strong pulses due to noise effects or to interference. Such a tube may be called also a sync clipper.

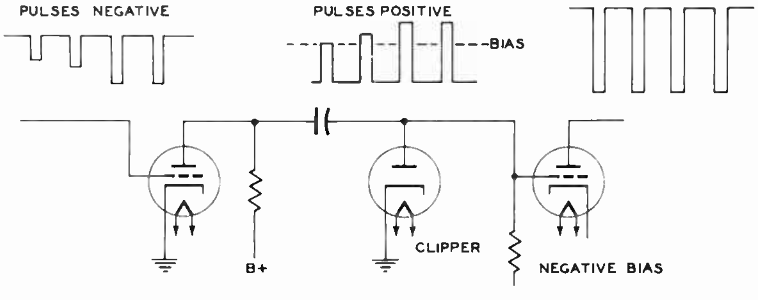


Fig. 9. A Diode Used as a Leveler or Clipper for Sync Pulses.

Diodes may be used as clippers, limiters, or levelers of sync pulses. One method is illustrated by Fig. 9. Sync pulses coming to the grid of the left-hand triode tube are of negative polarity, and in the output of this tube the pulses are positive due to signal inversion which always occurs in a triode amplifier. The positive pulses make the plate of the clipper diode positive and tends to make the diode conduct. But the plate of the diode is conductively connected to the negative grid-bias voltage source for the right-hand triode. Only when the positive voltage of the sync pulses exceeds the negative bias voltage will the clipper diode actually conduct and reduce this positive voltage. Thus sync pulse voltages applied to the grid of the right-hand diode are made fairly uniform and the output signal of this triode is likewise fairly uniform.

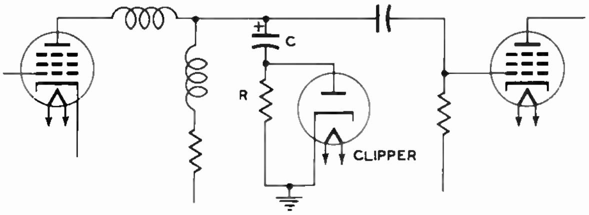


Fig. 10. A Clipper Diode Biased by a Capacitor and a Resistor.

Another connection for a pulse clipper is shown by Fig. 10. Here the clipper diode plate is connected through capacitor C to the lead between the plate of the left-hand amplifier tube and the grid of the right-hand amplifier. In the circuits of video amplifiers the signal consists of both picture variations and sync pulses. It is assumed that in the signal applied to the diode plate the sync pulses are positive. Resulting current flowing in capacitor C and between plate and cathode of the clipper tube causes charging of the capacitor in the polarities marked. The capacitor discharges slowly through resistor R, and maintains the clipper plate negative with reference to its cathode. That is, the clipper plate is negatively biased at a potential proportional to the average or normal voltage of the sync pulses. Should interference or other external forces produce sync pulses of more than average voltage, these higher voltages will overcome the negative bias and cause the clipper to conduct. The conduction loads the circuit sufficiently to level off most of the excess pulse voltage and to leave sync pulses of practically constant strength for the grid of the right-hand amplifier tube.

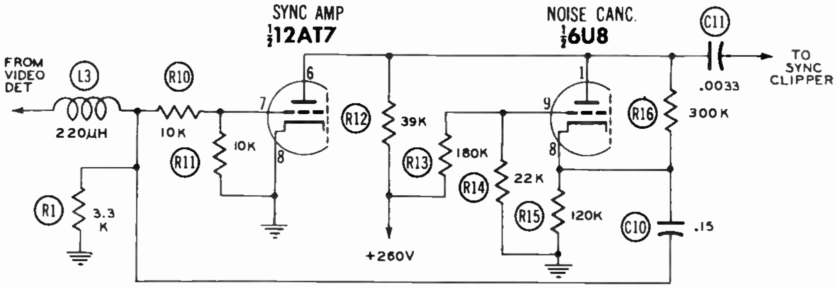


Fig. 11. Schematic Diagram of a Noise Cancellation Circuit.

Some sets use a noise inverter tube to prevent random noise from triggering the sweep circuits. In the circuit of Fig. 11, a composite video signal of negative polarity is fed from the video detector to the grid of the sync amplifier. A negative signal is also fed to the cathode of the noise-cancellation tube through capacitor C10. A positive bias is applied to the cathode by the action of resistors R16, and R15. A positive potential is also applied to the grid of this stage by the divider formed by resistors R13 and R14. The combined effect of these two voltages is to keep the noise-cancellation tube normally cut off. This stage does not affect the operation of the sync amplifier under these conditions.

When a strong noise pulse appears in the video signal, it is sufficient to over come the bias on the noise-cancellation tube and the tube conducts. The result is a negative-going signal at the plate. This signal cancels the positive signal appearing at the plate of the sync amplifier. A "hole" then appears in the signal from the sync amplifier for the duration of the noise pulse. By this means, the strong noise pulses are prevented from being fed to the sync clipper and false triggering of the sweep circuits is avoided.

The composite signal from the output of the sync amplifier is coupled to the grid of a sync clipper. This stage employs one triode section of a 12AT7. A small negative bias is supplied to the grid from the AGC line.

The circuit in Fig. 12 combines noise cancellation, sync separation, and sync clipping in one tube. The signal from the output of the video amplifier is applied to grid 3. This signal is strong enough to draw grid current during the sync pulse. The long time constant of the coupling capacitor and the 1.8-megohm grid resistor holds grid 3 at cut off during the remainder of the cycle. This action removes the video information and leaves only the sync pulses in the plate signal. This type separation was discussed earlier in this lesson. Clipping of the positive going pulses is accomplished by holding the screen voltage down by means of a dropping resistor.

The signal from the video detector is applied to grid 1. This signal is 180 degrees out of phase with the signal on grid 3. This would cause cancellation if the signals were of equal amplitude. The signal is much weaker, however, at grid 1 since the video signal has not yet been amplified. Grid 1 is biased near cut off. The bias is so arranged that a sync pulse is not quite strong enough to cut off current flow. The pulses are negative-going at this grid. At grid 3, the sync pulses are positive-going.

A large noise pulse would also be positive-going at grid 3 and would cause a false trigger pulse in the plate circuit if it were allowed to increase plate current. This same noise pulse, however, will be applied to grid 1 and will drive grid 1 more negative. If the noise pulse is stronger than the normal sync pulses, the whole plate circuit of the tube will be at cut off and no corresponding pulse will appear at the plate. This, then, is one limitation of the circuit. It will reject only noise pulses which are stronger than the sync pulses. This is not a serious consideration, however, since most noise is severe enough to cut the tube off.

Occasionally a noise pulse will occur during a sync pulse. In this case, the noise would cut off the tube and the sync pulse would be lost. Generally the loss of one or two horizontal pulses will not cause the picture to tear since the AFC circuit will hold the oscillator at the correct frequency during this very brief period.

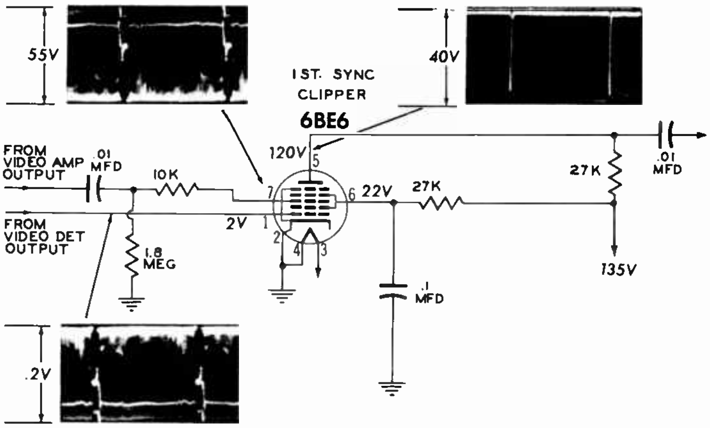


Fig. 12. A Circuit in which the Combined Functions of Sync Separation, Sync Clipping, and Noise Cancellation are Combined in a Single 6BE6 Tube.

E. Summary Questions

1. The DC component represents what part of the video?
2. Why is it necessary to restore the DC component?
3. Explain the operation of the grid leak bias type of DC reinserter.
4. Explain the purpose and operation of the separator stage.
5. Explain the purpose and operation of the clipper or limiter stage.
6. Describe briefly the operation of a noise inverter stage.

CATHODE-RAY TUBES FOR TELEVISION RECEIVERS

Objective

To study the construction and types of cathode-ray tubes used in television receivers.

References

Lesson Content

A. General

The picture tube is the television-receiver tube on whose relatively flat face are formed the lights and shadows of reproduced pictures or images. Pictures or patterns composed of lights and shadows result from rapid movement of a beam or stream of electrons over the sensitized inner surface of the screen material which coats the inside of the tube face. Density of electrons in the beam is varied to produce lighter and darker areas as the beam is rapidly moved or deflected horizontally or vertically over all parts of the screen area.

Picture tubes may be broadly classified as of two general types, one of which employs magnetic deflection and the other electrostatic deflection. Tubes designed for electrostatic deflections are used only in the smaller types of television receivers and in oscilloscopes.

Magnetic deflection picture tubes may be further classified as those designed for direct viewing of the picture screen and those designed for projection viewing. Pictures formed on the screens of projection type tubes are enlarged by a system of lenses or lenses and mirrors, and are displayed on a screen or mirror which is separate from the tube itself. This lesson describes picture tubes designed for magnetic deflection and direct viewing.

B. Picture Tube Construction

Electrons which form the beam in the picture tube are emitted, controlled in density, and accelerated in a part of the tube called the electron gun. The essential parts of the electron gun in a typical tube are shown by Fig. 1. An oxide coating on the forward end of the cathode sleeve is heated dull red by action of the heater which is enclosed within the sleeve. Electrons emitted from the cathode are drawn into a narrow stream at the opening through the control grid or grid number 1.

The electron stream then spreads to some extent as it is drawn on through grid number 2 which is operated at a fixed potential, usually about 250 to 300 volts positive with reference to the cathode. The electrons pass next through the anode, also called the accelerating electrode or grid number 3, where they are accelerated to maximum required velocity on their way to the screen.

The inside of the flared portion of tubes of all-glass construction is covered with a conductive coating of finely divided graphite which is electrically connected to grid number 3. This internal coating is part of the anode of the tube. Sometimes the internal coating and grid number 3, considered as a single electrical element, are called the anode. The internal coating collects electrons which leave the screen as a result of secondary emission at the point where primary electrons from the gun strike the screen.

Grid number 2, due to its constant potential, insures that control of electron density of the beam by control grid voltages will be practically unaffected by different potentials applied to the anode in different receivers.

Approximately half the types of all-glass picture tubes which are in general use have an external conductive coating over the flared portion, in addition to the internal coating. The external conductive coating is connected to ground through a contact spring attached to the chassis and acts as a shield against external electrical fields.

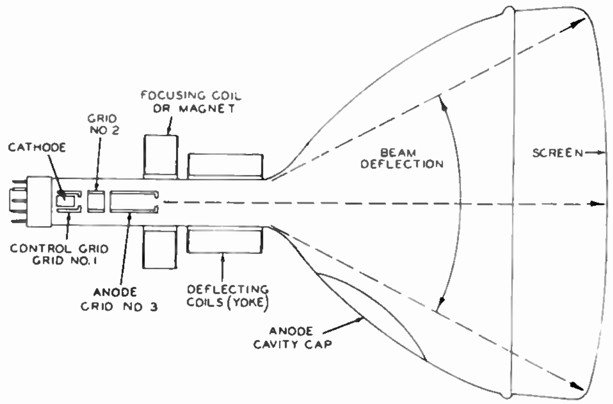


Fig. 1. Location of the Electron Gun in a Picture Tube.

The internal and external conductive coatings act as the plates of a capacitor with the glass of the tube envelope as dielectric. The capacitance of the coatings, which may be anything between 500 and 3,000 mmf, is used as a high-voltage filter capacitor with connections as shown in Fig. 2A. When the picture tube does not have an external coating a separate filter capacitor of 500 to 2,000 mmf is connected between the high-voltage lead and ground, as in Fig. 2B.

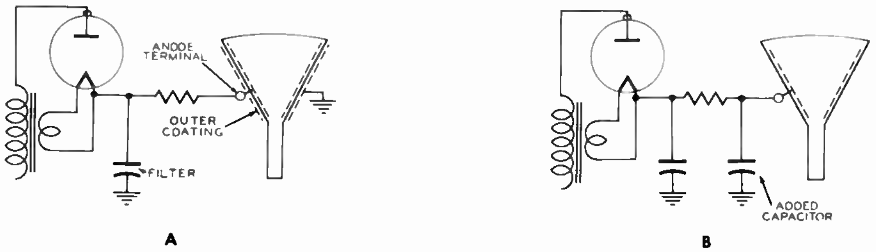


Fig. 2. Methods of Filtering High Voltage (A) Using the Aquadag Coating of the Picture Tube (B) By Adding a Capacitor.

The metallic conical portion of the envelope of metal picture tubes is an electrical part of the anode. Consequently this cone is at a very high potential and is dangerous to touch while the receiver is turned on. The high-voltage lead for the anode of metal-cone tubes is fitted with a clip connector which attaches to the front lip of the cone. On most all-glass tubes the anode terminal is a cap recessed in a cavity on the side of the flare which ordinarily is placed at or near the top when the tube is mounted. This recess is indicated in Fig. 1. Other all-glass tubes have for their anode terminal a ball which is not recessed.

C. Focusing Methods

The electron beam is still spreading to some extent as it reaches the space beyond the accelerating anode. An electrostatic or magnetic field must be used in this region to narrow the beam so it will present a very small spot on the face of the picture tube. This compressing of the beam's cross-sectional area is called focusing.

Originally the magnetically focused tubes used an external focus coil which was slipped onto the neck of the tube directly behind the deflection yoke. The focus control in these sets is a potentiometer which controls the amount of current flowing through the coil. Later on, some manufacturers used a heavy ring magnet with a coil fixed to it. The coil was quite small and was used as a fine adjustment of the total field strength to permit adjustment of the focusing. The focus control in this case, too, was a potentiometer to vary coil current.

Finally a completely permanent magnet focus assembly was perfected. This arrangement uses movable pieces which can be moved into or out of the main assembly to provide fine adjustment of the focusing. Fig. 3 shows some typical permanent magnet arrangements.

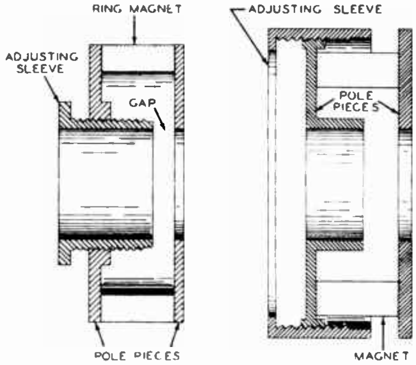


Fig. 3. Focusing Adjustments by Means of Threaded Rings of Magnetic Metal.

In some of these sets, a flexible shaft was brought out through the rear cover of the set near the neck of the picture tube to allow focusing with the cover in position.

The use of permanent-magnet focusing reduced the current drain on the power supply of the receiver allowing use of smaller transformers. In transformerless sets, the selenium rectifier will be run at lower temperatures, thus pro-longing their life.

The set manufacturers, in an effort to retain these advantages and reduce the costs of the focusing assemblies, once more directed their attention to electrostatic focusing. The possibility of a shortage of permanent magnet materials also spurred developement in this direction.

An extra anode, usually referred to as the "focusing electrode", is added to the electron gun assembly. In some tubes an external focusing voltage is required. Tubes requiring this extra voltage source are usually called simply "Electrostatic" tubes. Some of these tubes require a relatively high focusing voltage. The 12AP4, for example, requires 1190 to 1790 volts on the focusing electrode with 7000 volts on the final anode. The 17GP4 requires a focusing voltage of 2290 to 3110 volts with a final anode voltage of 12,000.

Since these voltages are considerably higher than the low voltage B+ of the receiver and quite a bit lower than the high voltage, either a separate supply was necessary or a bleeder across the high-voltage supply had to be used. In spite of these disadvantages, quite a few sets were built using one of these alternatives. Other electro-statically focused tubes have been developed which use much lower focusing voltages, within the normal B+ voltages, available in average low-voltage power supplies. The 17RP4 uses focusing voltages between minus 55 volts and plus 300 volts with 14,000 volts on the final anode.

The latest electrostatic tubes require no external voltage source for focusing. All focusing potentials are taken from other elements within the tube. These tubes are referred to by trade names like "Self-Focus", "Auto-Electrostatic", "Zero-Focus", etc... Some tubes of this type are 17KP4, 20JP4, and 21KP4.

D. Tube Voltages

All magnetic deflection picture tubes in general use are designed for 6.3 volts and 0.6 ampere in their heaters. Negative grid potential for complete cutoff of illumination on the screen of various types of picture tubes ranges from 33 to 77 volts. The higher the anode voltage and the higher the voltage on grid number 2 the more negative must be the control-grid voltage to attain cutoff with any given tube.

Fig. 4 shows typical relations between control grid voltage and brightness of the screen. One curve is drawn for 250 volts and the other for 400 volts on grid number 2. Curves showing relations between control grid voltage and anode current would be of the same general form. This would be expected, inasmuch as illumination is roughly proportional to electron density in the beam reaching the screen.

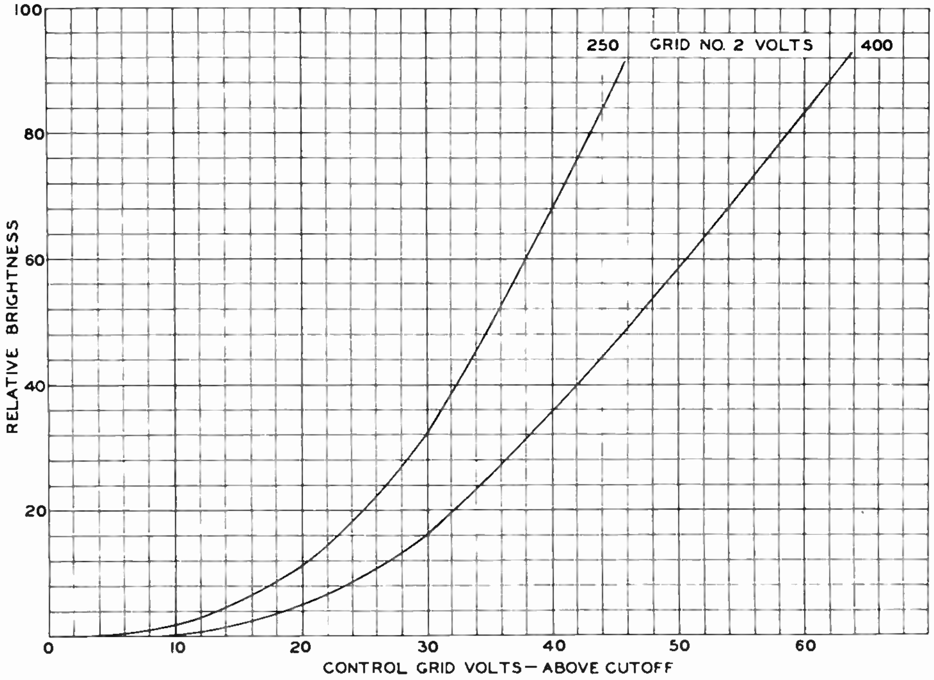


Fig. 4. Relations Between Control Grid Voltage and Brightness at the Screen of a Picture Tube.

Note that voltage shown on the graph is voltage above cutoff, it is not grid-cathode voltage. As an example, were cutoff potential to be 60 volts negative, the graph voltages related to the curves would be those subtracted from 60 volts, or would be the number of volts by which the control grid is made less negative than minus 60 volts in causing the degrees of brightness indicated by the curves.

All curves showing the effect of control grid voltage on brightness and on anode current are quite similar to curves showing relations between control grid voltage and plate current in triode amplifier tubes. These mutual characteristics or transfer characteristics of picture tubes may be used to illustrate relations between picture signal voltages and picture brightness just as they are used to illustrate relations between sound signal voltages, and sound output of amplifiers.

Maximum permissible anode potentials for 10-inch, 12-inch, and 14-inch picture tubes are between 10,000 and 12,000 volts, with typical operating voltages ranging from 7,000 to 11,000. For 15-inch to 24-inch tubes the maximum anode voltages are between 14,000 and 20,000 volts, depending on the type of tube, while typical operating voltages are between 9,000 and 18,000. 27 inch to 30 inch tubes have maximum voltages of 18,000 to 30,000 volts for the final anode with typical voltages ranging from 15,000 to 18,000 volts. Higher voltage on the anode tends to give better definition and greater brightness in the pictures.

E. Deflection of Beam

Factors affecting the distance the electron beam is deflected either way from the center of the screen are illustrated by Fig. 5. Deflection distance is directly proportional to strength or flux density in the magnetic field of the deflecting coil. Flux density, in turn, is approximately proportional to deflecting current in milliamperes, but depends also on permeability of any iron core used in the coil. Permeability of an iron core varies with changes of current and of flux. Deflection distance increases with increase of deflecting current in the coil, but not proportionately when the coil has an iron core.

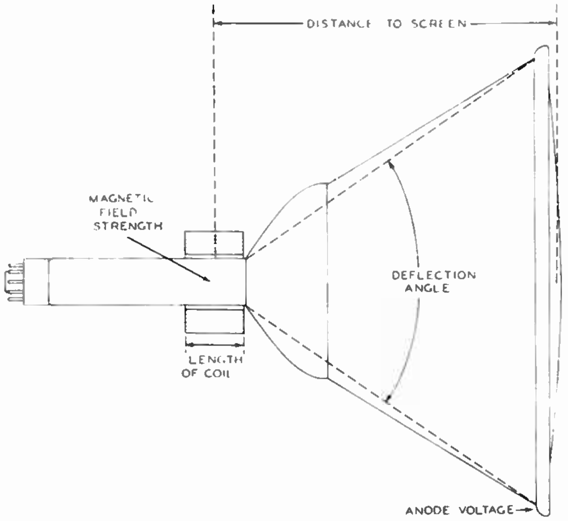


Fig. 5. Factors Which Affect Distance of Deflection in Magnetically Deflected Picture Tubes.

Deflection distance on the screen increases directly with length of the deflecting coil in line with the tube axis, or rather with length of the magnetic field when the field is uniform. The deflection is increased also, and increases directly, with increase of distance from the center of the deflecting coil to the center of the screen. This is because a longer electron beam over a certain angle moves farther at the screen end than does a shorter beam deflected over the same angle.

Deflecting distance is inversely proportional to the square root of anode voltage. The greater the anode voltage the less will be the deflection distance with all other factors remaining unchanged, but decrease of deflection will be only in the ratio of the square roots of the anode voltages. Anode voltage or electron accelerating voltage tends to pull the beam along a straight line, and opposes deflection or bending. It turns out that distance of deflection is increased by more deflection current in the coil, by less anode voltage, or by both these changes. Deflection is decreased by less deflecting current, more anode voltage, or both.

The tube illustrated by Fig. 5 is designed for a maximum deflection angle of 70 degrees. The tube illustrated by Fig. 1 is designed for a maximum angle of 56 degrees. Various types of picture tubes now in general use allow deflection angles all the way from 50 degrees, on most of the 10-inch tubes, up to 70 degrees on some of the tubes in 16-inch to 22-inch sizes of types having round envelopes and screens. All the rectangular tubes have maximum deflection angles of 65 to 90 degrees as measured across the diagonal line between opposite corners.

The same type deflecting yoke or deflecting coils may be used for nearly all picture tubes having deflection angles less than 66 degrees. All tubes having deflection angles of 66 degrees or more usually require a special wide-angle yoke.

F. Tube Types and Base Connections

Picture tubes are identified by type numbers such as 10BP4, 14CP4, and so on. The first number refers to the greatest diameter, at the screen end, to the nearest inch. For instance, the 10BP4 tube has an overall diameter of 10 1/2 inches, and the 16GP4 has an overall diameter of 15 7/8 inches. The first number in designations for rectangular tubes indicates the approximate equivalent diameter of a round tube which would provide the same size picture. The overall face size of rectangular tubes having 14 for their first number is 9 27/32" x 12 21/32". 17" rectangular tubes have 12 3/8" x 15 1/2" screens. 24" screens measure 18 7/16" x 22 11/16". The overall dimensions of a 27" screen are 20 11/32" x 25 13/32".

The first letter of the type designation indicates merely the order in which that particular design was registered with the Radio-Electronics-Television Manufacturers Association. For example, the 16CP4 tube was registered before the 16DP4, and the 16DP4 was registered before the 16EP4.

The second letter always is P. It stands for the word phosphor, which is the fluorescent coating forming the screen of the tube. The second number in the designation is the type number of the kind of phosphor used in the tube. All television picture tubes contain phosphor number 4, so the second number always is 4.

When a letter follows the second number this final letter indicates some modification of the original design, but a modification which calls for no changes in the circuits for which the tube is adapted. As an example, the 16AP4 tube is the original design while the 16AP4-A is electrically similar but has a face plate of a type which reduces reflections.

Fig. 6 shows base pin positions and connections for magnetic-deflection tubes. Pin positions are as seen from the bottom or the outside of the tube base. About 95 per cent of all magnetic-deflection tubes have the 12-D basing arrangement of the left-hand diagram. The elements in all these tubes are as described earlier in these pages. The 12-G basing arrangement is used on tubes of types 10MP4, 10MP4-A, 12VP4, and 12VP4-A. The 12-C basing is used on 10DP4 tubes in which anode number 1, connected to pin 6, is used for electrostatic focusing. Many of the larger types using electrostatic focusing and magnetic deflection are wired according to 12L.

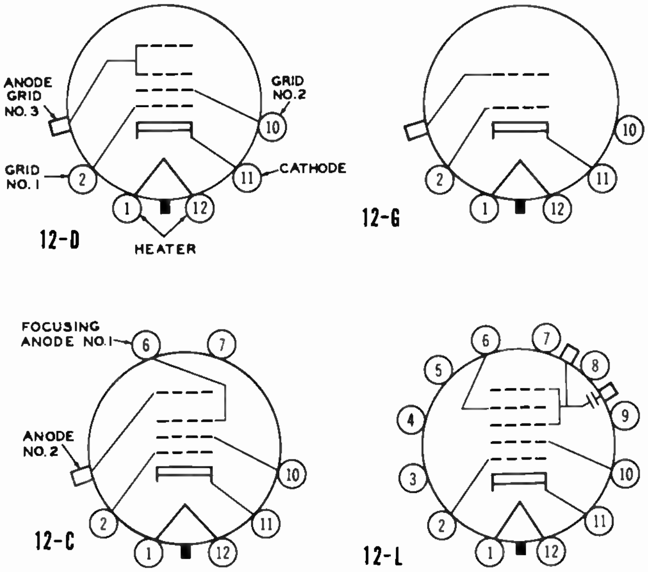


Fig. 6. Base Pin Positions and Element Connections for Magnetic Deflection Picture Tubes.

The base used on all magnetic-deflection picture tubes is of the type called a small-shell duodecal 7-pin base. Pins are spaced at 30-degree intervals around the circle. This spacing would permit a maximum of 12 pins, but there are pins in only some of the positions, as shown by the diagrams in Fig. 6. In addition to the pins which connect to internal elements there may be one or two extra pins with no internal connections.

Sockets for the magnetic-deflection tubes are specified as the duodecal type, in which there are opening and lug connections for all 12 pin positions. As an economy measure, some manufacturers make only half a socket (sometimes called a half-moon). Picture-tube sockets are supported only by being pressed onto the base pins of the tube, with circuit connections made through flexible wires leading to the socket lugs.

G. Screens for Picture Tubes

On the screen which covers the inside of the exposed face of the picture tube are solid materials which become luminous when their particles are struck by the electron beam. These materials are called phosphors. Different kinds of phosphorescent substances emit light of various colors when excited by the electron beam. Mixtures of these substances will produce intermediate hues and will produce an approximation of white.

The phosphors are identified by numbers. Phosphor number 4, used in all television picture tubes, gives the effect of white light by delivering radiations from blue through green and yellow. The full-line curve of Fig. 7 shows relative intensities of emission at various color wavelengths in the visible spectrum for phosphor number 4.

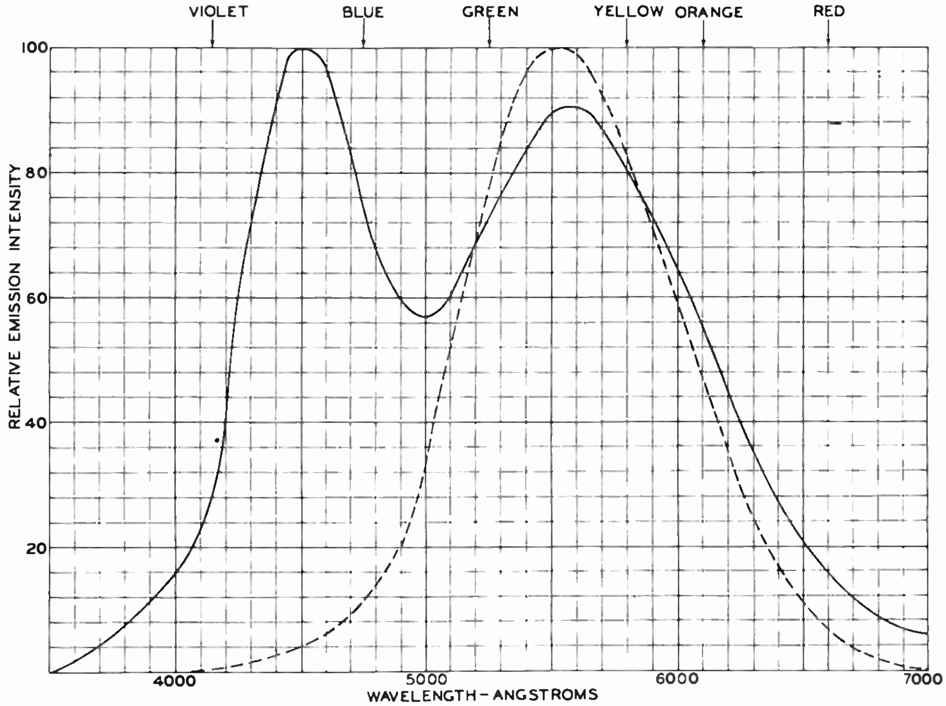


Fig. 7. Luminous Radiation at Various Wavelengths for Phosphor Number 4 (Solid Line) and Luminous Sensitivity of the Average Human Eye (Broken-Line).

Wavelengths are in Angstroms or Angstrom units. One Angstrom is a wavelength of one hundred-millionth of a centimeter or about one 250-millionth of an inch. A wavelength of 5,000 Angstroms, at the approximate center of the visible spectrum, corresponds to a frequency of 600 million megacycles per second. In the emission from phosphor number 4 there are peaks between violet and blue, and between green and yellow, with lesser intensities between blue and green, and at the violet and red ends of the curve. These emissions combine to produce the light seen on the picture-tube screen.

Among other phosphors in general use, number 1 is found on the screens of most oscilloscope tubes. The color of its trace is green. Phosphors 5 and 11 produce a blue trace suitable for photography of oscilloscope traces. Numbers 7, 12, and 14, produce combinations of blue, yellow, and orange traces used for radar observation. Number 15, with a blue-green trace, is used for flying-spot scanning in film reproduction.

The broken-line curve of Fig. 7 shows average human eye response to the various color wavelengths when radiation intensity is uniform for all wavelengths. Maximum eye sensitivity, for normal vision, is to a greenish-yellow hue of about 5,550 Angstroms in wavelength.

In the light or the luminescence appearing on the picture-tube screen there are two effects. One is called fluorescence, the light which ceases instantly when the electron beam moves on. The other is phosphorescence, which causes emission of light from the phosphor particles for an appreciable time after the beam has left a spot on the screen. Phosphorescence accounts for what is called persistence of the particular phosphor considered.

Persistence of phosphor number 4 is long enough to help prevent the appearance of flicker, but is short enough that luminescence remaining at the end of a field period is only a few per cent of the initial value. Persistance which is too long would carry the picture of one frame over into following frames, and objects moving at high speed would be followed by streamers of light.

H. Reflections in Picture Tubes

One of the chief hindrances to satisfactory viewing of television pictures consists of reflection from various picture tube surfaces of light coming from lamps and windows within the room. There is reflection from the front or outside surface of the glass in the tube face and from the back or inner surface of this glass. There is some reflection also from a light colored phosphor.

Reflections may appear as images of lamps or windows superimposed on the television pictures. Even when there are no distinct images the diffused external light reflected back along with the picture has the effect of lightening the areas which should be dark or nearly black and of reducing the contrast. Increasing the contrast control may help, but dark areas still may remain gray in tone. Reducing or shutting off the room lighting will prevent reflection, but this is inconvenient and distasteful to viewers.

Reflection effects may be reduced to some extent by placing in front of the picture tube a thin sheet of glass or transparent plastic lightly tinted with blue or green. These filter screens may increase the apparent contrast. Polaroid filter screens make a decided reduction of reflection from the picture tube and increase contrast by restoring dark areas to their correct tones, but there is considerable loss of overall brightness. This loss may be compensated for with the brightness control if a strong signal is available.

Another approach to reduction of reflection consists of coating the outside of the picture tube face with some material which does not give sharply defined or specular reflection but causes slight diffusion. Still another method consists of changing the shade of the phosphor from very light gray to a much darker gray by adding substances which serve this purpose without interfering with fluorescence. Then there is reduction of light intensity reflected outward from the phosphor. Also the picture light reflected back from the glass surfaces of the tube face is absorbed to a greater extent by the phosphor, and there is less scattering of light from crystals in the phosphor, with the result that definition shows some improvement.

Many of the more recently designed picture tubes have face glass or face plates consisting of a neutral-density filter which often is called a gray filter face plate or which may be identified by trade names such as Filterglass and Teleglas. This kind of glass absorbs much of the light energy entering it from the room so that only a fraction of such light reaches the inner surface and the screen to be reflected back outward. There is, however, relatively little absorption of picture light passing from the screen outward. Picture areas which should be dark, then are little affected by external light and there is increase of apparent contrast.

In addition to reflections from the picture tube itself there may be mirror-like reflections from the front and back surfaces of the protective glass or plastic sheet which is mounted in front of the tube face. Usually it is possible to prevent such reflection by slightly changing the position of the receiver. Some sets have the protective plate tilted slightly outward at the top so that reflected images can be seen only from points near the floor of the room.

I. Screen and Mask Sizes

The image as originally formed in all camera tubes is of width and height proportions shown by full lines of Fig. 8A. The image is a rectangle with width of 4 units and height of 3 of the same units. This gives the standard aspect ratio of 4/3.

Were the image to be completely displayed on the screen of a round picture tube the corners of the rectangle would have to remain within the useful screen diameter. This useful screen diameter may be anything from one to one and one-half inches less than maximum outside diameter of the tube. The outside diameter in inches is roughly equal to the first number of the type designation, being somewhat greater than the type number in most 10-, 12-, and 15-inch tubes, and about equal to the type number or less than the type number in the larger sizes.

In order to provide a larger picture on any given useful screen diameter, many receivers using round picture tubes employed masks which are rounded out at the sides or at both the sides and the top and bottom. One popular mask opening is shown by full lines in Fig. 8B. The picture is enlarged to the size indicated by the broken-line rectangle. Portions of the four corners of the picture thus are cut off, but since there is little of interest in the corners of most television pictures this cutting is not too objectionable.

In Fig. 8C there is additional rounding of the top and bottom of the mask, and loss of the picture corners as shown by broken lines. The circular mask shown by diagram D requires that the height of the picture be increased, beyond the true aspect ratio until the height equals the width. Objects then appear with their height one-third greater than the actual proportion to width in the original image.

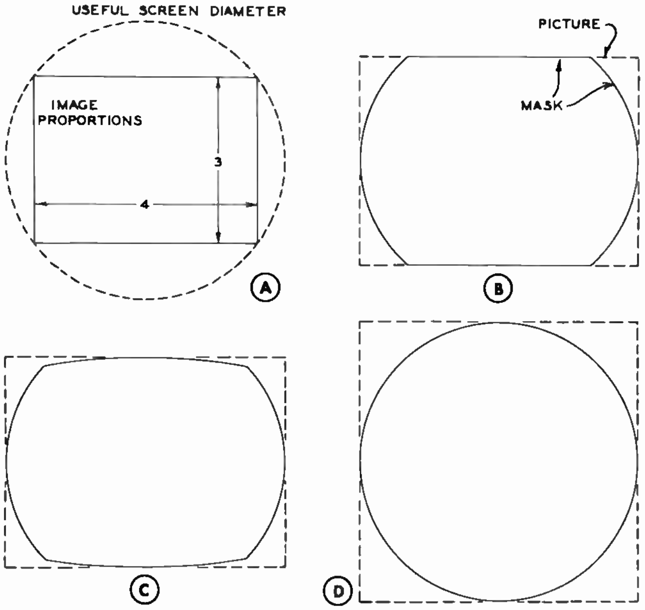


Fig. 8. Picture Areas and Mask Proportions.

With the advent of the rectangular picture tube the problem of either having the picture out of proportion or having a smaller picture has been practically eliminated. As shown in Fig. 9, the face of the rectangular tube is nearly equal to the 4/3 aspect ratio of the transmitted picture.

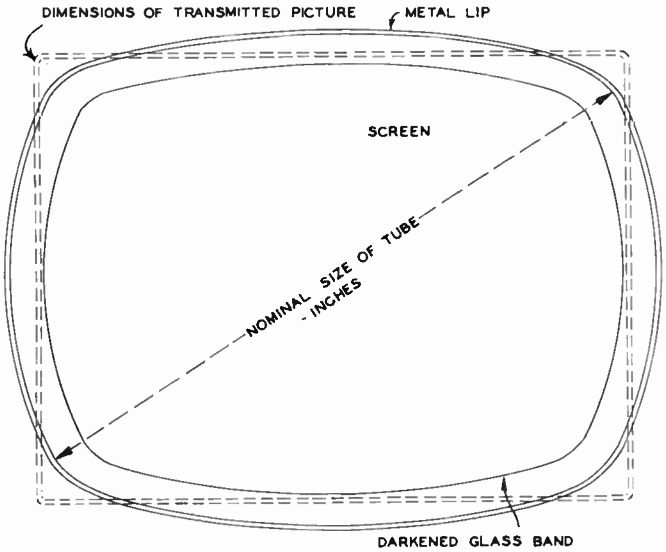


Fig. 9. The Useful Screen Area of a Rectangular Picture Tube is Nearly the Same Proportions as the Standard Aspect Ratio.

J. Spherical and Cylindrical Face Plates

Most picture tubes have spherical face plates, meaning that the outside of the glass face is curved in all directions like the surface of a sphere or ball of large diameter or radius. This construction is shown in Fig. 10. In a typical 27 inch tube the face plate radius may be about 40 inches. Luminous or illuminated objects in various directions from the front of the tube may be reflected from the curved face plate.

Some tubes have cylindrical face plates, as in Fig. 10. The outside of the face is curved from left to right like a section of a cylinder standing vertically, but there is no curvature from top to bottom. There may be reflections from objects at either side, but there is less chance of reflections from above or below the viewing level.

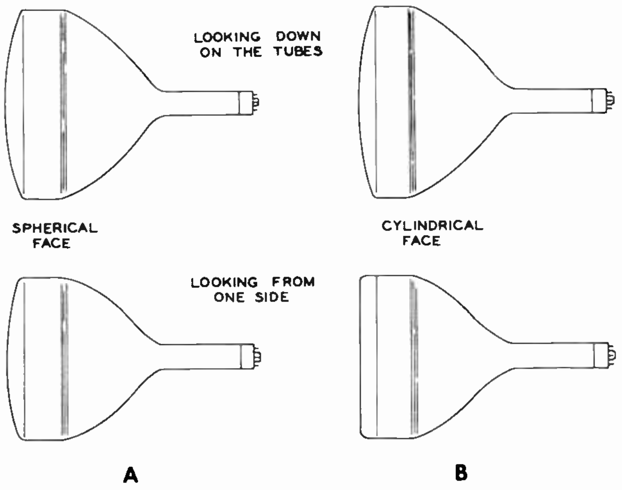


Fig. 10. Comparison of Spherical and Cylindrical Face Tubes.

K. Metal-backed Screens

In a picture tube having an aluminized or metal-backed screen there is deposited over the inner surface of the phosphor coating a very thin layer of aluminum. This layer is so thin that beam electrons penetrate it and excite the phosphor as usual. The principle advantage is increased brightness for any given drive voltage and beam intensity. With two tubes identical except for an aluminized screen in one of them, with both operated at the same element voltages, the one with the metallized screen will show 25 to 40 per cent greater brightness.

The thin layer of aluminum acts somewhat like a mirror in reflecting outward through the face much of the light which otherwise would go back inside the tube. This improves contrast. The metal backing has good electrical conductivity and allows electrons from the beam to more easily flow off the screen. The backing also gives considerable protection should ions reach the screen. The earliest tubes having aluminized screens were used without ion trap magnets, although the electron guns were straight and concentric.

L. Summary Questions

1. What is the heater voltage for the CRT?
2. What is the average negative grid cutoff voltage?
3. What factors affect the deflection of the beam?
4. How do reflections affect the picture?
5. What determines the screen and mask size?
6. What determines the distance of electrostatic deflection?
7. How is the picture centered or positioned in electromagnetic deflection?
8. What are the advantages of the aluminum backed tube?
9. What is the advantage of using a cylindrical face plate?

MULTIVIBRATOR AND BLOCKING OSCILLATOR

Objective:

To study the construction, circuits, and use of the multivibrator and blocking oscillator sweeps.

References:

Lesson Content

A. General

The purpose of sweep oscillators in television receivers and oscilloscopes is to control charging and discharging times of a capacitor which furnishes sawtooth voltages for directly or indirectly deflecting the picture-tube beam vertically or horizontally. A sweep oscillator is essentially an electronic switch shunted across the saw-tooth capacitor. When the oscillator tube is made non-conductive by highly negative grid voltage, Fig. 1A, it allows the capacitor to charge from the power supply through a resistor. Direction of electron flow is shown by arrows. When the oscillator tube is made conductive by positive grid voltage, Fig. 1B, the capacitor discharges through the tube as shown by arrows.

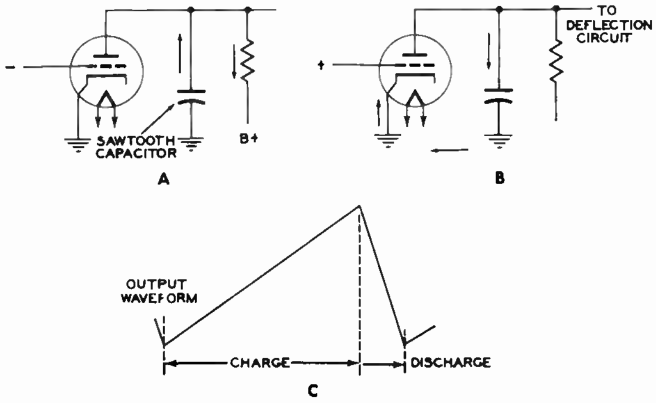


Fig. 1. How a Sweep Oscillator Controls Charge and Discharge of the Capacitor.

Fig. 1C indicates charging of the capacitor is at a relatively slow rate, which produces the gradual rise of sawtooth voltage for causing a horizontal active trace or a vertical downward travel of the beam in the cathode-ray tube. Charging continues while the grid of the tube is held negative. When the grid is made positive there is a rapid discharge of the capacitor (due to sudden drop in plate voltage), producing the sharp drop of saw-tooth voltage which causes horizontal or vertical retrace in the cathode-ray tube. The discharge period lasts only while the grid of the tube is held positive. Capacitor discharge and retrace are immediately followed by another charge and active deflection of the beam. The types of sweep circuits to be discussed are multivibrators, and blocking oscillators.

B. Relaxation Oscillators

A relaxation oscillator is a type in which control-grid voltage is changed by the charging and discharging of a capacitor or inductor through a resistance rather than as a result of oscillations in capacitance and inductance. That is, the operating frequency of the relaxation oscillator depends on capacitive and resistive time constants rather than on resonant frequency in a capacitance and inductance. The output of a relaxation oscillator is not naturally a sine wave, but may be a pulsed wave, a square wave, a triangular wave, a saw-tooth wave, or other forms. The output may be changed to a sine wave by suitable filtering. The charge-discharge capacitor will produce the saw-tooth waveform which is necessary for oscilloscope and TV receiver sweep circuits.

The frequency of a relaxation oscillator may be quite easily synchronized with that of a periodic voltage. The oscillator is adjusted to operate naturally at a frequency slightly lower than the desired rate, and the synchronizing voltage is applied in a manner to hasten the C-D capacitor discharge or the change of grid voltage and thus start each cycle of oscillation in time with synchronizing pulses.

C. Multivibrator Oscillator

One of the earliest relaxation oscillators is the multivibrator, of which a typical circuit is shown by Fig. 2. It should be noted that this style of multivibrator is used for testing and frequency-measuring equipment, but is not the type employed as a sweep oscillator or deflection oscillator in modern television receivers. The oscillator shown here is essentially a two-stage resistance coupled amplifier with the output of one stage fed back as input to the other stage.

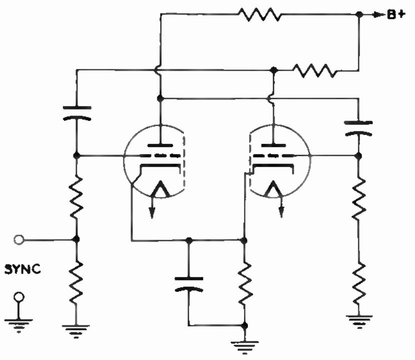


Fig. 2. The Multivibrator Circuit Connections.

Feedback is in such polarity as to reinforce the changes of grid voltage in the first stage, this being due to the fact that voltage is inverted in polarity between grid and plate of any tube. For example, when the grid of the first tube is going positive its plate is going negative. This causes the grid of the second tube to be driven negative, and the plate of that tube goes positive. The positive-going plate voltage from the second tube is fed back and added to the positive-going grid voltage of the first tube, with which the action began.

The feedback voltages which act in the same way as existing grid voltages drive plate current to saturation in one tube and to cutoff in the other tube. Then the actions can continue no further in the original directions, but reverse and again cause saturation and cutoff in the two tubes. The operating frequency depends on the time constant of the capacitors feeding the grids and the resistances between the grids and ground. The frequency may be altered by adjustment of either capacitance or resistance, usually the latter. A synchronizing voltage may be applied to either grid circuit.

D. Time Constant

The time which a capacitor requires to charge to 63 per cent of the impressed voltage is shown as the time constant of the circuit. This can be written as a formula:

$$t - RC$$

where

t = time in seconds.

R = resistance in megohms.

C = capacity in microfarads.

The time constant of the saw-tooth capacitor and charging resistor, in Fig. 1A, is too long to permit charging the capacitor to the full voltage of the power supply during the time in which the tube grid remains negative. The charge is thus limited in order to use only the first portion of the charging curve, which is fairly straight or linear. This helps maintain satisfactory linearity of deflection.

The frequency at which the capacitor is charged and discharged must be the same as the deflection frequency, which is 60 cycles per second for vertical deflection or is 15,750 cycles per second for horizontal deflection in TV receivers. The sweep oscillators usually are either of the blocking type or else are multivibrators. In both of these types, the operating frequency is fixed by combined effects of resistance-capacitance time constants in the oscillator grid circuits and the vertical or horizontal sync pulses coming to these circuits.

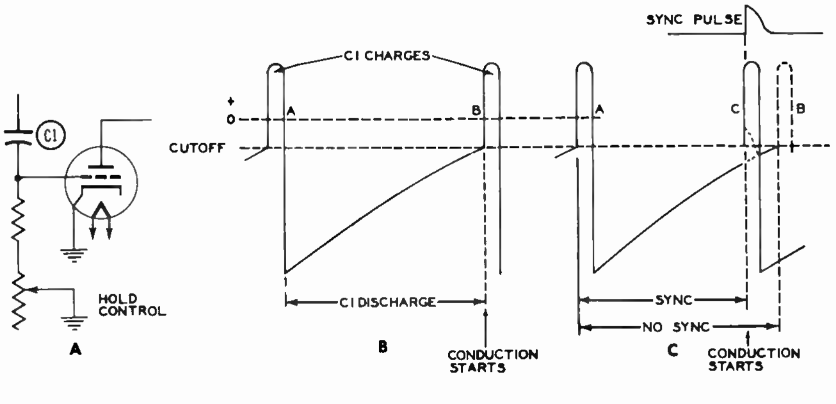


Fig. 3. How the Sync Pulse Controls the Sweep Oscillator Frequency.

Frequency is regulated by adjustment of a grid-circuit resistor which, in connection with a grid circuit capacitor, determines the time period during which the grid remains so negative as to keep the tube nonconductive. The adjustable resistor is a hold control, shown in Fig. 3A. Frequency is adjusted to a rate just a little slower than that of the sync pulses.

In Fig. 3B, changes of grid voltage which would occur in the absence of sync pulses are shown. The principal difference between various blocking oscillator circuits and various multivibrator circuits is in the manner of producing these grid voltage changes. There is at first a short interval, "A", during which the grid is made positive and in which the flow of grid electrons charges grid capacitor C1. At the end of this interval the grid is suddenly made negative to a value well below the plate cutoff value. Then the grid capacitor discharges rather slowly through the hold control resistor until grid voltage rises to the cutoff value, whereupon conduction in the tube starts a train of events which cause the grid again to become positive, at B, and the entire grid voltage cycle repeats over and over.

In Fig. 3C the sync pulse effect is shown. These pulses, of positive polarity, add their potential to the grid voltage just before the instant at which conduction would have started due to the action previously described. The result of adding the sync pulse potential to the grid voltage is to bring the grid voltage above the cutoff value at the instant of the pulse. This starts conduction in the tube, and there is a charging interval at C instead of at B as would have occurred with no sync pulse. The time period from A to C, marked Sync, corresponds to the correct deflection frequency as determined by sync pulse frequency. This time is shorter, or the frequency is somewhat higher, than A to B which is marked No Sync.

The sweep oscillator will continue to act even when there are no sync pulses, as when no television signal comes into the receiver circuits. Action will be at a frequency somewhat lower than signal sync frequency, in Fig. 3B, but there will be continual deflection of the beam in the picture tube.

E. Blocking Oscillator

Fig. 4 shows a typical circuit for a blocking oscillator. Grid capacitor C1, the hold control resistor, and the saw-tooth capacitor have been shown in preceding figures. The size-control resistor of Fig. 4 is equivalent to the charging resistor of Fig. 1. There is inductive feedback from plate to grid of the oscillator tube through the transformer. Transformer connections are such that feedback is of a polarity which increases the grid voltage in which ever way it is already changing. That is, the feedback is positive or is regenerative. Sync pulses are applied to the grid circuit through the grid winding of the transformer.

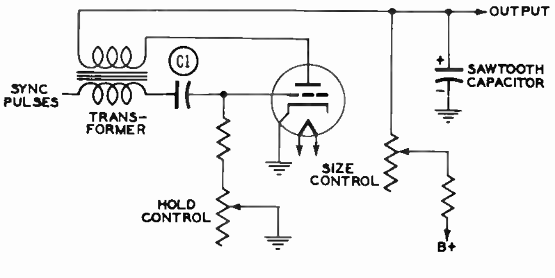


Fig. 4. Blocking Oscillator Connections.

There are continual changes of plate current in the tube, but to explain the action we shall commence with a period during which plate electron flow is increasing in the tube and in the plate winding of the transformer. At this time the grid voltage is becoming less negative or more positive, which accounts for the increase of plate electron flow. Regenerative feedback makes the grid still more positive. As the grid becomes positive there is an electron flow in the grid circuit, which charges capacitor C1 to make the side toward the grid of negative polarity. The charge voltage will reach approximately the peak value of feedback voltage. This action is like that occurring with grid-leak bias.

Feedback from the plate circuit continues because the plate electron flow continues to increase. The increase of electron flow in the plate circuit is not instantaneous because it is acting through inductance of the transformer plate winding wherein counter-emf slows down the rate of increase. Consequently, the grid is driven more and more positive, which causes plate electron flow to increase to saturation at whatever value is proportional to applied plate voltage. This increase of plate electron flow is shown in Fig. 5A with the simultaneous changes of grid voltage shown in Fig. 5B.

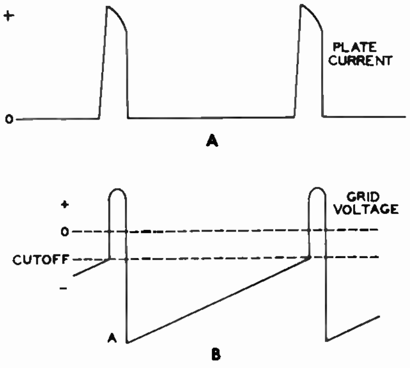


Fig. 5. Changes of Plate Current and Grid Voltage in a Blocking Oscillator.

The length of time for the plate electron flow to reach saturation increases with more inductance in the transformer. It is desirable to have small inductance and small distributed capacitance to lessen this time and keep the plate electron pulses narrow or of short duration, for retrace time cannot be short unless these pulses are short. When the plate electron flow reaches saturation there is no further change of electron flow; therefore, no further induction through the transformer and no further feedback. Grid voltage then commences to drop toward zero.

The negative-going grid voltage decreases the plate electron flow. This decrease is a change which again causes feedback, but now the feedback polarity is such as to drive the grid more and more negative, which in turn, causes further decrease of the plate electron flow until this electron flow drops to zero. Now the charge which was placed on grid capacitor C1 forces the grid voltage to a negative value far below cutoff, at A, in Fig. 5B. The capacitor discharges slowly through the hold control resistance, allowing the grid to become less and less negative until reaching cutoff voltage or until a sync pulse brings the grid voltage to or above cutoff. When this happens there is a new pulse of plate electron flow and the entire action repeats.

F. Discharge Tube

In some receivers the charge and discharge of the saw-tooth capacitor are controlled by a discharge tube which is made alternately conductive and nonconductive by a blocking oscillator. Typical connections are shown by Fig. 6. The oscillation and discharge functions usually are performed by the two sections of a twin triode tube.

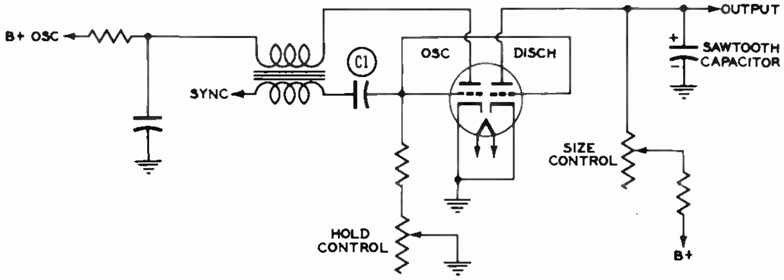


Fig. 6. Discharge Tube Used with a Blocking Oscillator.

Oscillator connections are essentially the same as in Fig. 4, except that the oscillator plate is connected through the transformer plate winding to the B+ voltage for this section of the tube rather than to the saw-tooth capacitor and the output. The two cathodes are connected together and to ground. The two grids are connected together. Then changes of grid voltage in the discharge section must be exactly the same, and must occur at the same time, as in the oscillator. The plate of the discharge section connects to its own B+ voltage through the size control, also to the saw-tooth capacitor and the output, just as does the plate of the oscillator in Fig. 4.

While the oscillator grid voltage is so negative as to prevent conduction, there likewise can be no conduction in the discharge section, and there is charging of the saw-tooth capacitor from the B+ supply. When the oscillator grid voltage becomes positive, the saw-tooth capacitor discharges through the discharge section.

With a discharge tube in the circuit the B+ voltage applied to this tube, and to the saw-tooth capacitor is made higher than B+ voltage on the oscillator, thus allowing a higher charge voltage on the saw-tooth capacitor and a stronger sawtooth signal voltage for the following deflection circuits. The relatively low B+ voltage on the oscillator allows smaller electron flow at the saturation, a quicker change of the plate electron flow, and faster action or higher frequency.

G. Cathode-Coupled Multivibrator

Multivibrator sweep oscillators employ two triodes or two sections of a twin triode, as in Fig. 7, so connected that changes of plate voltage or cathode voltage from each section are applied to the grid of the other section to make the sections alternately and oppositely conductive and nonconductive. The two sections are coupled through the common cathode resistor R1. Section B is shunted across the saw-tooth capacitor to control charge and discharge of that capacitor as this section is made alternately nonconductive and briefly conductive. The saw-tooth capacitor is charging while section B is cut-off and discharging while section A is cut-off. This is shown pictorially in Fig. 7.

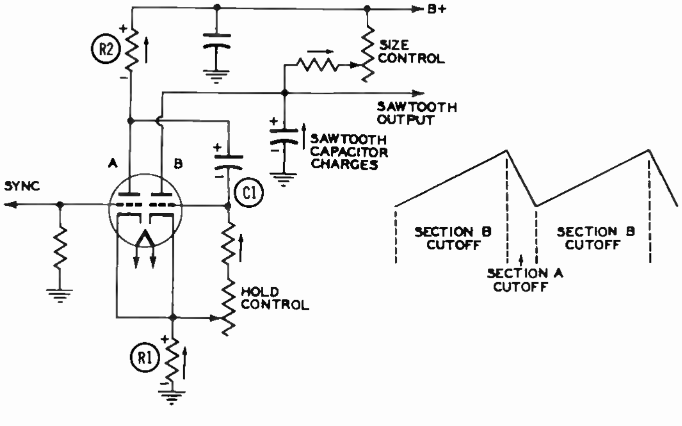


Fig. 7. A Cathode-Coupled Multivibrator Circuit.

The action may be presumed to begin with electron flow as shown by the arrows, and occur when B+ voltage is applied to the circuit. One electron path is through cathode resistor R1, the hold control resistor, capacitor C1, and resistor R2 to B+. Capacitor C1 is charged in the polarity marked.

We can begin the cycle by assuming C1 is discharging. The direction of electron flow is shown by the arrows in Fig. 8. This flow makes the grid of section B sufficiently negative with respect to its cathode to keep section B at cut-off.(See polarity markings on grid B resistors in Fig. 8.)

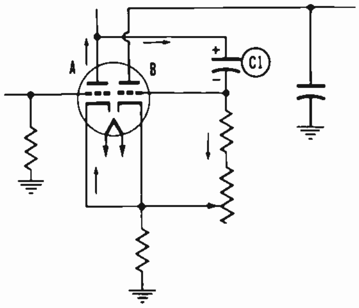


Fig. 8. Actions in the Grid and Plate Circuits While C1 is Discharging.

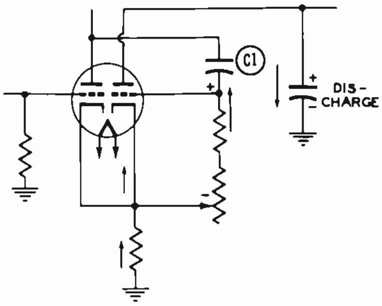


Fig. 9. Actions in the Grid and Plate Circuits While C1 is Charging.

Eventually C1 will discharge to a point where the discharge current will no longer hold the grid of section B negative enough to keep this section cut-off. We have now reached the uppermost peak of the waveform shown in Fig. 7.

When section B starts conducting, the cathode current suddenly increases causing the cathode voltage to go more positive with respect to ground. Since grid A is returned to ground, this action is in effect the same as applying a large negative grid voltage to section A. This voltage is great enough when section B is conducting heavily to keep section A cut off. The section A plate voltage increases to a value near the B plus voltage while section A is cut off.

Capacitor C1 will, therefore, start charging again. This charging current will cause grid B to go positive with respect to its cathode, maintaining high cathode current and voltage. At this time the discharge capacitor is discharging through section B. Electron flow during this portion of the cycle is shown in Fig. 9.

When capacitor C1 is fully charged the positive voltage on the grid of section B will decrease causing a drop in section B plate current. This will in turn drop the cathode potential and allow section A to start conducting. The resulting drop in plate voltage in section A is coupled through C1 to drive grid B more negative. The combination of these two actions soon cuts off section B and we are at the lowest point of the waveform in Fig. 7, ready to start another cycle.

Operating frequency of the oscillator is determined in the absence of sync pulses by the charge and discharge time of capacitor C1, whose potential fixes the time at which section B of the tube is made conductive to allow discharge of the saw-tooth capacitor. Discharge time for capacitor C1 is varied by adjustment of the hold control resistance.

Sync-pulse voltages of negative polarity come to the grid of section A while this section is conductive, as in Fig. 8. The pulse voltages are amplified and inverted by this section, and are applied through capacitor C1 to the grid of section B. The amplified pulse, now positive, makes the grid of section B positive. Thus this section becomes conductive at the instant of each sync-pulse voltage, and allows discharge of the saw-tooth capacitor. The condition represented in Fig. 9 lasts during only the very brief period of discharge for the saw-tooth capacitor.

Fig. 10 shows the circuit of a multivibrator sweep oscillator with which coupling between the tube sections is not through a common cathode resistor but is through capacitors C1 and C2 connected between the plate of each section and the grid of the other section. Section B acts as an electronic switch across sawtooth capacitor C3 to control charge and discharge of this capacitor and this section is made alternately nonconductive and conductive by charge and discharge of grid capacitor C2. The saw-tooth capacitor is charged through the size control resistance.

An increase of the plate electron flow in section A lessens its plate voltage because of more voltage drop in resistor R1. The less positive plate voltage, applied through capacitor C2 to the grid of section B, makes that grid less positive or more negative. This change of grid voltage decreases plate current in section B and there is an increase of plate voltage on this section because of less drop in the size control resistance. The increased plate voltage or more positive plate voltage is applied through capacitor C1 to the grid of section A, making the grid still more positive and causing further increase of plate current and drop of plate voltage in that section until the plate electron flow reaches saturation.

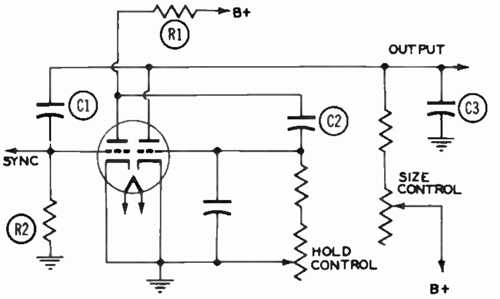


Fig. 10. A Capacitor-Coupled Multivibrator Circuit.

Capacitor C2 now is charged in a polarity and to an extent of making the grid of section B negative beyond the value for cut off of plate electron flow. This condition continues until capacitor C2 discharges through the hold control resistance sufficiently to allow resumption of plate electron flow in section B. Then an increase of plate electron flow in section B drops the plate voltage on this section, and the effect is carried through capacitor C1 to make the grid of section A become negative. Currents and voltages now are changing in polarities opposite to those first assumed. This action continues until there is plate electron flow cutoff in section A while capacitor C1 discharges through grid resistance R2. At the completion of this discharge there will be an increase of plate electron flow in section A, and the whole process repeats.

Sync pulses of negative polarity are applied to the grid of section A, are amplified, inverted, and applied to the grid of section B to make B conductive and allow discharge of the saw-tooth capacitor at the instant of the pulse voltages. The small capacitor from the grid of section B to ground bypasses high-frequency interference voltages which otherwise might act like sync pulses and trigger the tube.

H. Summary Questions

1. What is the purpose of a sweep oscillator?
2. Explain briefly the operation of the types of sweep oscillators.
3. Explain the need for time constants in the grid circuits of the sweep oscillator.
4. What is the purpose of the charge-discharge capacitor. Explain its action.

VERTICAL SWEEP CIRCUITS

Objective:

To study the basic circuits used to produce the sweep currents required by the vertical deflection coils.

References:

Lesson Content:

A. General

The vertical oscillator is used to produce changes of current, which are then amplified by the vertical output tube, and then applied to the vertical deflection coils to deflect the electron beam from the top to the bottom of the picture tube, and return the beam to the top during blanking periods. We shall now discuss the operating principles of the vertical deflection system.

B. Formation of Saw - Tooth Current

Lesson 21 discussed the operation of the blocking oscillator and multivibrator circuits for generating a saw-tooth voltage waveform. A saw-tooth voltage waveform is needed for the deflection of the electron beam in an electrostatically deflected picture tube such as used in oscilloscopes and early 7" television receivers.

Present day television receivers employ picture tubes with magnetic deflection. In magnetically deflected picture tubes, deflection is obtained by means of the magnetic field which is set up by a saw-tooth current in the deflection coils contained in the yoke mounted around the neck of the picture tube.

In order to obtain the saw-tooth current waveform needed for deflecting the electron beam from the top to the bottom of the screen and returning it to the top again a trapezoidal voltage is needed, since a saw-tooth voltage will not produce the correct current waveform needed for deflection.

To understand why this is the case let us first review the theory of inductance. Assume that we have a coil of pure inductance, which contains no resistance at all, and impress a square-wave voltage across it. The instant the voltage is applied to the circuit the voltage across the coil will immediately rise to the maximum value; however, the current through the coil will gradually increase to its maximum value.

The reason for the gradual increase in current is that surrounding an inductance carrying a current, a magnetic field is present whose intensity is proportional to the strength of the current. If the current is changed in value, the magnetic field also changes in value. This magnetic field sets up a storage of energy which requires a certain expenditure of energy for its production. The expenditure of new energy is required only when we attempt to change the amount of flux associated with the inductor by changing the value of current through the inductor. This energy then appears as a "self induction" voltage which tends to oppose the voltage applied to the circuit to start the current flow. When the current in the inductor is increasing, due to an increase in the applied voltage, the self-induction voltage tends to retard the current flow and make it "lag" in respect to the applied voltage.

Fig. 1 illustrates the current waveform which would be obtained if a symetrical square wave was applied across the coil which we assume has no resistance. At point A the input voltage (E_I) and the voltage across the coil (E_L) both rise to their maximum value; however, the current through the coil (I) starts its gradual, linear increase in value. At point B the voltages E_I and E_L both drop to minimum and the current starts its gradual decrease in value since the self inductance of the coil serves as a driving potential to produce a linear decrease in current from point B to point C.

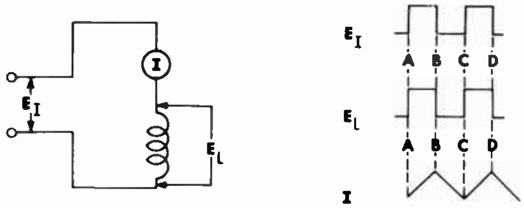


Fig. 1. A Square-Wave Voltage Will Produce a Saw-Tooth Current in a Pure Inductance.

This produces a triangular current waveform through the coil. If we can lengthen the "rise" portion and decrease the "decay" portion of the waveform we will have the waveform needed for deflection of the beam. This can be done if we apply the waveform shown in Fig. 2A to the coils.

Since it is impossible to make a coil without resistance we must also examine the effects of the resistance of the windings on the waveform. Fig. 2B shows a pure resistance in the circuit in place of the pure inductance of Fig. 2A. With a pure resistance in the circuit the current is in phase with the voltage and a saw-tooth voltage (E_R) applied to the circuit will produce a saw-tooth current (I_R) in the resistance.

Fig. 2C illustrates a practical deflection coil. The resistor and coil in series represent the resistance and inductance which are present in any coil. The input voltage E_T is a combination of the rectangular voltage (E_C) and the sawtooth voltage (E_R). Actually this waveform is the sum of the instantaneous pulse and a sawtooth.

The sawtooth or linear rise of the trapezoidal wave will produce a sawtooth wave of current through the resistive portion of the circuit. The instantaneous pulse portion of the wave will produce a sawtooth wave of current through the inductive part of the circuit. I_T in Fig. 2C shows the resulting current waveform which is needed for proper deflection of the electron beam on the picture tube screen.

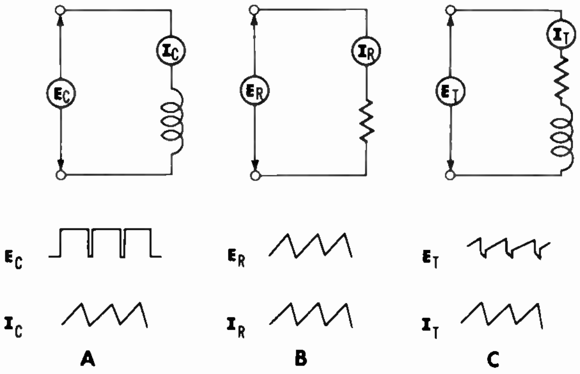


Fig. 2. Voltage and Current Waveforms Inductance and Resistance Circuits.

C. The Vertical Oscillator

The blocking-oscillator and multivibrator circuits in Lesson 21 produced a sawtooth-voltage waveform; however, as we have now learned, a trapezoidal voltage or saw-tooth current waveform is needed for magnetically deflected tubes. A trapezoidal voltage waveform can be produced by a simple change in the basic circuit as shown in Fig. 3.

The only change made in the circuit is the addition of peaking resistor R2. The formation of the trapezoidal wave is as follows.

When the sawtooth capacitor (C1) discharges, the electron flow is through the peaking resistor (R2) and through the tube, as shown by the arrows in Fig. 3. The rate at which the capacitor discharges is thus slowed down as determined by the time constant of C1 and R2. This time constant is long enough to prevent complete discharge of the capacitor while the tube is conductive. While the grid is positive the voltage across the tube between plate and cathode and also across C1 and R2 drops all the way from A to C on the curve.

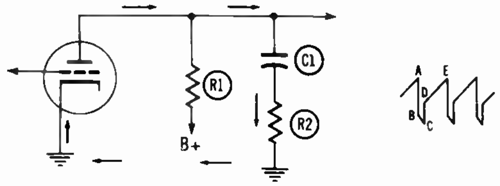


Fig. 3. Vertical Peaking Circuits Which Forms the Trapezoidal Waveform.

The voltage across the capacitor cannot change instantly, since its discharge path through R2 and the plate resistance of the tube is not zero. The difference in voltage must therefore appear suddenly across the peaking resistor R2. After this initial sudden change of voltage, the capacitor discharges exponentially, through R2 and the tube, until the tube again becomes nonconductive at point D on the curve.

As the tube is cut off, the B+ potential is suddenly applied to the capacitor through R2 and R1. Again, the capacitor voltage cannot rise instantaneously. The voltage across R2 must once more change abruptly after which the capacitor charges in its normal fashion along the curve from D to E, and another cycle is started.

In some circuits R1 is adjustable. The time constant is then changed and more or less charge is retained on the saw-tooth capacitor. This will alter the instantaneous rise of voltage which follows the discharge, changing the distance between C and D on the curve and, of course, the slope of the saw-tooth voltage rise between D and E.

1. Blocking Oscillators

Fig. 4 shows a typical blocking oscillator circuit used in a commercial television receiver. The operation of this circuit was discussed in the previous lesson. Sync pulses are applied via

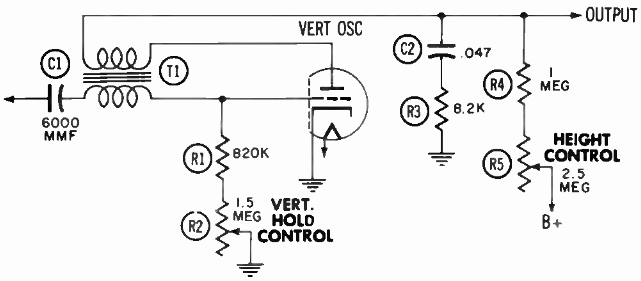


Fig. 4. Partial Schematic Diagram of a Typical Vertical Blocking Oscillator.

C1. The sawtooth-forming capacitor is C2 and the peaking resistor is R3. The vertical hold control (R2) varies the free-running frequency of the oscillator by changing the time constant of the R-C network in the grid circuit. R5 varies the height by changing the time constant of the charge path and changing the amplitude to which the saw-tooth capacitor is allowed to charge before the tube conducts.

2. Multivibrators

A typical commercial cathode-coupled multivibrator circuit is shown in Fig. 5. Operation of this circuit was explained in Lesson 21. R1 is the common cathode resistor. R5 controls the free-running frequency of the oscillator. By decreasing the grid resistance of V1B the frequency is increased and by increasing the resistance in the grid circuit the frequency is decreased. R6 varies the height by controlling the amplitude of the saw-tooth waveform which is developed across C3 and R7, the sawtooth-forming capacitor and peaking resistor respectively.

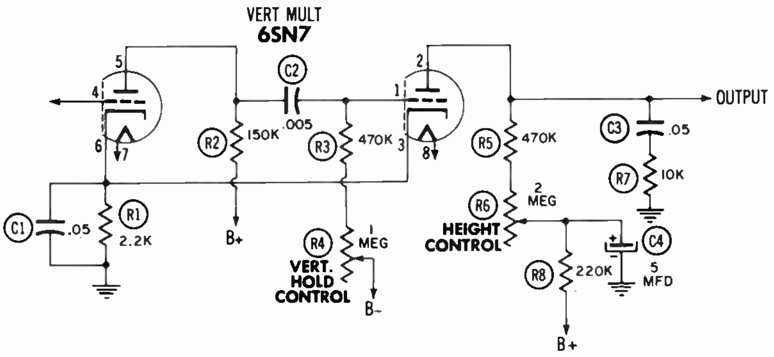


Fig. 5. A Cathode-Coupled Multivibrator Circuit Used in Vertical Sweep Circuits.

D. The Vertical Output Stage

In a number of receivers employing magnetic deflection for the picture tube, we find a vertical sweep system similar to that in Fig. 6. These circuits extend from the plate of the vertical oscillator or discharge tube through to the vertical deflection coils which are part of the deflection yoke on the neck of the picture tube.

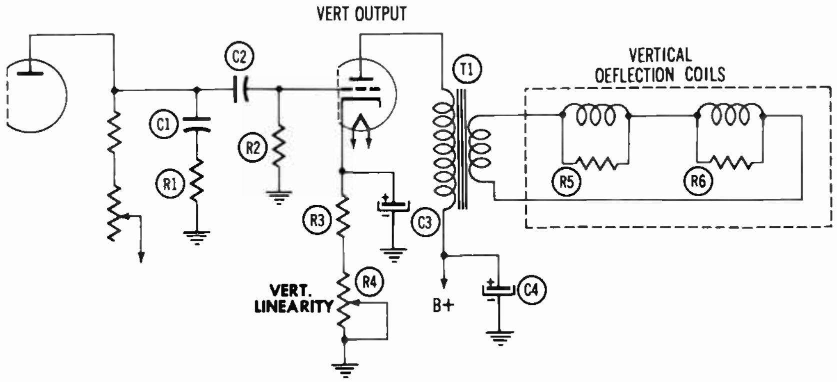


Fig. 6. A Typical Vertical-Output Circuit.

The vertical-amplifier tube may be a power triode, or a power pentode, or it may be either a pentode or a beam-power tube connected with its plate and screen tied together to act as a triode. The height control resistor in the B+ lead to the oscillator or discharge tube, the saw-tooth capacitor C1, and the peaking resistor R1 have been described earlier. The purpose of resistor R1 is to retard the discharge of the saw-tooth capacitor, thus producing the trapezoidal voltage waveform required to produce a saw-tooth current in the magnetic deflection coils.

The sweep amplifier is biased by grid rectification due to grid capacitor (C2) and grid leak resistor (R2) action, and also by cathode bias resulting from the voltage drop across the resistors between cathode and ground or B-. The cathode bias is adjusted by the vertical linearity control R4. This permits shifting the point on the grid-voltage plate-current curve the tube operates on. This changes the amplification characteristic of the input sweep signal. In this way the input signal can be "distorted" slightly so that a more linear sweep is provided, since the output of the vertical oscillator is rarely perfectly linear.

The output-amplifier plate circuit includes the primary of the vertical-output transformer. In the secondary circuit of this transformer are two vertical deflection coils. Across each coil is shunted a resistor (R5 and R6) which prevents oscillating currents from being set up by the inductance and capacitance in the coil circuit.

As mentioned before, there are many variations of the basic vertical-output circuit. Sometimes 1/2 of a twin-triode tube is used as a blocking oscillator and the other half is used as the vertical-output tube. Other manufacturers use a power-pentode tube. An autotransformer type vertical-output transformer is used in many receivers instead of the isolation-type transformer shown in Fig. 6. The circuit in Fig. 7 uses a pentode tube (connected as a triode) and an autotransformer type vertical-output transformer.

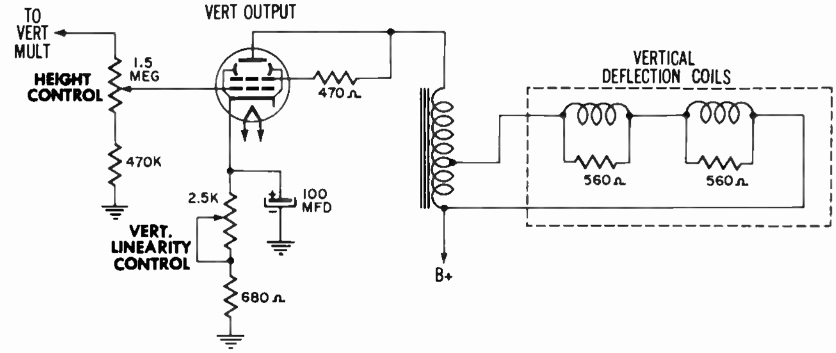


Fig. 7. A Vertical-Output Circuit Employing a Pentode Tube (Connected as a Triode) and An Autotransformer.

E. Combination Vertical Multivibrator-Vertical Output Tube

Another method employed for vertical sweep is illustrated in Fig. 8. This circuit uses one section of a twin triode tube as 1/2 of the multivibrator and the other half serves the dual function of a vertical multivibrator and vertical-output tube. The circuit in Fig. 8 is the same as the basic unbalanced multivibrator, with the circuit designed so that V2 will conduct longer than V1. This is accomplished by making the time constant of C7-R9 much longer than C2, R1, and R4. The trapezoidal waveform is formed across C6 and R10, the saw-tooth capacitor and peaking resistor respectively. This waveform is coupled to V2 through C7. In this stage the waveform is amplified to the desired height before it is fed to the deflection coils.

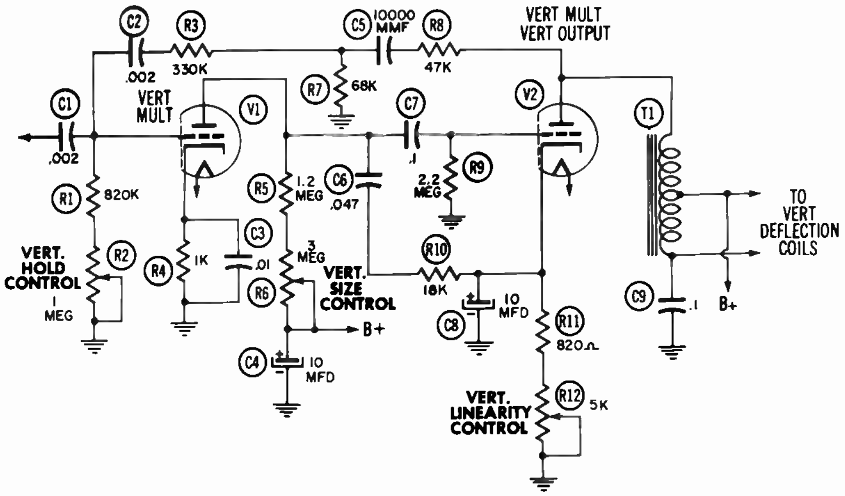


Fig. 8. The Output Tube in This Circuit also Functions as Part of the Multivibrator.

F. Vertical Retrace Blanking

Many television receivers employ a vertical retrace blanking circuit to blank out any vertical-retrace lines that might appear on the face of the picture tube. Vertical-retrace lines appear as white horizontal lines extending in an upward direction on the picture tube face. While the transmitted signal incorporates a blanking pulse to eliminate this condition, the effectiveness of the blanking pulse is sometimes restricted by various conditions in the receiver. These lines are actually horizontal trace lines which occur during the vertical retrace period. For purpose of designation they are referred to as vertical-retrace lines.

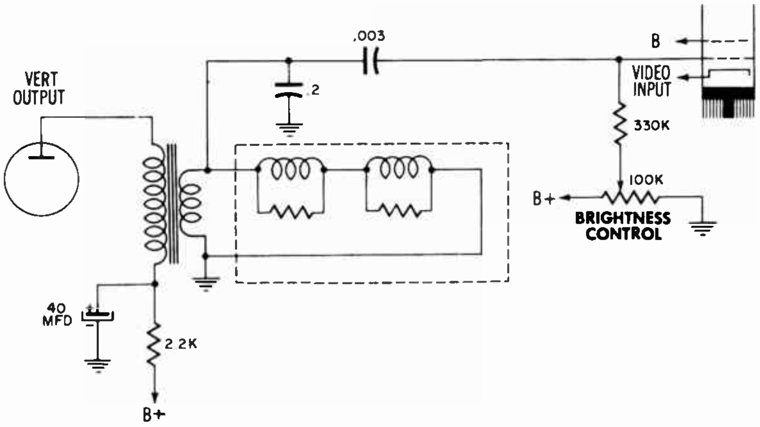


Fig. 9. Vertical-Retrace Blanking Circuit Applying a Negative Pulse to the Picture-Tube Grid.

The method employed in many receivers to eliminate vertical retrace lines consists basically of a circuit to couple a pulse voltage from the vertical deflection circuit to one of the elements of the picture tube. When this pulse, of proper polarity, is applied to the picture tube the electron beam is cut off. A negative going pulse is fed to the grid of the picture tube and a positive going pulse is desired if the pulse is to be applied to the cathode of the picture tube.

There are a number of ways in which the picture tube may be driven beyond beam cut off during the vertical retrace period. Fig. 9 shows a negative-going pulse being taken from the vertical output transformer secondary and applying it to the picture-tube grid.

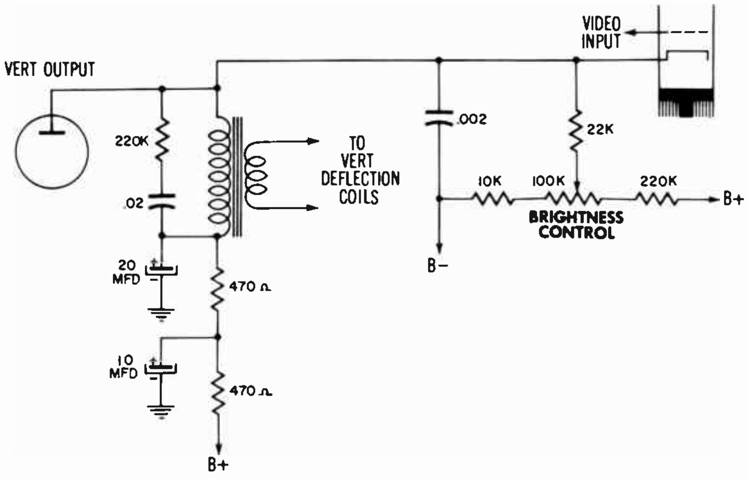


Fig. 10. Vertical-Retrace Blanking Being Applied to the Picture-Tube Cathode.

Another method of applying vertical-retrace blanking is shown in Fig. 10. Here the pulse is taken from the vertical-output tube plate and applied to the picture-tube cathode.

Still another method of obtaining the vertical-blanking pulse is illustrated in Fig. 11. A lead is connected between the picture-tube grid and the peaking resistor.

The pulse voltage can be taken from other points in the vertical circuit also. The important thing to remember is that if the pulse voltage for retrace blanking is to be applied to the picture-tube cathode the pulse must be of a positive-going polarity. If the pulse is to be applied to the picture-tube grid a negative-going pulse must be used.

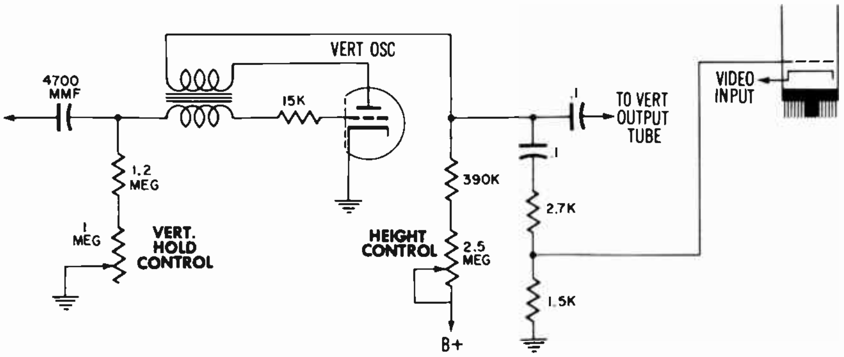


Fig. 11. A Circuit Where the Blanking Signal is Obtained From the Peaking Network.

HORIZONTAL SWEEP CIRCUITS

Objective

To study the basic circuits used to produce the sweep currents required by the horizontal-deflection coils.

References

Lesson Content

A. General

The horizontal oscillator is used to produce changes of current which cause correct horizontal deflection of the picture-tube electron beam during active lines, and to return the beam to the left hand edge of the picture during the blanking periods. We shall now examine the operating principles of a horizontal-deflection system.

B. Beam Deflection

When using 525 lines and 30 frames per second, making a horizontal deflection frequency of 15, 750 cycles per second, each complete line period (active and retrace) takes about 63.5 millionths of a second. About 10 millionths of this time is required for retrace during the horizontal blanking time, leaving about 53.5 millionths of a second for the active horizontal line. For magnetic deflection, current in the deflecting coils then must increase steadily from a minimum to a maximum value during 53.5 millionths of a second in order to carry the beam from one side of the screen to the other, and during the following 10 millionths of a second the current must decrease to its original minimum value. Fig. 1 shows these changes of current. A current or voltage rising and falling in this manner is called a saw-tooth wave. In practice, the wave will not be exactly a sawtooth due to resistive and reactive elements in the entire deflection system.

The action of the oscillator tube and discharge tube were discussed earlier in this book. By varying the height of the saw-tooth wave in Fig. 1, you would vary the total amount of sweep amplitude and thereby vary the total amount of deflection of the beam. Since the beam is being moved horizontally by this circuit, you would then be changing the width of the picture. Fig. 2 shows one way of accomplishing this.

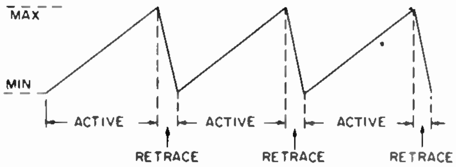


Fig. 1. The Sawtooth Wave of Current Required for Deflecting the Electron Beam.

Another way to adjust the width would be to place a variable capacitor across R_g which would by-pass some of the signal. By increasing capacity, more of the signal will be bypassed to ground and a narrow picture will result.

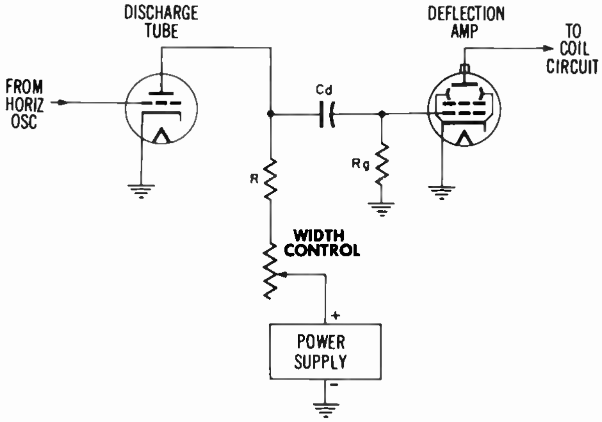


Fig. 2. How a Capacitor May Be Charged and Discharged to Produce a Sawtooth Wave of Potential.

C. Control of Oscillator

In many television receivers there is automatic control for the frequency of the sweep oscillator. The purpose of such AFC systems (automatic frequency control systems) is to keep the oscillator frequency under the sole control of the sync pulses. An AFC system acts to prevent momentary loss of synchronization which might result from interference due to sparking electrical devices or from other "noise" effects. The control also compensates for moderate drift of the sweep-oscillator frequency. In its correction of frequency drift, the AFC system acts somewhat as an automatic hold control of limited range, although it seldom replaces the regular hold control.

All AFC systems utilize the same fundamental principle, as follows: Sync pulse voltages are combined with voltages taken from the oscillator tuned circuit or from some point following the oscillator output. The combined voltage waveform is utilized to produce a voltage or current which, when returned to the oscillator circuit, will correct any deviation of oscillator frequency.

A voltage taken from the oscillator circuit or from any point beyond the oscillator output is, of course, varying at the actual frequency of the oscillator and may be either higher or lower than the frequency of sync pulses. An output voltage may be taken from the saw-tooth capacitor, from the plate or screen circuit of the sweep amplifier, or from the secondary circuit of the sweep output transformer, which includes the deflection yoke of magnetic-deflection systems.

Sync pulse voltage and oscillator voltage at their respective frequencies are combined in a control tube which may be a discriminator or a phase detector employing a triode, or a diode tube. In some AFC systems the output of the control tube is fed through a reactance tube to the grid circuit of a Hartley oscillator. In other systems the output of the control tube is fed directly after amplification to the grid of a blocking oscillator or a multivibrator oscillator.

Control voltage or correction voltage applied to the grid of a blocking oscillator must be negative if oscillator frequency is to be made lower, or positive if oscillator frequency is to be made higher. When applied to the grid of the first section of a multivibrator the control voltage must be positive if oscillator frequency is to be made lower, or negative if the frequency is to be made higher.

D. Discriminator and Reactance Tube AFC System

Fig. 3 is a circuit diagram for an AFC system employing a reactance tube and a frequency or phase discriminator for synchronizing a Hartley oscillator in a horizontal-sweep section. A reactance tube uses phase shifting to produce the same effect as varying a capacitor (or in some cases, a varying coil). Capacitor C_k and resistor R_k are the units which apply voltage, at the oscillator frequency in the tank circuit, to the reactance tube cathode. Capacitor C_p is the unit which allows reactance-tube plate current to flow in the oscillator tank, while excluding B+ voltage and direct current. The reactance tube grid circuit extends through a noise filter and through discriminator load resistors R_a and R_b to a source of negative grid bias for the reactance tube. Correction voltage is produced in these resistors.

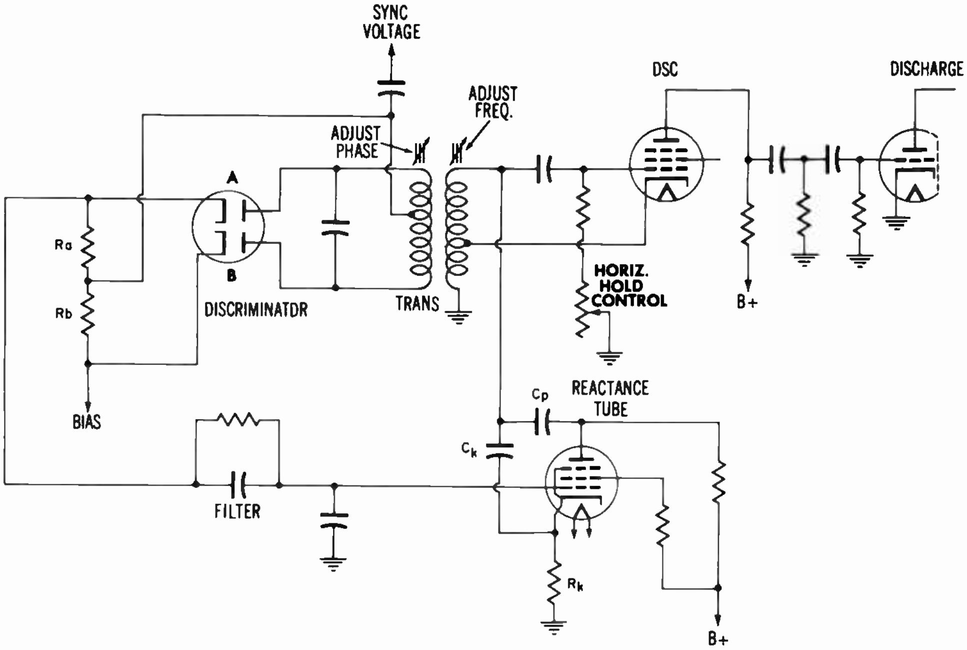


Fig. 3A. Horizontal AFC System Using a Discriminator and Reactance Tube with a Hartley Oscillator.

The oscillator tank inductor forms the primary of a transformer whose center-tapped secondary connects to the discriminator plates. A sine-wave voltage induced in the secondary makes the plate of diode A positive with reference to the center tap while the plate of diode B is made negative, and vice versa. Each diode conducts while its plate is positive.

Conduction current of diode A flows upward through resistor R_a, and conduction current of diode B flows downward through resistor R_b. When the oscillator frequency is the same as the resonant frequency of the transformer secondary, as tuned by the fixed capacitor between diode plates, there will be equal conduction currents and equal but opposite currents in resistors R_a and R_b so far as these currents are influenced only by the sine-wave voltage. Voltages accompanying the currents in resistor R_a and R_b cancel, and no correction voltage is applied to the reactance-tube grid.

If the oscillator frequency is not the same as the resonant frequency of the transformer secondary, diode conduction currents and voltages across R_a and R_b will not be equal. Net voltages or difference voltages across the two resistors will be positive or negative, and will alter the grid voltage and plate-current amplitude of the reactance tube. This would make the oscillator frequency equal to that of resonant frequency in the transformer secondary.

Positive sync pulses come to the transformer secondary center tap and to the junction between resistors R_a and R_b. The positive pulses are rectified to cause conduction currents in the diodes. Because the sync pulses are applied at center points they make the plates of both diodes positive at the same time. Resulting pulses of current are equal and opposite in resistors R_a and R_b, and accompanying voltages would cancel when due only to action of the sync pulses.

Actually the sine waves and sync pulses combine at the two diodes as shown by Fig. 3B. If the oscillator is in time with or is correctly synchronized with the received signals, pulses in both diodes will occur while sine waves go through zero, as shown by the top diagram. These pulses cause equal but opposite voltages which cancel in resistors R_a and R_b of Fig. 3. Then no correction voltage is applied in the grid circuit of the reactance tube.

As the oscillator frequency tends to become fast, or higher than sync pulse frequency, the sine waves will occur earlier. Then the sync pulses will appear while diode A is non-conductive, but B is conductive. More current will flow in diode B and in resistor R_b, and the net voltage across the load resistors will become negative toward the grid of the reactance tube. This reduces oscillator frequency, as is required to restore synchronization.

Should the oscillator frequency become slow, the conditions would be as at the bottom of Fig. 3B. Sine waves would occur later, and during pulse periods diode A would be conductive, with diode B non-conductive. Then more current would flow in resistor R_a to make the net voltage across the load resistors positive toward the reactance-tube grid. This would increase oscillator frequency as required.

The purpose of the filter in Fig. 3A is primarily to furnish a slight time delay for instantaneous changes of correction voltages developed in the discriminator load resistors. Then the correction voltage at the reactance-tube grid is of an average value resulting from several sync pulses, and the control system does not respond to single intermittent pulses of interference or noise. Otherwise, these undesired pulses might cause the picture to jump sideways.

Service adjustments for this AFC system are in the discriminator transformer. A movable slug in the primary alters the resonant frequency of the oscillator tank circuit. This adjustment should be made with the contrast control retarded, brightness turned up, and the horizontal hold control at its mid-position. Should a vertical dark bar (horizontal-blanking bar) appear in the picture, the phasing adjustment is altered to move this bar just outside the picture area.

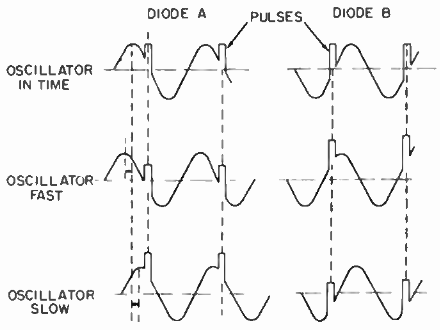


Fig. 3B. How Sync Pulses and a Sine-Wave Voltage Combine at the Discriminator Diodes.

E. Variable Pulse-Width AFC System

Shown in Fig. 4 is a circuit diagram of an AFC system in which the grid voltage and frequency of a blocking oscillator are regulated by varying the time duration or width of the sync pulses. A dual-triode tube is employed as the control tube and blocking oscillator. In the cathode circuit of the control tube V1, resistor R_g is also in the grid-to-ground circuit of the blocking oscillator V2. The voltage across R_g is altered by changes of conduction in the control tube, which are caused, in turn, by differences between oscillator output frequency and the frequency of received sync pulses. The control voltage becomes part of the oscillator grid voltage, and increases or decreases oscillator frequency as may be required for synchronization.

Capacitor C_c in series with resistor R_b, and capacitor C_d are in parallel with resistor R_g. These capacitors are charged by pulses of conduction current through the control tube, and discharge rather slowly. Holding the charges for a fraction of a second prevents the control voltage across resistor R_g from being affected by momentary pulses of interference or noise.

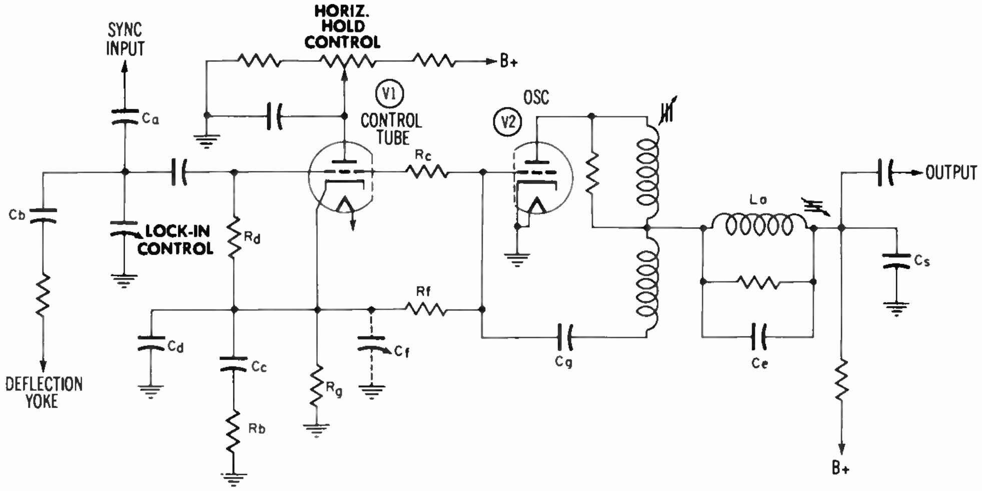


Fig. 4. An AFC System In Which Variation of Sync-Pulse Width Alters the Oscillator Bias.

To the grid of the control tube are applied positive sync pulses coming from the sync section of the receiver through capacitor C_a and the capacitor in series with the grid. A saw-tooth voltage derived from the deflection-yoke circuit is also applied to the grid of the control tube. Sync pulses and the saw-tooth voltage combine at the grid of the control tube, as shown in Fig. 5.

At the top of Fig. 5 are shown conditions when the sweep is in time, which means that frequency of sawtooth voltage from the oscillator output is correctly in synchronization with the received sync pulses. About half of each pulse rides on the sawtooth-voltage peak, and the remainder is down in the trough. The portion of the pulse on top of the peak makes the combined positive voltages great enough to overcome part of the negative bias at the control-tube grid and make this tube conductive.

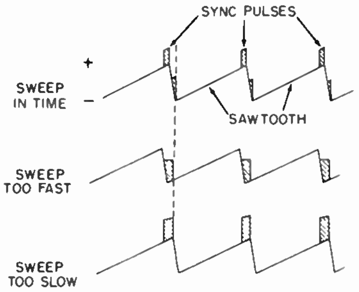


Fig. 5. How the Effective Width of Sync Pulses is Varied By Their Combination with a Saw-Tooth Voltage.

Should the sweep be too fast, meaning that oscillator frequency is too high, a greater part or possibly all of each sync pulse drops into the trough, as shown by the center diagram. This reduces or completely prevents conduction in the control tube. Should oscillator frequency become too low, as shown by the bottom diagram, a greater part or possibly all of each sync pulse rides on top of the saw-tooth peak. This increases the time of conduction in the control tube.

Each period of conduction in the control tube charges capacitor C_c and C_d, which are in the cathode circuit, making the upper plates of these capacitors positive. The greater the total duration of conduction periods in the control tube the greater is the charge and the voltage placed on the capacitors. Since these capacitors are connected across resistor R_g, the positive voltage of the capacitors counteracts more or less of that part of the oscillator negative grid bias which is across resistor R_g.

When oscillator frequency becomes too high there is less charging of capacitors C_c and C_d, and oscillator grid bias is allowed to become more negative. This will lower the frequency of a blocking oscillator. Should oscillator frequency become too low there will be an increase of capacitor charge and voltage. Then the oscillator bias is made less negative and oscillator frequency is increased.

Feedback from plate to grid of the oscillator is through the autotransformer shown at the right of the tube in Fig. 4. An adjustable core in this transformer allows varying the free-running frequency of the oscillator. Output to the sweep amplifier which follows the oscillator is from the transformer tap. On the output line is adjustable inductor L_a, sometimes called a stabilizing coil or waveforming coil. In the inductor L_a and paralleled capacitor C_e is produced a sine-wave voltage which adds itself to the voltage waveform at the oscillator grid to increase effective amplitude of sync pulses which should trigger the oscillator, while reducing effective amplitude of other pulses, including those due to interference and noise.

In some receivers there is an adjustable capacitor C_f in parallel with capacitors C_c and C_d. Adjustment of C_f varies total capacitance which is charged from the control tube, thus varying the charge voltage and its effect on oscillator bias. The adjustable lock-in capacitor in the grid circuit of the control tube acts as a variable bypass to allow greater or less amplitude of combined control voltages to act on the grid of this tube. Instead of an adjustable capacitor a fixed unit may be used in this position. All adjustments mentioned so far are service adjustments. The one front panel adjustment is the horizontal hold control in series with the plate of the control tube. This adjustment varies plate voltage on the control tube and thus alters the amount of charging current for capacitors C_c and C_d.

F. Phase Detector and Multivibrator

Shown in Fig. 6 is a circuit diagram for an AFC system where the correction voltage is developed by a phase detector which changes the grid voltage on a multivibrator sweep oscillator when the oscillator frequency tends to vary from the sync pulse frequency. Positive sync pulses are applied to one plate and negative sync pulses to one cathode of the phase detector from plate and cathode of an inverter which is part of the sync section in the receiver.

To the other plate and cathode of the phase detector, which are tied together, is applied a saw-tooth voltage which originates as pulses from the sweep-output transformer and is changed to saw-tooth form by resistors and capacitors on the line going to the phase detector.

The sync pulses and the saw-tooth voltages applied to the phase detector are shown in Fig. 7. As with any tube containing a cathode and plate, the plate must be positive with respect to the cathode to make the tube conduct. Accordingly, the diodes can conduct only when there are positive sync pulses on the plate of diode A, and negative pulses on the cathode of diode B.

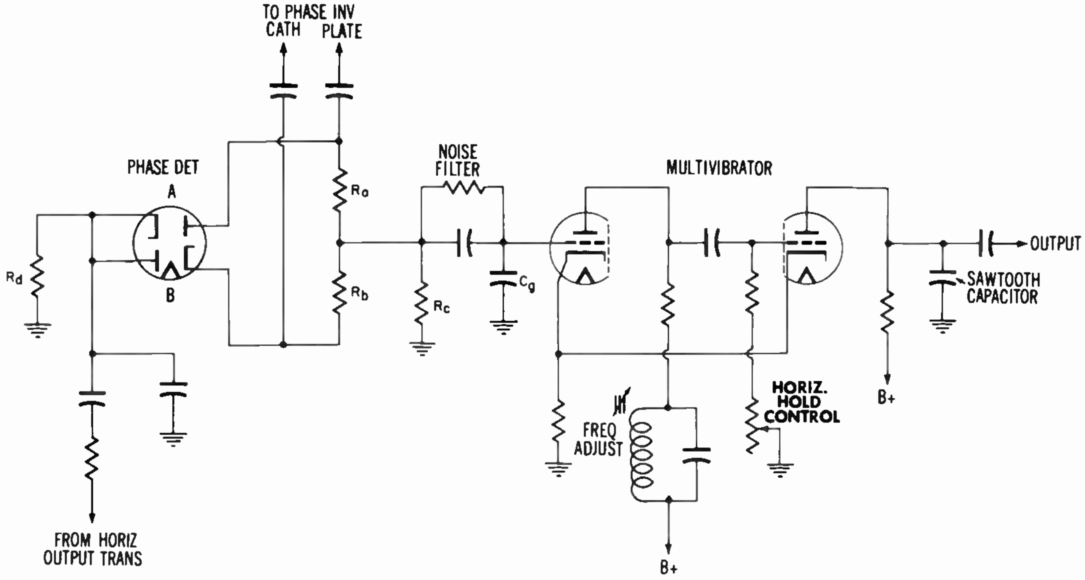


Fig. 6. Phase Detector for Direct Frequency Control of a Multivibrator Oscillator.

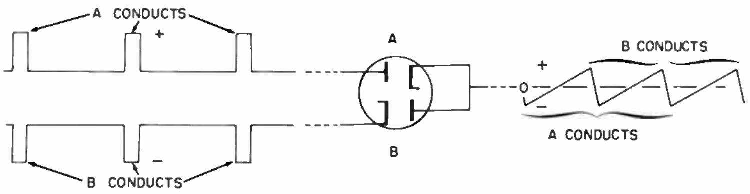


Fig. 7. Sync Pulses and a Saw-Tooth Voltage as Applied to Opposite Sides of a Phase Detector.

Consider next the effects of the saw-tooth voltage which is applied simultaneously to the cathode of diode A and to the plate of diode B. Diode A can conduct only while the sawtooth is on the negative half-cycle, for only then is the cathode of A negative. Diode B can conduct only while the sawtooth is positive, for only then is the plate of B positive. Under the combined effects of the sync pulses and the saw-tooth voltage, neither diode can conduct except during sync pulses, and then only if the saw-tooth voltage is of certain polarity.

In Fig. 8, the sync pulses are marked on the saw-tooth voltages as the sawtooths affect diode A and diode B. Half-cycles which make each diode conductive are in solid lines, with non-conductive half-cycles in broken lines. At 1, the oscillator frequency is correct in relation to received sync pulses. Conduction occurs only while the saw-tooth voltage is at or near zero. There is but little conduction in either diode, and is equal in the two diodes.

At 2 the oscillator frequency has become too low, and its cycles occur slightly later in relation to sync pulses. Then there is conduction in diode A because the sawtooth is on a half-cycle making A conductive. But there is no conduction in diode B because the same sawtooth half-cycle makes B non-conductive. At 3 the oscillator frequency has increased and cycles of saw-tooth voltage occur slightly earlier in relation to sync pulses. Now, there is no conduction in diode A, but there is conduction in diode B.

Diode currents are rectified direct currents which can flow only in conductive paths, not through any of the capacitors. Direct current for diode A follows the path (on Fig. 6) upwards through resistor R_d from cathode to plate in the diode and downward in resistors R_a and R_c. For diode B the direct current flow is upward through resistor R_c, down through R_b, from cathode to plate in the diode, and downward in resistor R_d. Resistor R_c is between the grid and cathode of the oscillator, by way of the noise filter and ground connections. Therefore, any voltage developed across R_c becomes part of the oscillator grid voltage.

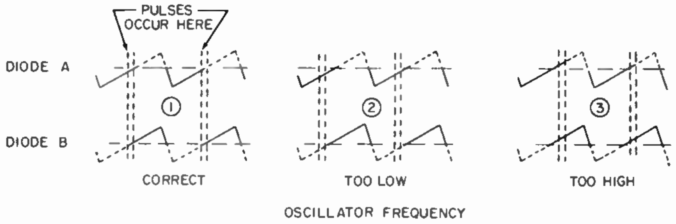


Fig. 8. Conductions in the Phase-Detector Diodes.

Diode currents flow oppositely and partially balance in resistor R_c. When there is a greater conduction in diode A, the top of R_c and the oscillator grid become more negative to increase oscillator frequency. Fig. 8 shows that such conduction occurs when oscillator frequency commences to become lower — so there is correction of frequency. Greater conduction in diode B, resulting from an increase of the oscillator frequency, causes the top of resistor R_c and the oscillator grid to go more positive, or actually less negative. This lowers the oscillator frequency to provide correction.

The only service adjustment for the AFC system of Fig. 6 is marked FREQUENCY ADJUST on the diagram. In the inductor and paralleled capacitor are produced a sine-wave voltage at the frequency of oscillation. This sine wave is added to the voltage at the grid of the second section of the multivibrator. When this added voltage is suitably phased it raises the effective amplitude of sync pulses which should trigger the oscillator, while reducing the effective amplitude of all other pulses, both sync and noise. This stabilizes oscillator frequency in relation to sync pulses. Adjustment consists of setting the inductor core so that with the hold control at its mid-position, the pictures lock into synchronization. The adjustment may be varied slightly to maintain synchronization over the widest possible range of hold control settings.

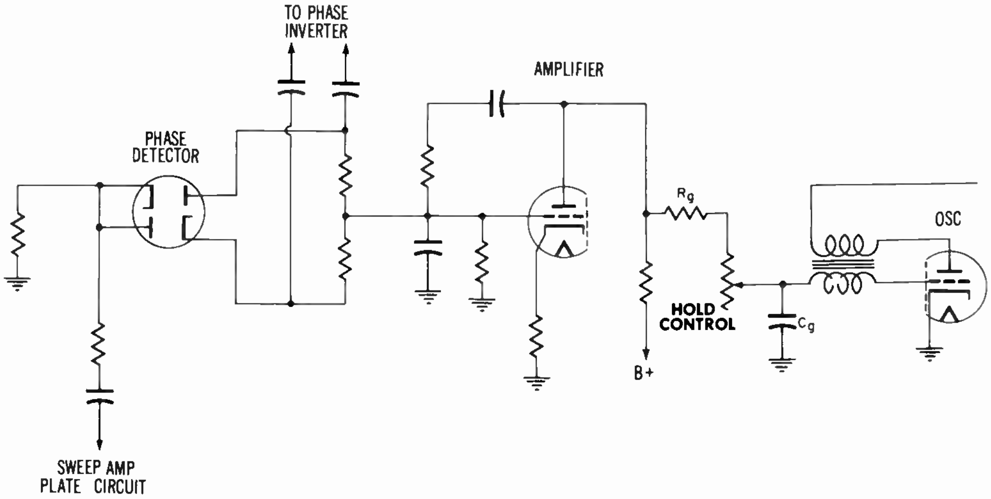


Fig. 9. An AFC System Employing an Amplifier Between a Phase Detector and a Blocking Oscillator.

There are modifications of the phase detector method of automatic frequency control, of which Fig. 9 is one example. Here the correction voltage is strengthened and its polarity is inverted in an amplifier tube between the control tube and a blocking oscillator. In this case, inversion of the correction voltage is necessary because at the grid of a blocking oscillator the effects of positive and negative correction voltages are just the reverse of their effects at the synchronizing grid of the multivibrator.

An amplifier may be used between the phase detector and the grid of the second section of a multivibrator where polarity of the correction voltage must be opposite to that at the first grid in order to have the same effects on oscillator frequency.

G. Triode Phase Detector for AFC

Fig. 10 shows a system which uses a triode AFC tube as a phase detector. Positive sync pulses (1) are taken from the inverter plate and applied to the AFC grid. To this grid is applied a saw-tooth voltage (2) obtained from the plate of the second section of the multivibrator oscillator. The sync pulses and saw-tooth voltage combine at the AFC grid as shown by the waveform at 3. Positive peaks of this composite waveform cause grid current to flow in the path of the broken-line arrows, through resistors R_a and R_b.

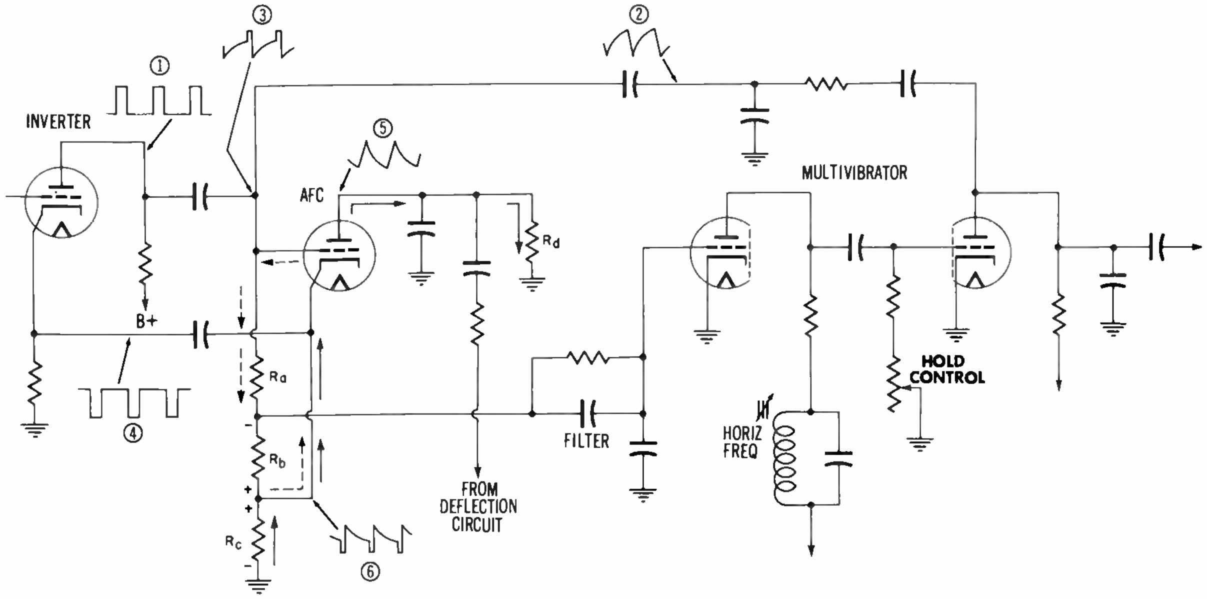


Fig. 10. A Triode is Used as a Phase Detector to Regulate Frequency of the Sweep Oscillator.

Negative sync pulses (4) from the phase-inverter cathode are applied to the cathode of the AFC tube. To the plate of this tube is applied the saw-tooth voltage (5) obtained from the deflection system. Voltages having the waveforms at 5 and 4 combine at the cathode of the AFC tube to produce the plate current waveform at 6. Plate current flows as shown by full-line arrows, from the plate through resistor R_d to ground and from ground through resistor R_c back to the cathode.

The DC return circuit for the first grid of the oscillator extends through the noise filter resistor to the top of resistor R_b, thence through R_b and R_c to ground, and back to oscillator cathode. Voltage due to AFC grid current in R_b tends to make the oscillator grid negative because the negative end of R_b is toward the oscillator grid. Voltage due to AFC plate current in resistor R_c tends to make the oscillator grid positive, because the positive end of R_c is toward the oscillator grid.

Voltage on the oscillator grid will be the difference between the opposing voltages across R_b and R_c and will be of a polarity depending on which of these resistors carries greater current and has a greater voltage drop. When the saw-tooth (oscillator) voltage and received sync pulses are in correct synchronization, grid current and plate current in the AFC tube are such as to produce equal and opposite voltages across resistors R_b and R_c. These voltages cancel and no correction voltage is applied to the oscillator grid.

Should the oscillator tend to run slow, the saw-tooth voltages shift in relation to sync pulses to make AFC grid current greater than AFC plate current. Then the oscillator grid is made more negative to increase oscillator frequency. Should the oscillator tend to run fast, the phase shift of oscillator output and saw-tooth voltages is such as to increase AFC plate current more than AFC grid current. This makes the oscillator grid less negative and decreases oscillator frequency.

The only service adjustment is a movable slug in the inductor marked HORIZONTAL FREQ. This inductor is adjusted so that the picture remains synchronized with the horizontal hold control turned as far as possible in either direction.

H. Functions of the Horizontal Output Tube

The horizontal-output tube's primary function is to supply the sweep currents to the deflection yoke. The output transformer acts in much the same way as the output transformer in a radio set in this respect.

In addition, the output stage delivers energy to the high voltage supply. The Flyback-Power Supply uses the energy in the output transformer and yoke during retrace to supply pulses to the high voltage rectifier. A single tube rectifier circuit will deliver up to about 15,000 volts. Higher voltages are available by using several rectifier tubes in voltage doubler or tripler circuits.

Circuit connections for a typical flyback or pulse-operated power supply are shown in Fig. 11. This style of power supply, shown at the top of the diagram, may be connected to any of the deflection yoke circuits in general use. One such circuit is shown in the lower part of the diagram.

At the instant of plate-current cutoff in the horizontal output amplifier there is a collapse of magnetic fields in the deflection yoke circuit, which include the secondary winding of the output transformer. It is this collapse that starts retrace. The sudden change of magnetic field induces a pulse of negative potential in the secondary. Induction between secondary and primary induces a positive pulse in the primary winding. In the portion of the primary connected between the amplifier plate and damper cathode this pulse potential reaches 4,000 volts or more. The upward extension of the primary makes this winding an autotransformer, and between the top and bottom of the entire winding the pulse potential is stepped up to something of the order of 8,000 to 10,000 volts. This potential varies with operating conditions in the sweep amplifier and yoke circuits and on the strength of the negative pulse initially produced in the yoke circuit.

The high voltage pulses are applied to the high-voltage rectifier. The positive pulses applied to the plate of the rectifier tube V1, cause the tube to conduct and charge C_a as shown. Between pulses, V1 does not conduct and C_a discharges through ground, the flyback transformer, C_b, and R. This charges C_b with the indicated polarity. After several cycles of operation, C_a and C_b charge to the full value of E. When the positive pulses reoccur, another E is superimposed on C_b, thus making the voltage from point A to ground E + E or 2E, thus doubling the voltage.

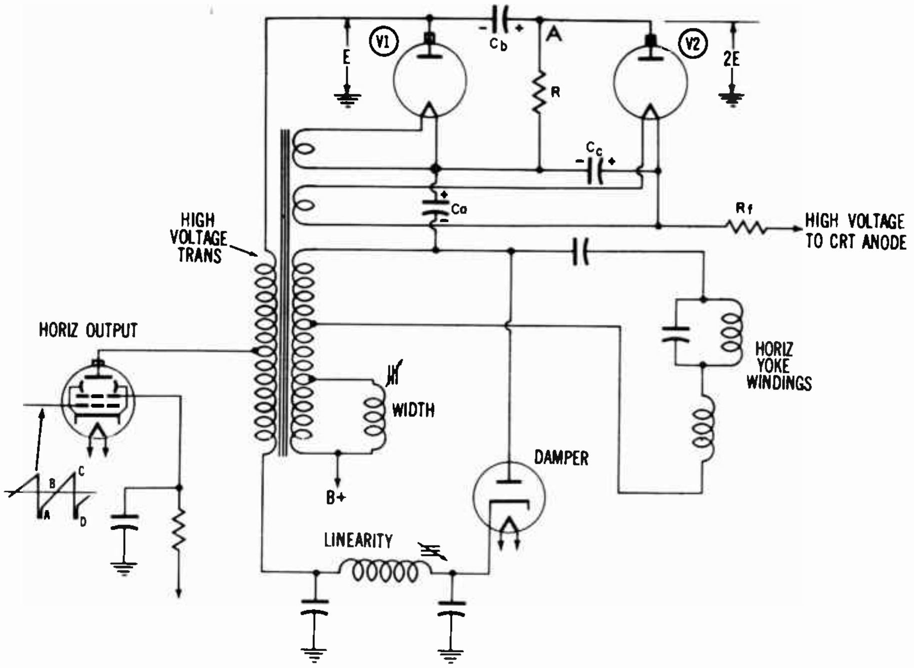


Fig. 11. A Typical Horizontal - Output Circuit Employing a Voltage Doubler to Produce the Required High Voltage.

Capacitor C_c is connected to the V2 filament which is, in effect, connected to point A (through the V2 plate), when V2 conducts. After many cycles of operation, C_c will charge to a value of 2E. This action discharges C_b which is then recharged during the period between pulses of E by the discharge of C_a. The voltage at the filament of V2 is applied to the picture tube anode through R_f. Filtering is achieved in many sets by the capacitance existing between the aquadag coating and the glass envelope of the picture tube.

Power supply voltage is affected to some extent by adjustment of width controls, drive controls, and peaking controls, since these adjustments alter the plate current of the output amplifier and currents in the yoke circuit. Any failure which prevents operation of the output amplifier stops the high voltage supply to the picture tube. Damper failure stops the high-voltage supply when output-amplifier plate voltage is furnished through the damper circuit.

I. The Purpose of the Damper Circuit

A typical horizontal-output circuit is shown in Fig. 11. The input driving voltage which is applied to the horizontal-output amplifier from the preceding stage, is shown at the left.

Time A on the waveform is negative but advancing in a positive direction. During this time, no current is flowing through the tube. Gradually, the input voltage advances in a positive direction, and overcomes the negative tube bias at the cutoff point, and current starts flowing through the tube. This current passes through the primary winding of the flyback transformer and induces in the secondary winding a voltage which results in a saw-tooth current that travels through the deflection coils. This is the deflection current that swings the electron beam from left to right across the face of the picture tube.

The current build-up continues until point C is reached on the waveform. At this instant it suddenly plunges to point D, and plate current of the tube is cutoff. This causes the magnetic field in the transformer and deflection coils to collapse at a rate determined by the inductance and capacitance present in the secondary circuit of the transformer. This causes the circuit to oscillate, which is not desirable since the oscillating current flowing through the deflection coils would not swing the beam back quickly from the right-hand side of the screen to the left-hand side. The object is to get rid of the excess energy still remaining in the circuit, and this is the purpose of the damper tube. After the first half-cycle, the oscillating voltage becomes positive and the damper tube conducts, placing such a load across the secondary circuit that the excess energy is quickly absorbed.

J. Boost Voltage.

The boost voltage is a voltage which is lower in value than the high voltage applied to the picture tube anode, and higher in value than the voltage supplied from the low-voltage supply. This boost voltage is fed to such stages as the horizontal-output amplifier, horizontal oscillator, and the vertical-output amplifier, enabling them to develop large amounts of deflection power required by the wide-angle picture tubes now in use.

The boost voltage is developed across capacitor C2 of the damper circuit, shown in the lower half of Fig. 11. Tube boost voltage is usually 100 volts or more higher than the low voltage B+ applied to the plate of the damper.

K. Summary Questions

1. What is the purpose of AFC?
2. Name the different AFC systems used.
3. What is the purpose of the horizontal oscillator?
4. What are the two functions of the horizontal output tube?
5. What is the purpose of the damper tube?
6. What is the boost voltage?

ULTRA-HIGH FREQUENCY TV

Objective

To continue the study of television frequencies and compare VHF and UHF signals.

References

Lesson Content

A. Introduction

Television broadcast frequencies for UHF, extend from 470 to 890 megacycles. Each ultra-high frequency channel occupies 6 megacycles, which allows 70 channels in this band. Ultra-high frequency channels are numbered consecutively from 14 through 83, a continuation of the numbering for channels 2 through 13 in the very-high frequency television broadcast band. Refer to Fig. 1 for channel frequencies.

Channel No.	Frequency Band (Mc)	Video Carrier	Sound Carrier
2	54-60	55.25	59.75
3	60-66	61.25	65.75
4	66-72	67.25	71.75
5	76-82	77.25	81.75
6	82-88	83.25	87.75
7	174-180	175.25	179.75
8	180-186	181.25	185.75
9	186-192	187.25	191.75
10	192-198	193.25	197.75
11	198-204	199.25	203.75
12	204-210	205.25	209.75
13	210-216	211.25	215.75
14	470-476	471.25	475.75
15	476-482	477.25	481.75
16	482-488	483.25	487.75
17	488-494	489.25	493.75
18	494-500	495.25	499.75
19	500-506	501.25	505.75
20	506-512	507.25	511.75
21	512-518	513.25	517.75
22	518-524	519.25	523.75
23	524-530	525.25	529.75
24	530-536	531.25	535.75
25	536-542	537.25	541.75
26	542-548	543.25	547.75
27	548-554	549.25	553.75
28	554-560	555.25	559.75
29	560-566	561.25	565.75
30	566-572	567.25	571.75
31	572-578	573.25	577.75
32	578-584	579.25	583.75
33	584-590	585.25	598.75
34	590-596	591.25	595.75
35	596-602	597.25	601.75
36	602-608	603.25	607.75
37	608-614	609.25	613.75
38	614-620	615.25	619.75
39	620-626	621.25	625.75
40	626-632	627.25	631.75
41	632-638	633.25	637.75
42	638-644	639.25	643.75
43	644-650	645.25	649.75
44	650-656	651.25	655.75
45	656-662	657.25	661.75
46	662-668	663.25	667.75
47	668-674	669.25	673.75
48	674-680	675.25	679.75
49	680-686	681.25	685.75
50	686-692	687.25	691.75
51	692-698	693.25	697.75
52	698-704	699.25	703.75
53	704-710	705.25	709.75
54	710-716	711.25	715.75
55	716-722	717.25	721.75
56	722-728	723.25	727.75
57	728-734	729.25	733.75
58	734-740	735.25	739.75
59	740-746	741.25	745.75
60	746-752	747.25	751.75
61	752-758	753.25	757.75
62	758-764	759.25	763.75
63	764-770	765.25	769.75
64	770-776	771.25	775.75
65	776-782	777.25	781.75
66	782-788	783.25	787.75
67	788-794	789.25	793.75
68	794-800	795.25	799.75
69	800-806	801.25	805.75
70	806-812	807.25	811.75
71	812-818	813.25	817.75
72	818-824	819.25	823.75
73	824-830	825.25	829.75
74	830-836	831.25	835.75
75	836-842	837.25	841.75
76	842-848	843.25	847.75
77	848-854	849.25	853.75
78	854-860	855.25	859.75
79	860-866	861.25	865.75
80	866-872	867.25	871.75
81	872-878	873.25	877.75
82	878-884	879.25	883.75
83	884-890	885.25	889.75

Fig. 1. Television Channel Frequencies.

The video carrier in each ultra-high frequency channel is 1.25 mc above the low limit. There is the standard separation of 4.5 mc between video and sound carriers bringing the sound carrier frequency 0.25 mc below the high limit of the channel. These are the same frequency distributions as in each very-high frequency television channel, with vestigial-sideband transmission in both cases.

In UHF wave propogation there is less bending at and around objects in the path of the waves, and transmission more nearly approaches a line-of-sight direction between transmitting and receiving antennas. Intervening structures, rises of land, trees, and other objects cut off the UHF waves somewhat more than VHF waves. With transmitting power and conditions more roughly equivalent between transmitters and receivers, the maximum reception distance for UHF signals may be about the same or slightly less than for VHF signals.

A major advantage in UHF television broadcasting is the reduction or elimination of electrical interference of the spark type, and from sources operating at such moderately high frequencies as used in medical and some industrial apparatus. The chief disadvantage, is the increase of signal energy losses at ultra-high carrier frequencies.

B. UHF-VHF, Frequency-Conversion Systems

Receiver differences principally for UHF and for VHF television signals are confined to the parts preceding the IF amplifier. The IF amplifier and everything following it are used without changes of any kind for reception in both bands. The parts or sections of the television receiver which are different for UHF and VHF reception are those concerned with converting modulated carrier signals to modulated IF signals by means of oscillators and mixers.

1. Single Conversion

With the exception of changes in tuned circuit design necessitated by the far higher UHF carrier frequencies, what is possibly the most noticeable difference between UHF and VHF tuners of types which have been commonly used is the absence of RF amplifiers for UHF signals. Such amplifiers always are found between antenna and mixer for VHF reception. RF amplifiers for UHF carrier frequencies have been omitted because the tube noise has been found excessive in relation to the inherently weak received signals. Signals from UHF antenna tuning circuits are applied directly to the UHF mixer, in combination with voltage from the UHF oscillator in UHF receivers. Equivalent gain is furnished by amplifiers which follow the mixer in UHF receivers.

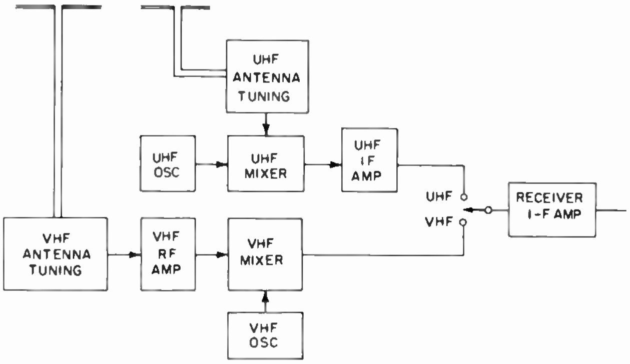


Fig. 2. Tuner Circuits in Which there is No RF Amplifier for UHF Signals.

A combination of UHF and VHF tuning is shown in simplified form by Fig. 2. A beat frequency equal to the difference between frequencies of the UHF carrier and UHF oscillator appear at the output of the UHF mixer. This is the frequency at which the regular IF amplifier of the receiver operates for VHF reception, and now also for UHF reception. The gain for ultra-high frequencies which would have been secured from an RF amplifier, if present, is provided by the stage marked UHF IF Amp inserted between the UHF mixer and the regular IF amplifier.

Tuners for VHF consist of the usual RF amplifier, RF oscillator, and mixer. A band switch connects the VHF mixer to the receiver IF amplifier for VHF reception, and connects this IF amplifier to the output of the UHF IF amplifier for UHF reception. Additional contacts on the band switch would disconnect the B+ voltages from the oscillator of the tuner not in service.

The separate UHF IF amplifier stage may be omitted as shown in the arrangement of Fig. 3. Here the VHF RF amplifier stage, in the VHF tuner, acts in its usual capacity and also as the amplifier required after the UHF mixer. UHF antenna tuning, together with the UHF mixer and oscillator, are the same as before. But, instead of being switched through a UHF IF amplifier stage to the regular IF amplifier of the receiver, the UHF mixer now is switched to the input for the RF amplifier in the VHF tuner. With this arrangement the beat frequency from the UHF mixer will be the IF frequency of the receiver.

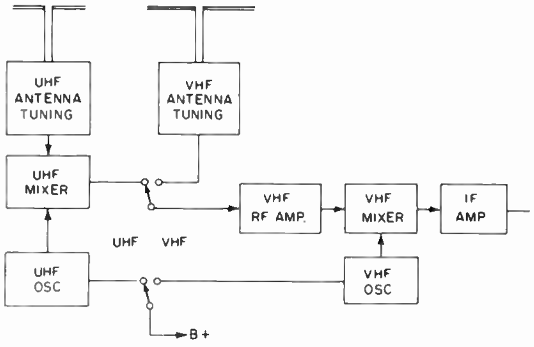


Fig. 3. A System in Which the RF Amplifier of the VHF Tuner is Used as an Additional Amplifier Following the UHF Mixer.

For UHF reception, the VHF RF amplifier and mixer circuits are tuned to the IF frequency of the receiver, which is also the beat frequency from the UHF mixer. The band switch is placed in the UHF position, thus connecting the UHF mixer to the VHF RF amplifier and at the same time applying B voltage to the UHF oscillator while cutting it off to the VHF oscillator. When the band switch is changed back to the VHF position the UHF mixer and oscillator are cut off while the VHF antenna circuit and oscillator are reconnected in the usual manner.

Figs. 2 and 3 illustrate the single conversion method of UHF reception. This method is single conversion because frequency conversion from UHF carrier to receiver intermediate is accomplished at one step, in the UHF mixer. When employing a single conversion process the receiver intermediate frequency is in the 40-mc range, as with 45.75 mc for video and 41.25 mc for sound.

2. Dual Conversion

A method called double conversion is illustrated in Fig. 4. The UHF carrier frequencies first are converted in the UHF mixer to a lower frequency which is usually that of one of the VHF channels. This frequency from the UHF mixer then is converted again, by the VHF mixer, to the intermediate frequency used in the receiver IF amplifier. The VHF antenna is disconnected during the UHF reception.

Double conversion is always employed when separate converter units are used as attachments to allow UHF reception on any VHF television receiver and sometimes when separate VHF and UHF tuners are installed in the receiver. A typical external converter arrangement is illustrated by the block diagram in Fig. 5. The converter unit contains the UHF antenna, tuning circuits, mixer, and oscillator; also a stage of amplification operating at the beat frequency or UHF intermediate frequency from the mixer output and its power supply. The tuner of the VHF receiver must be adjusted to the UHF IF frequency for reception of all UHF channels. Any UHF channel may be selected by tuning the oscillator of the converter and the UHF antenna. A typical UHF converter is shown in Fig. 6.

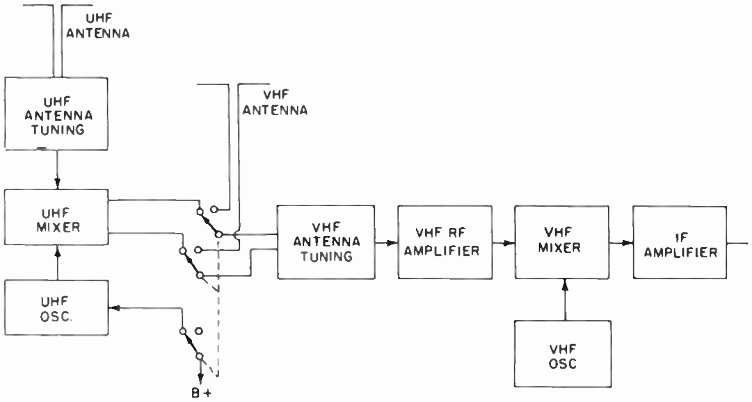


Fig. 4. A Double Conversion System in Which Both the UHF Mixer and VHF Mixer Remain in Operation for UHF Reception.

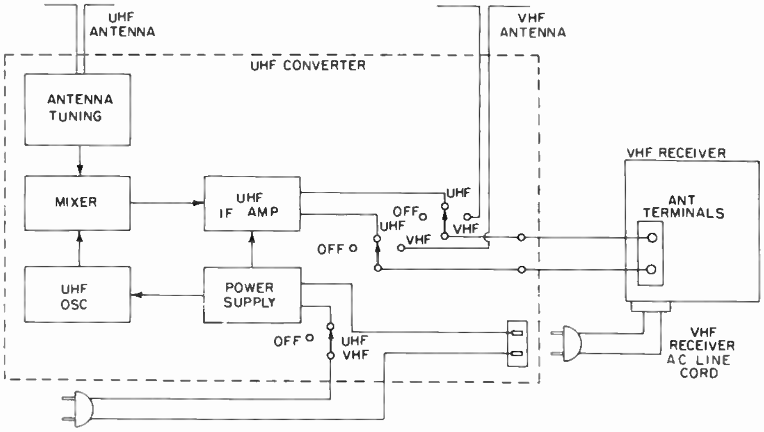


Fig. 5. Circuit Arrangement of a UHF Converter Employing Double Conversion.

The AC power line is connected into a band switch that is part of the converter. This switch has positions for OFF, UHF, and VHF. In either the UHF or VHF position the AC line is connected through the band switch to the power supply in the converter, and also to the regular power cord of the VHF receiver which is plugged into an outlet on the converter. With the band switch in its UHF position the UHF IF amplifier stage within the converter is connected to the antenna terminals of the VHF receiver. In the VHF position the VHF antenna, attached to the converter, is connected through the band switch to the antenna terminals of the VHF receiver.

The design of the converter may be adjusted so broadly that its signal output extends over approximately the range for two adjacent VHF channels. Then the VHF tuner may be set for whichever of these two channels is not used for VHF reception in the locality where the receiver is located. (As an example): The converter output might be centered at 82 mc, which is the high limit of VHF channel 5 and the low limit of channel 6. The VHF selector would be set for whichever of these two channels is not allocated to any nearby television station. In other cases the converter output may cover only the frequencies for one channel, and be pretuned for a VHF channel not locally allocated. The VHF tuner must be in correct alignment for the channel used for UHF reception, also for immediately adjacent channels in order to avoid pickup of VHF signals that would cause trouble.

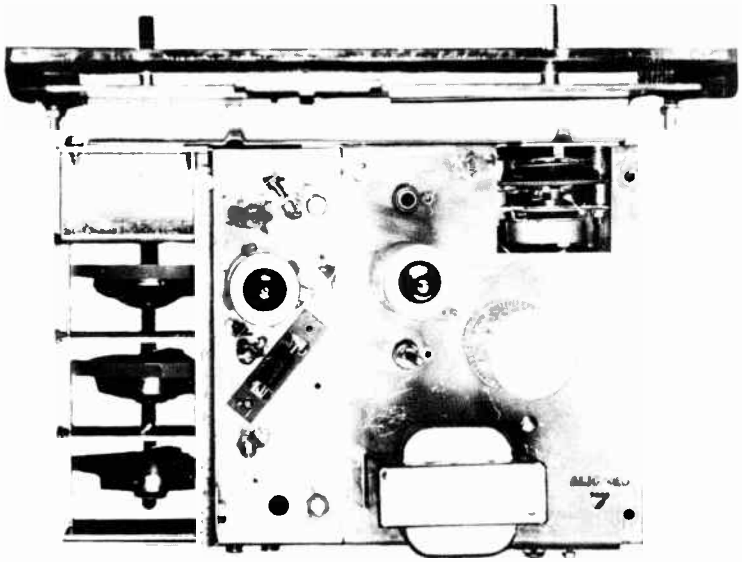


Fig. 6. Top Chassis View of a UHF Converter.

Many receivers employ two built-in tuners — one for VHF and one for UHF reception. When this method is used there is often a separate position on the VHF tuner for UHF reception. When the receiver is tuned to this position the bandswitch is activated for UHF reception and the VHF tuner is tuned to the UHF IF frequency which, in this arrangement may not be that of one of the VHF channels. Often,127 mc is used as the UHF IF frequency when two internal tuners are used. In some receivers, however, the UHF IF frequency is that of one of the VHF channels and a separate switch is added on the front panel of the receiver to switch from VHF to UHF. Operation then is the same as when a separate UHF converter is used.

When employing double conversion,the UHF oscillator frequency must be lower than the UHF carrier frequency to be received, so that the video and the sound intermediate frequencies for the receiver IF amplifier may be correctly related to each other, with the sound intermediate below the video intermediate. What happens may be illustrated by an example in which the following conditions are assumed.

UHF reception is to be from channel 26, in which the video carrier is 543. 25 mc and the sound carrier 547. 75 mc.

The VHF tuner is set for channel 5, in which the video carrier frequency is 77. 25 mc and the sound carrier 81. 75 mc.

Receiver intermediate frequencies are 25. 75 for video and 21. 25 for sound.

The following tabulations show the resulting frequency conversions with UHF oscillator frequency below and above the UHF carrier frequencies. When oscillator frequency is higher than the UHF carriers, the final sound intermediate always will be higher than the video intermediate. This would be incorrect in accordance with the standard alignment of television IF amplifiers.

UHF FREQUENCY CONVERSIONS

Oscillator frequency lower than carrier frequencies	Video	Sound
UHF carriers, channel 26	543.25	547.75
UHF oscillator frequency	466.00	466.00
Resulting beat frequencies	77.25	81.75
VHF oscillator, for channel 5	103.00	103.00
From UHF mixer, as above	77.25	81.75
Beats, to IF amplifier	25.75	21.25

Oscillator frequency higher than carrier frequencies	Video	Sound
UHF oscillator frequency	620.50	620.50
UHF carriers, channel 26	543.25	547.75
Resulting beat frequencies	77.25	72.75
VHF oscillator, for channel 5	103.00	103.00
From UHF mixer, as above	77.25	72.75
Beats, to IF amplifier	25.75	30.25

C. Tubes for UHF

Tubes for UHF have been designed for satisfactory performance at the ultra-high television carrier frequencies, among them being oscillators, mixers, and amplifiers. In all UHF tubes interelectrode capacitances are small. Lengths and inductances of internal connections to elements have been reduced, and parallel leads to a single element often are used for further reduction of inductance in the tube and in connected circuits.

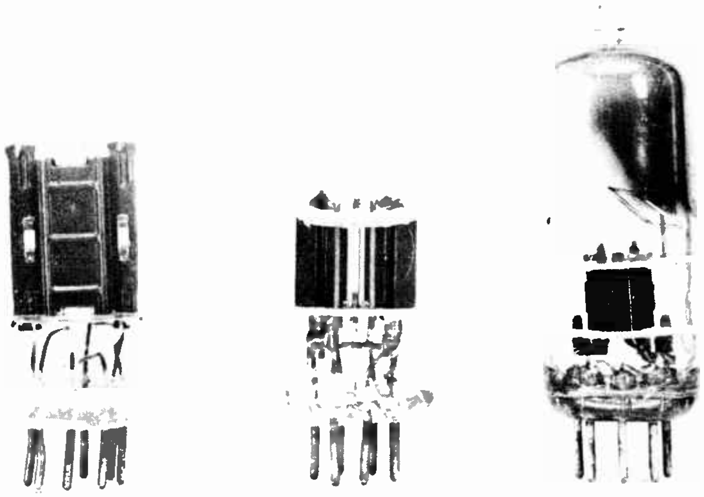


Fig. 7. The Tube at the Right, Designed for UHF Applications, Has Short Internal Leads Which Reduce the Internal Inductances.

Even in ordinary miniature tubes the internal elements themselves are of small dimensions. A comparison is shown by Fig. 7. At the left are the elements of a miniature pentode of the general purpose type. At the center are the elements of a 6J6, often used as a combined oscillator-mixer in VHF tuners. At the right is a 6AF4 UHF oscillator, built with a regular miniature envelope and 7-pin base, but with the very small plate, grid, and cathode assembly which may be seen inside the bulb down near the base. The 6AF4 has operating characteristics very similar to those of the 6F4 acorn tube.

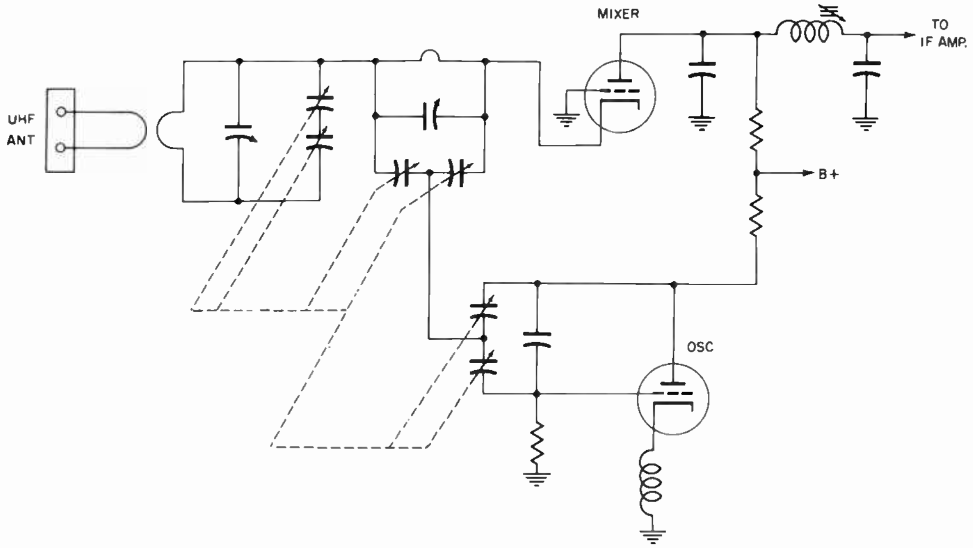


Fig. 8. Simplified Diagram of a UHF Tuner.

Among other UHF receiver tubes is the 6AN4 designed for 7-pin type. With operating voltages ordinarily applied, they may be used either as a mixer or as an amplifier. This miniature 6AN4 as an amplifier has transconductance of 10,000 micromhos, and as a UHF mixer has conversion transconductance of 2,900 micromhos. This, and other tubes designed especially for UHF amplification have noise factors considerably lower than found in ordinary general purpose types.

Tuners may have circuits basically like those for VHF reception and frequency conversion, as illustrated by the example of Fig. 8. There is a tuned antenna circuit coupled to a tuned mixer input circuit but there is no RF amplifier and the mixer is used in a grounded grid circuit.

The oscillator is a modified Colpitts type, with all necessary inductance in leads and connections within and outside the tube. Each of the three tuned circuits is resonated by one section of a three-gang capacitor. Each section will have its own trimmer capacitor.

E. Crystal Diode Mixers

Any element which is capable of acting as a detector may be used also as a mixer for frequency conversion, since the prime requirement is non-linear rectification or unequal current in opposite driving directions when alternating voltage is applied to the element. A number of germanium crystal diodes have been designed especially for mixer service at the television ultra-high frequencies, including the 1N72, 1N82, CK710, G7, and others.

At the left in Fig. 9 is a 1N72 germanium crystal diode and at the right is a type 9006 UHF diode tube, of about the same size as a 6AL5 or a 6AK5 miniature tube. The 1N72 will operate satisfactorily at input frequencies of 100 mc to 1,000 mc, with a noise figure of approximately 15 decibels.

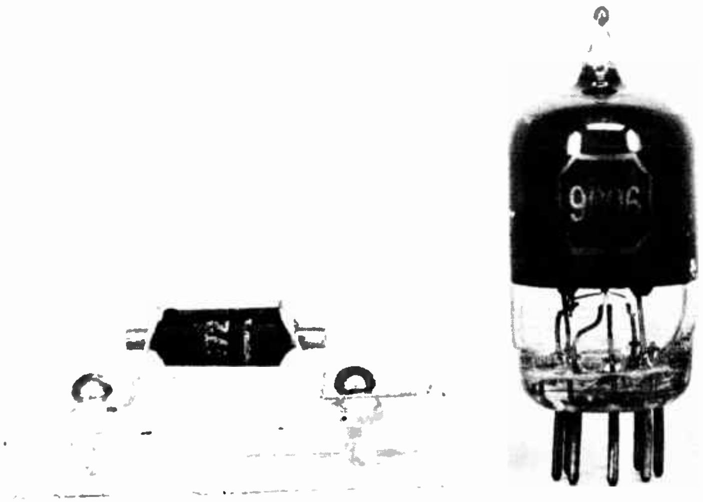


Fig. 9. A UHF Crystal Diode Used as a Mixer, and a Miniature Diode Tube.

A simplified circuit diagram for a UHF tuner is shown in Fig. 10. This tuner contains a crystal diode mixer, a triode tube oscillator, and a triode amplifier for the beat frequency or intermediate frequency from the carrier and oscillator voltages that combine in the mixer circuit. As mentioned before, the IF amplifier is needed because no RF amplifier is used. There is no gain in the crystal mixer, but instead there is a loss of 60 per cent or more of the signal strength in this kind of mixer. The crystal mixer requires less voltage from the oscillator or less injection voltage than a tube used as a mixer, and the crystal has a noise factor lower than that of tubes not particularly designed for UHF mixers.

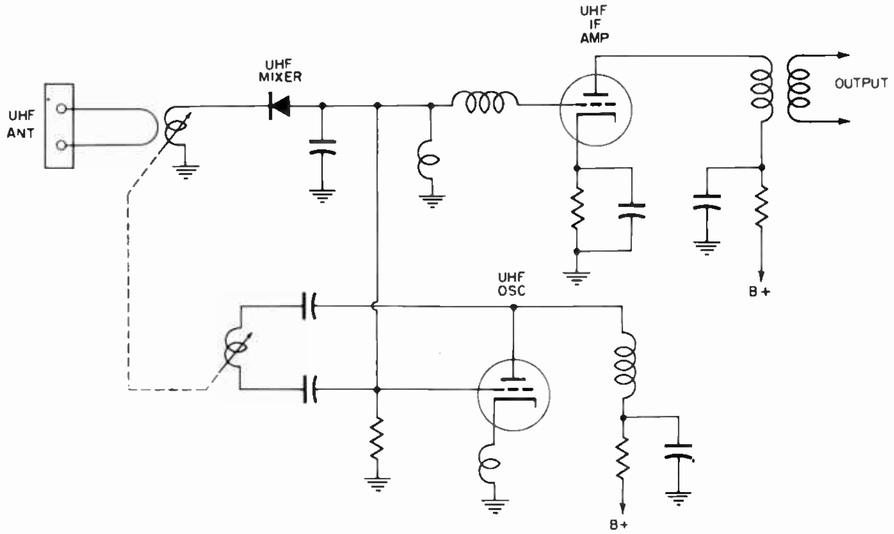


Fig. 10. Connections Between a Crystal Diode Mixer, UHF Antenna, and UHF Oscillator Tube.

F. Tuning Inductances and Capacitances

Even though the fundamental principles of UHF circuits employed in UHF tuners may be the same as in tuners for very-high and other radio frequencies, the physical constructions are entirely different in many respects. This is due to such factors as the large inductive reactances of even the shortest straight conductors, and the small capacitive reactance between even the smallest conductors which are separated by insulation dielectric.

For resonance at the lower limit, the middle, and the high limit of the UHF television band, the products of capacitance and inductance must have approximately the following oscillation constants.

470 mc. Micromicrofarads x Microhenrys = 0.115

680 mc. Micromicrofarads x Microhenrys = 0.056

890 mc. Micromicrofarads x Microhenrys = 0.032

Dividing the oscillation constant by any given capacitance will give the inductance required for resonance at the corresponding frequency, and dividing by a given inductance will give the required capacitance at the same frequency. For example, if total circuit capacitance is only 5 mmf and the frequency is 680 mc, dividing the oscillation constant, 0.056 by 5 gives approximately 0.011 microhenry as the inductance for resonance.

The inductance of one inch of straight wire of number 20 gauge is about 0.019 microhenry, and of one-half inch of this wire it is about 0.008 microhenry. Therefore a resonant circuit for the preceding with between one-half and one inch of straight wire, uses gauge number 20.

Straight conductor inductance is not directly proportional to length. Doubling the length more than doubles the inductance.

The cross sectional and surface areas of conductors, have important effects on inductances. A small diameter conductor of any given length has more, not less, inductance than one of greater diameter having equal length. Inductance is increased by using smaller diameters, and is decreased by using larger diameters. This may be illustrated by comparing the inductances of one-inch lengths of conductors having different diameters, as follows:

No. 30 gauge.	Diameter 0.010 inch.	Inductance 0.0254 microhenry.
No. 20 gauge.	Diameter 0.032 inch.	Inductance 0.0190 microhenry.
No. 10 gauge.	Diameter 0.102 inch.	Inductance 0.0136 microhenry.

When inductance must be reduced to an extent greater than allowed by a practicable increase of conductor diameter, two or more conductors (not too close together) may be wired in parallel.

Stray capacitances in UHF tuned circuits are large enough that the addition of a variable tuning capacitor of ordinary design, with maximum to minimum capacitance ratio large enough for tuning through the UHF band, would result in a total capacitance too great for use with inductances ordinarily attainable. It is for this reason that UHF tuning usually is with variable inductances used in combination with circuit and tube capacitances. Adjustable capacitances are, however, employed for tracking and other service adjustments.

Effective values of capacitances which appear unavoidably in tuned circuits may be reduced by arranging as many capacitances as possible in series with one another, thus making good use of the laws which apply to all capacitances in series. Trimming capacitances may be in series with fixed capacitances. While this reduces the range of the adjustable unit, the range for trimming purposes ordinarily remains large enough.

UHF receivers and converters may have quarter-wave shorted resonant lines for tuning elements. A quarter-wave shorted line acts like a parallel resonant circuit when the length is adjusted by sliding contacts which bridge across the two sides of the line, and may be moved by a tuning control to the position at which the line becomes resonant at the frequency of an oscillator.

Figure 11 shows a tuning unit of this kind. There are three sections, one for tuning the UHF oscillator, a second for tuning the antenna-mixer coupling, and a third for the antenna input circuit. The two sides of each line consist of concentric circular strips of metal embedded in low loss insulating material. The UHF channels are selected by the sliders which short the lines at any required point around the circles. The sliders are attached to a common shaft that is rotated by the control for channels.

Fig. 11. A UHF Tuning Unit Having Adjustable Quarter-Wave Shorted Lines for Oscillator, Mixer, and Antenna Circuits.

Circuits containing quarter-wave shorted lines are shown by Fig. 12, with the three lines represented as pairs of parallel conductors. Portions of the lines above the shorting bars have no effect on resonant frequencies, the effective length of line being determined by the portions between the shorting bars and connections for antenna, mixer, and oscillator. The mixer is shown as a crystal diode, but could, of course, be a diode or triode tube.

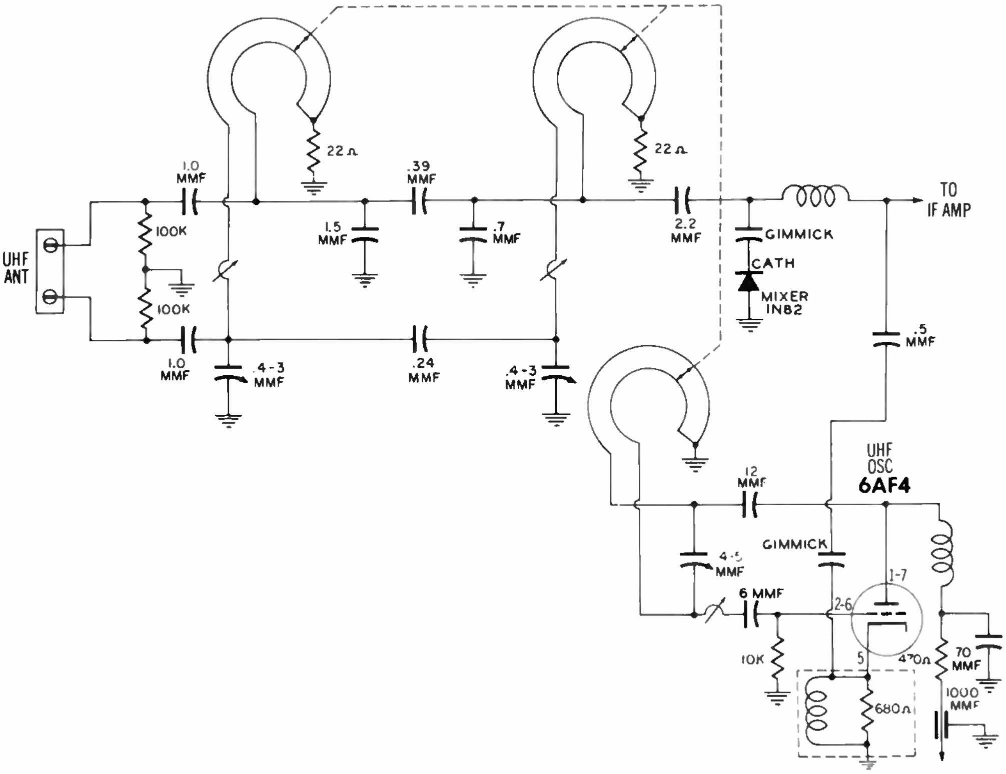


Fig. 12. Quarter-Wave Resonant Lines with Adjustable Shorting for UHF Tuning.

In Fig. 12 the higher frequencies would be obtained with the bars or sliders downward to the limit of their travel. The upper ends of the two conductors of each line are permanently connected together and through resistors to ground as a means for completing return circuits for tubes and crystals as may be required by circuit design.

The electrical length of a resonant line is considerably greater than the actual measured or physical length which is the same as saying that the physical length of the conductors from the shorting bars to the open ends is much less than the length of a quarter-wave in air at the resonant frequency. This is because inductances and capacitances are added by external circuit conductors, by various trimmer elements, and by internal inductances and capacitances of connected tubes. There is also a reduction of velocity constant because the line conductors are supported by dielectric material rather than in air, and this tends to make the electrical length greater than the physical length.

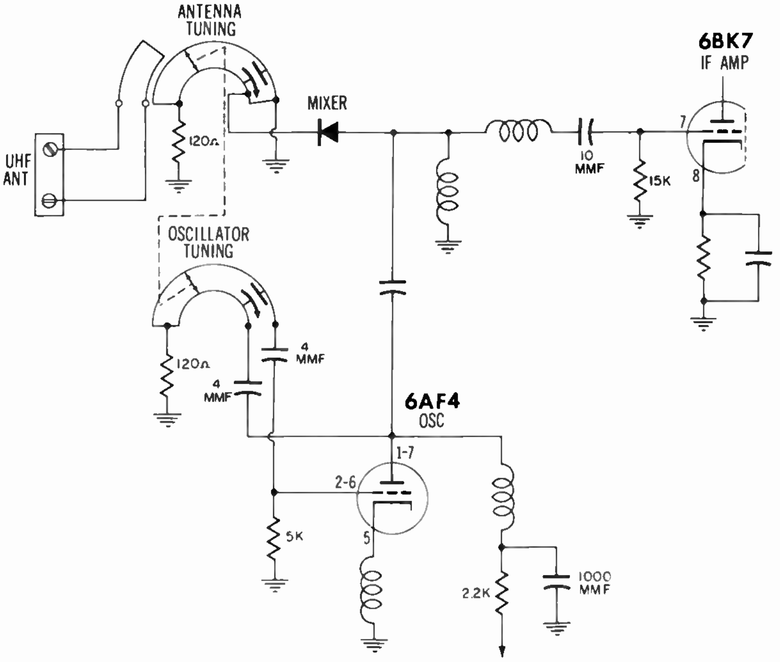


Fig. 13. Two Shorted Quarter-Wave Resonant Lines for Tuning the Antenna, Mixer, and Oscillator Circuits.

Desirable tracking of antenna, mixer, and oscillator circuits may be provided by making the line conductors of different dimensions, widths, thicknesses, or both at various points. Variations of this kind may be seen in Fig. 11. Tracking at various points in the frequency range may be accomplished in whole or in part by trimmer capacitances on the line conductors. Such trimmers may be seen at the open ends of the lines in Fig. 13. Additional trimming capacitances might be placed at points intermediate between the open and the permanently shorted line ends.

Only two resonant lines are used for tuning in Fig. 13. The line at the top of the diagram tunes the antenna input and the coupling to the mixer, with antenna at one end and mixer at the opposite end of this line. The lower resonant line is tuned to the UHF oscillator frequency.

Spacing between the two conductors of a resonant line affects the characteristic impedance of the line, and by appropriate choice of spacing, the line impedance may be matched to impedances of connected circuits and tubes. Wider spacing increases the line impedance. The characteristic impedance of the line is not altered as the effective length is changed by moving the shorting contacts on the bars. The length does not affect the line inductance ratio.

Mechanical design of shorting contacts on the conductors of a quarter-wave line is important in relation to continued good performance. At the point of shorting there is maximum current, which calls for contacts of ample area. But voltage at this point is minimum, and may be so small that it cannot force the large current through even the slightest trace of corrosion.

At carrier and oscillator frequencies in the UHF television range there is a strong tendency toward radiation of signal energy from resonant lines. This requires that the adjustable lines be enclosed by effective shielding, well grounded to the chassis. The outside shielding enclosure was removed when making the picture of Fig. 11. As may be seen, there are shielding partitions between the adjacent sections in the tuning unit.

Another UHF tuning circuit which behaves in this range of frequencies like an ordinary parallel resonant circuit at lower frequencies is called the cavity resonator, whose principle is illustrated by Fig. 14. At A is represented a parallel resonant circuit consisting of a coil and capacitor. By using two coils or inductors in parallel, as at B, the effective inductance is reduced and the resonant frequency raised.

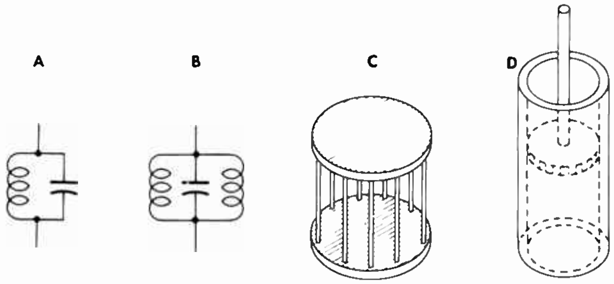


Fig. 14. Elementary Principle and Development of the Cavity Resonator.

To provide much less inductance, and higher resonant frequency, the coiled inductors may be replaced with straight conductors, and a large number of them used in parallel, which results in the circuit shown at C. The top and bottom plates furnish capacitance, and vertically between them are the electric field lines. In horizontal paths around the inductors are the magnetic field lines.

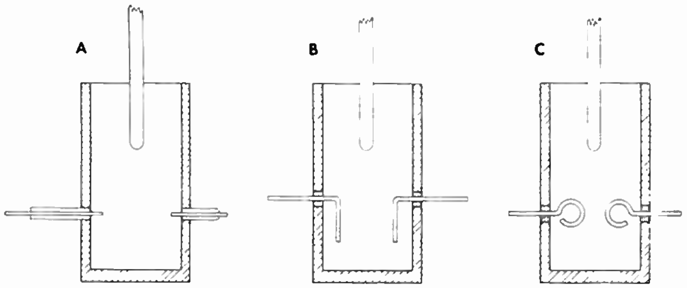


Fig. 15. Methods of Putting Signal Energy Into, and Taking it Out of Cavity Resonators.

So many straight inductors are used so that they form a continuous hollow cylinder, as at D. The bottom plate remains unchanged, but the top one is arranged to slide up and down as a plunger. This is one form of cavity resonator. Electric and magnetic waves now are reflected back and forth inside the cavity. If the length below the plunger, or the diameter, or both are made such that reflected waves reinforce direct waves there will be standing waves set up inside the cavity and the behavior will be generally similar to that of a resonant line on which there are standing waves. The cavity may be cylindrical or rectangular.

Inside the cavity, dimensions determine the frequency at which there are standing waves, or resonance. The frequency of resonance may be varied without changing the cavity dimensions if a conductor in the form of a flat narrow sheet or a slug is inserted to various distances within the cavity, thus changing the pattern of the standing waves. This latter method works very well for UHF television tuning purposes.

Signal energy may be put into and taken out of the cavity in a variety of ways. At A in Fig. 15 the central conductors of coaxial lines extend into the cavity for short distances beyond the outer or shielding conductors, which are joined to the cavity walls. At B two conductors pass through insulating bushings into the cavity, and the inner ends are bent in line with the lines of the internal electric field. At C there are small open loops, not complete circles, passed in through insulating bushings and positioned so that the internal magnetic lines, traveling around horizontal paths go through the openings of the loops. The methods at A and B provide capacitive coupling, while that at C provides magnetic or inductive coupling.

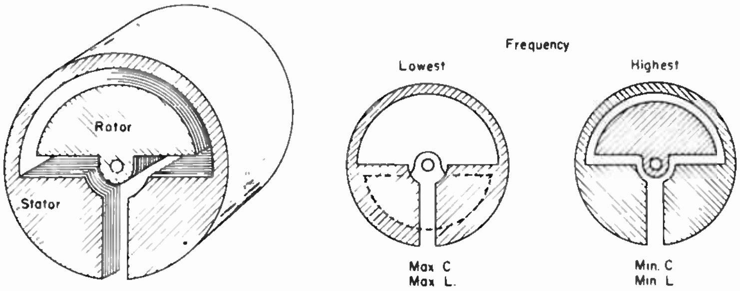


Fig. 16. The Principle of One Form of Butterfly Capacitor.

The butterfly capacitor principle is shown by Fig. 16. The stator plates are part of a cylinder which is slotted along one side, the bottom in the illustration. This construction makes the stator not only a portion of the capacitor but also a sort of single turn inductor. Plates of the rotor are arranged to mesh between stator plates as usual. The assembly is made rather deep from front to back in proportion to the diameter, as a means for decreasing the inductance.

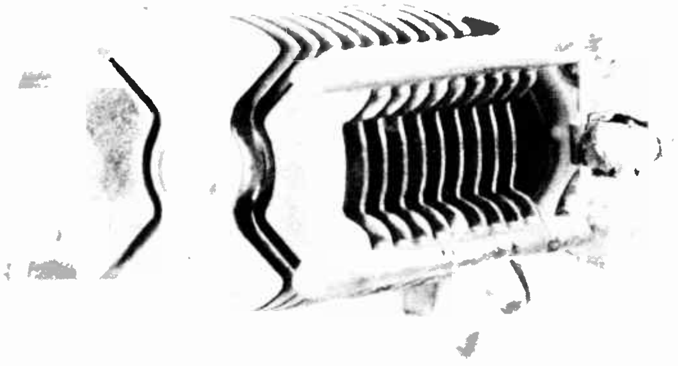


Fig. 17. A Common Form of Butterfly Capacitor.

At the time the rotor plates are fully meshed with the stator plates there is maximum capacitance, as with any variable capacitor. At the same time the stator cylinder is left with maximum open space and consequently has maximum inductance. With capacitance and inductance both of maximum values the resonant frequency is lowest. With rotor plates all the way out of mesh and capacitance is of minimum value. Since the rotor plates then fill most of the air space formerly open inside the cylinder, the inductance is reduced to minimum. With minimum capacitance and inductance the resonant frequency is highest to which the unit will tune. Frequency of resonance at intermediate values depends on the position of the rotor.

Fig. 16 shows only one of several butterfly capacitors. Other designs have plates of the general form shown by Fig. 17, which is a picture of a butterfly capacitor having two groups of stator plates at the left and right with between them a group of rotor plates shaped somewhat like the outstretched wings of a butterfly. It is the shape of the rotor that gives the capacitor its name. A butterfly tuning circuit based on the capacitor in this picture would be completed by fitting a metal cylinder around the outside of the stator plates, with cylinder and plate supports making good electrical contact.

The wide tuning range of the butterfly circuit results from simultaneous changes of inductance and capacitance. Both factors vary together between maximum and minimum values. Various practical designs provide frequency ratios, maximum to minimum megacycles, of from about 2 1/2 to 1 up to as great as 7 1/2 to one. The butterfly easily covers the entire band. Since the ratio in the UHF television band is 890 to 470 mc, it is less than 2 to 1.

G. Oscillator Drift

Drift of oscillator frequency until circuit parts reach stable operating temperatures causes the same difficulties in UHF reception as at lower frequencies. Since the oscillator frequency combines with carrier frequency to produce the intermediate beat frequency, any great change of oscillator frequency may so change the intermediate as to throw it outside the range within which the IF amplifier has correct frequency response.

The most common cause for oscillator drift is change of temperature in parts of the resonant circuit during the warm-up period, usually with a decrease of resonant frequency as temperature rises. This effect may be compensated for with temperature compensating ceramic capacitors, as is done with VHF oscillators and others. Another common cause is change of plate voltage applied to the oscillator tube. This varies the oscillator frequency and also the output which is the injection voltage to the mixer. Variations of oscillator plate voltage also change the relative strengths of harmonic frequencies, which sometimes are used instead of the oscillator fundamental for formation of intermediate beat frequencies.

Frequency drift of oscillators in well designed UHF tuners is not enough to cause much difficulty when the sound system of the receiver is of the intercarrier type. With this system the modulated sound signal, at 4.5 mc, results from the difference between video and sound carriers and the difference between video and sound carriers intermediate frequencies, and it is not altered by variations of oscillator frequency. When the receiver sound system is of the dual or split type an oscillator frequency drift of 1/20 of one per cent at the middle of the UHF band would throw the sound intermediate completely outside the usual passband of the sound IF amplifier, and much smaller drifts would make the sound decidedly unsatisfactory.

H. VHF Oscillator Harmonics

The separate UHF oscillator may be dispensed with by using harmonic frequencies from the VHF oscillator during UHF reception. This method is chiefly useful in the design of channel strips used in turret tuners, wherein all principal frequency-conversion elements for a single UHF channel may be mounted on one set of strips. With no UHF oscillator needed, and with the UHF mixer a crystal diode type, there is ample space at a single turret position for all circuit elements required for reception of any one UHF channel.

Fig. 18 shows the general scheme of connections. UHF antenna tuning and crystal mixer circuits may be any of the usual types. The beat frequency in the VHF section of the receiver is practically always in the 40-mc range of intermediates. During UHF reception the RF amplifier and also the RF mixer tuning are made resonant at the intermediate frequency, and act as additional IF amplifier tubes, with the VHF oscillator cut off from the VHF mixer. The RF amplifier is a cascode type which provides the high gain and low noise factor required for an amplifier following a UHF crystal mixer.

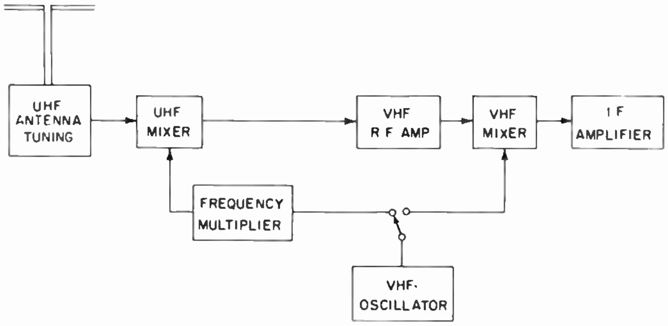


Fig. 18. To the UHF Mixer is Applied a Harmonic of the Fundamental Frequency at Which the VHF Oscillator Operates.

The VHF oscillator, during UHF reception, is connected through a frequency multiplier circuit to the UHF mixer circuit. The frequency multiplier takes the place of a UHF oscillator and is resonated at the frequency of the second, third, or fourth harmonic of the VHF oscillator which is the oscillation frequency required in the UHF mixer circuit for the channel received. In the system illustrated there is only one conversion between UHF carrier and receiver intermediate frequencies, this occurring in the UHF mixer. Consequently, the oscillation frequency for this mixer is higher than the carrier frequencies of the received channel.

The heavy lines in Fig. 19 show a frequency multiplier circuit. The principle is the same as in multiplier circuits using electronic tubes. Such tubes are operated with negative grid biases so strong as to cut off, or nearly cut off, plate current during great negative alternations of grid voltage, and to leave only a series of current pulses for positive alternations. Consequently a crystal diode rectifier may be used. The crystal diode is biased to insure operation at the sharpest portion of the bend on its characteristic curve.

In the output of the crystal there are many harmonics of the fundamental frequency at which the VHF oscillator is operating. These harmonics, along with the fundamental, go to the harmonic selector, which is a parallel resonant circuit tuned for the harmonic frequency to be applied to the UHF mixer. The selector circuit responds strongly at the tuned harmonic frequency, while the fundamental and other harmonics pass to ground quite freely.

The selector circuit may be for harmonics coupled to the mixer circuit in any of various ways. In Fig. 19 there is inductive coupling, with the mixer side tuned to the desired harmonic frequency. UHF carrier frequencies are coupled into the mixer circuit from the antenna tuning circuits. The resulting beat frequency is applied to the grid of the IF amplifier, which is the RF amplifier tube for VHF reception, tuned to the intermediate frequency. Also, the mixer crystal may be biased for operation on the most favorable point of its characteristic curve. The following calculations show how this system works out on the most favorable practice. It is assumed that the VHF oscillator, during UHF reception, may be tuned for any fundamental frequencies between 172.33 mc and 232.75 mc, all of which are within the normal range for any VHF oscillator. The third harmonic of this frequency could be used for reception of UHF channels 14 through 44, and the fourth harmonics for channels 45 through 83. The table shows frequency relations for channels 14 and 83, at the bottom and top of the UHF band.

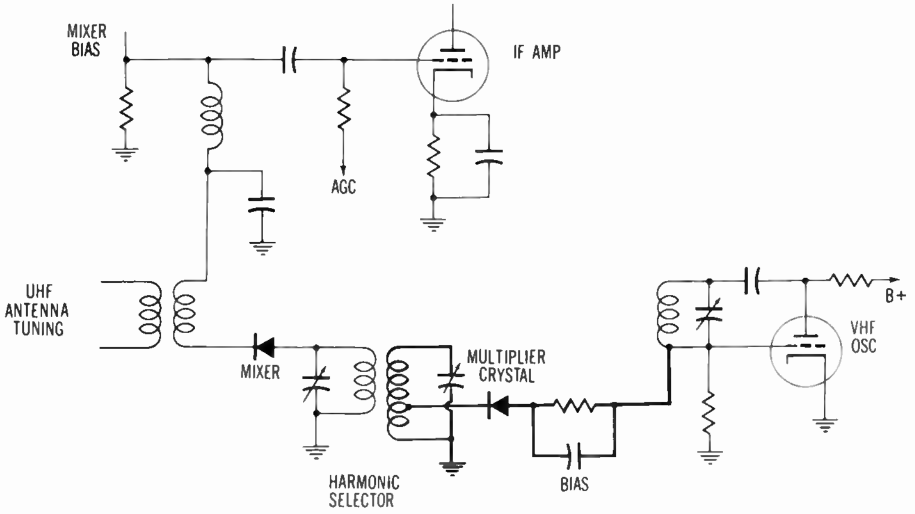


Fig. 19. A Frequency Multiplier Circuit Used Between the Oscillator and the UHF Mixer.

USING HARMONICS FROM VHF OSCILLATOR

	Channel 14		Channel 83	
	Video	Sound	Video	Sound
VHF osc. fundamentals, mc	172.33	172.33	232.75	232.75
Harmonics — 3rd	517.00	517.00		
4th			931.00	931.00
UHF carrier frequencies, mc	471.25	475.75	885.25	889.75
Intermediates (beats), mc	45.75	41.25	45.75	41.25

There are several tuners or converters having UHF oscillator tubes not in any way related to the VHF oscillators, and employing second or third harmonics of the oscillator frequency for injection into the mixer circuit. This permits use of tubes well suited for operation as oscillators in the VHF band instead of the types especially designed for ultra-high frequency operation.

I. UHF Circuit Elements

Difficulties in wiring and placement of parts in UHF circuits arise from the large inductive reactances of even the shortest and straightest conductors, from the small capacitive reactances between all conductors close to one another, and from the exceeding small inductances and capacitances which, together are resonant at ultra-high frequencies. Shortest possible leads and a minimum of dielectric material are of even greater importance in UHF circuits.

Resonant circuits must be isolated from other circuits by voltage-dropping resistors or by RF chokes where fairly high resistance cannot be used. High-frequency circuits must be completed through capacitances by-passing the currents around other circuits. Bypass capacitors to ground must be close to RF chokes used for circuit isolation. Decoupling chokes ordinarily are found in all plate and screen circuits; also, in both sides of leads to tube heaters. Grounding of plate, grid, and cathode returns for any one tube should be to the same point for avoidance of inductive couplings in metal between separated grounds.

Some of the elements and connections for antenna, mixer, and oscillator circuits in a typical unit are shown in Fig. 20. Parts associated with a tube are grouped close to the socket, with supports and interconnections by terminals and pigtail leads of the units themselves, to eliminate wire connections. Sockets must be made with low-loss dielectric materials. Tubes should be held rigidly by their sockets. Oscillator tubes always are provided with close fitting shields held securely to the chassis by grounding clamps.

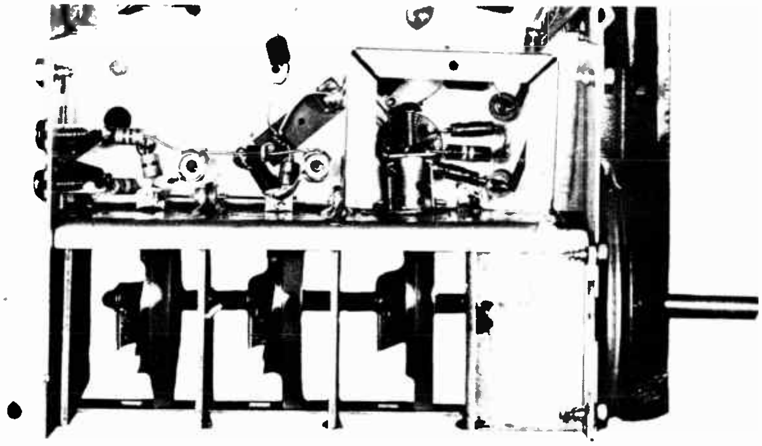


Fig. 20. Circuit Elements and Connections in a UHF Tuning System.

Diagrams usually represent inductors and capacitors by the usual symbols for such elements, but structurally the actual elements may bear little resemblance to those in circuits operating at lower frequencies. Capacitances may be furnished by any adjacent pieces of metal, however small, with any kind of dielectric material between them. Inductive couplings may be those between two straight conductors of small size, or between a screw or a metal pin and other parts. Coils, when used, are of diminutive size when in resonant circuits, but may be much larger for RF chokes.

J. Summary Questions

1. What is the frequency range of UHF TV channels 14 through 83?

2. What are the lower limit, upper limit, picture and sound frequencies for each of the following UHF channel numbers?

   Channel 20
   Channel 26
   Channel 32
   Channel 38
   Channel 44

3. Is an RF amplifier stage used in UHF? Why?

4. Explain oscillator "drift".

JOB SECTION

TABLE OF CONTENTS

JOB NO. PAGE NO.

USING THE OSCILLOSCOPE

Objective

To become familiar with all the controls of the oscilloscope.

References:

Lesson No. 1

Material Required: 1 Oscilloscope, 1 6.3 volt filament transformer.

A. Related Information

For years the scope was considered a laboratory instrument and was used only in factories and research laboratories. The few service technicians who owned them usually allowed this particular equipment to gather dust since he wondered if the time required to learn to handle this equipment was worth while.

Now that FM and Television have come of age, the man in the shop must know how to handle a scope to get the most usefulness out of it. Today this instrument is considered by many service technicians as the most versatile instrument in the shop.

As with any test equipment, you must be so familiar with the controls that you reach the various ones almost without conscious thought. Practice is the only way to gain this familiarity.

B. Suggested Procedure

1. Before turning the scope on, set the controls to these positions:

   Vertical and Horizontal Centering — half of the complete knob rotation; Brightness (Intensity) — half of the complete knob rotation; Focus — half of the complete knob rotation; Vertical and Horizontal Gain — completely counter-clockwise; Coarse Frequency and Vernier Frequency — completely counter-clockwise; Sync Selector — to External Sync position; Sweep Selector — to External Sweep position.

2. The centering controls are adjusted as soon as the scope is warmed up and are seldom used thereafter. Begin with these first.

   (a) Turn the scope on and allow about thirty seconds to one minute for warm-up.

(b) As soon as dot appears, reduce the brightness until the dot is just visible. CAUTION! It is very important that you do not leave a bright spot on the tube, especially if it is quite small. A permanent brown spot will be burned on the face of the tube making this area useless.

(c) Adjust the vertical and horizontal centering controls until you have the dot in the center of the screen. Repeat this step several times until you can center the dot quickly.

(d) If the dot does not appear in step B, advance the brightness control about one quarter turn and try your centering controls again.

3. The Focus control adjusts the spot size. It is correctly adjusted when you have reduced the spot to minimum size.

(a) Do not leave the spot in one place very long once it is adjusted. The cathode - ray tube is often the most expensive single part in the scope and the whole instrument is useless without a good, clean screen.

(b) Reduce the brightness control setting until the spot disappears.

4. The Sweep Controls

(a) Switch the Sweep Selector to the "Internal" position.

(b) Advance the Horizontal Gain Control about half way.

(c) Slowly advance the Brightness (Intensity) control until you see a horizontal line across the face of the CRT. You can adjust the length of this line with the Horizontal Gain Control.

(1) The line should be adjusted until it fills about 2/3 of the screen width.

5. Observing a Signal on the Scope

(a) Connect the secondary of the filament transformer to the vertical input of the scope.

(b) Adjust the vertical gain control until the pattern fills about 2/3 of the height of the CRT.

(c) The pattern is now probably a meaningless jumble of lines.

(1) Adjust the horizontal sweep vernier control until you get one complete cycle on the CRT. Since you are now sweeping the face of the tube once during each input cycle, the internal oscillator is operating at the line frequency. In most locations this will be 60 cps.

(2) Turn the sweep vernier control until you see two complete cycles. The internal oscillator (sweep) oscillator is now running half as fast as the line frequency. What is the frequency of the oscillator now? ________ cps.

6. The Sync Control

(a) With the 2 sine waves still on the CRT, try to make the pattern stand still by carefully adjusting the Sweep Vernier control. There will nearly always be a tendency for the pattern to drift.

(b) Turn the Sync Selector to the "Internal Sync" position. Slowly advance the Sync control knob until the pattern stops or "locks" in place. This is the correct setting for this control.

(c) Now advance the Sync control knob until sine waves start changing shape. This effect is a visible display of distortion.

(1) Keep this result in mind later on when you are aligning FM or TV sets. Hours can be wasted trying to get a pattern similar to the one shown in the service data, simply because the sync control was turned too high.

7. The Scope as an AC Voltmeter

   (a) Adjust the vertical gain control until the pattern is an even number of inches in height. Do not disturb any of the other controls.

   (b) Remove the filament transformer leads from the vertical input terminals of the scope.

   (c) Touch the input terminal which is not grounded with your finger and measure the height of the trace.

      (1) Divide this dimension into the even number of inches you set the trace for in step "A", then multiply your answer by 6.3 volts.

      (2) You now know the number of stray volts charge your body is picking up.

      (3) This stray voltage is used by experienced service technicians as an audio signal generator for quick checking of audio stages in various electronic equipment.

   (d) Several students should try this. The amount of voltage varies from person to person and from day to day.

IDENTIFYING THE STAGES IN A COMMERCIAL FM RECEIVER

Objective

To learn to quickly identify the various stages in an FM receiver.

References: Lessons 5 and 6

Material Required:

One FM receiver.

One Schematic Diagram of the Receiver (Tube types should not show on this diagram).

A. Related Information

There are many distinctive "signs" inside the set which will lead you directly to the circuit you want to check without having to circuit trace the entire receiver. This job will help you learn to recognize the "signs" without waiting for the slow process of experience to teach you these tricks.

B. Suggested Procedure

1. On a sheet of 8 1/2"x 11" paper draw a rough outline of the top of the receiver chassis.
    (a) Mark down the tube numbers and the big parts like the power transformer, tuning gang, speaker, IF transformers, output transformer, etc.
2. Locate the rectifier tube first and write the word "rectifier" on your drawing.
    (a) Look for these "signs" for quick identification.
        (1) One wire from the power line will go directly to this tube socket in AC-DC sets.
        (2) The rectifier tube will usually contain the letter "X," "Y," or "Z."
        (3) In transformer powered sets, the tube will be near the transformer or possibly mounted on the transformer case.
        (4) In transformer powered sets, at least two wires will go directly to the rectifier socket. They will usually be red. If the tube number starts with the number "5" it is usually a rectifier tube and in this case there will be four wires going to the rectifier socket.
3. Locate the audio output stage next. Indicate its location on your sketch.
    (a) Here are the signs to look for.
        (1) The size of the output tube will often be larger than that of any other tube except the rectifier.

(2) Output tubes usually look black. If the glass envelope is clear, you will see a black coating on the plate of the tube.

(3) Follow the speaker wires to a heavy transformer with an iron core. This is the audio output transformer. It will have a blue lead going directly to the plate of the audio output tube.

4. Find the first audio stage and show its location on the sketch.

(a) Check these signs.

(1) The center terminal on the volume control will usually have a capacitor connected from this point directly to the grid of the first audio tube.

(2) You can work back from the output stage. There will be a capacitor between the plate of the first audio tube and the grid of the output tube.

(3) The first audio tube is usually a triode with a large resistor from its plate to B plus. This resistor will be of the order of 0.5 meg.

5. Identify the discriminator or ratio detector and label your sketch accordingly.

(a) Look for these features.

(1) This stage usually uses the smallest tube in the set. The type 6AL5 is the most popular.

(2) Watch for multi-purpose tubes! The two diodes may be in the first audio tube.

(3) One end of the volume control (the end which does not go to B minus) will have a capacitor and resistor in series leading to the socket of the discriminator, or a capacitor and resistor in series to the ratio detector transformer. A comparison of the discriminator and ratio detectors is illustrated in Fig. 1.

6. Now start at the other end of the set and find the RF amplifier. This tube is sometimes called a pre-selector. Occasionally, you will run across a set without this stage. In this case the antenna will go directly to the mixer.

(a) How to identify this stage.

(1) This stage is usually a pentode although some of the most modern sets may use a dual triode.

(2) The antenna leads go directly to this stage.

(3) This tube will usually be a miniature type.

7. Find the oscillator and mark its location on the sketch.

(a) Identifying features.

(1) A wire will run from the smallest section of the tuning capacitor to the grid of the oscillator. Usually a very small capacitor will be in series with this lead.

(2) If a variable coil arrangement is used for tuning, follow the lead from the smallest coil.

8. In some sets, the mixer tube will be separate from the oscillator to minimize drift. If your set uses separate tubes, find the mixer and note its location on your sketch.

(a) Here are the signs to look for.

(1) Both the RF amplifier and the oscillator will feed this tube.

    (2) The plate of this stage will go directly into the first IF transformer.
    (3) The tube will be physically close to the tuning gang.

9. The only tubes left are in the IF strip; mark them on your drawing.
    (a) Some things to watch for
        (1) There may be two, three, or four tubes in this strip.
        (2) If the set uses a discriminator, the final tube may be a limiter instead of an IF amplifier. A limiter will usually have a dropping resistor of a high value in series with the lead from the transformer to B plus.

10. When you finish your chart, go through the set quickly again. You should now be very familiar with this particular chassis.

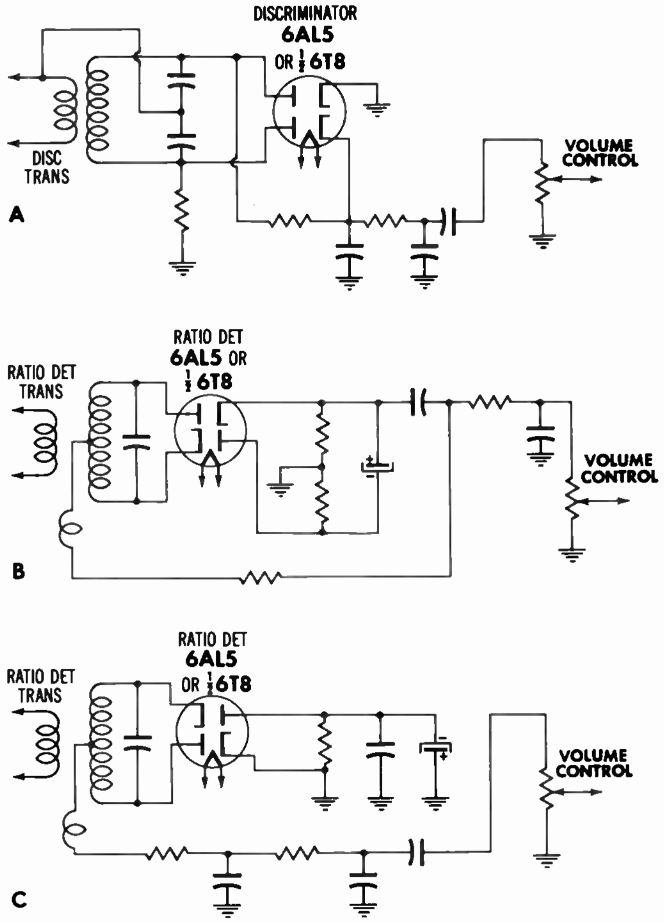


Fig. 1. (A) Discriminator Circuit. (B) Ratio Detector Circuit. (C) A Variation of the Circuit Shown in (B).

IDENTIFYING THE TUBES IN A COMMERCIAL TELEVISION RECEIVER

Objective:

To learn to rapidly identify the various sections in a television receiver.

Reference: Lesson No. 12

Material Required:

One commercial television receiver. One top view tube layout of set with no tube designations marked.

A. Related Information

By noting the combination of symptoms and the reaction of the set to adjustment of the various controls, it can be determined which sections of the receiver are not functioning properly. This job will help the student in recognizing the various sections of a television receiver.

B. Suggested Procedure

1. Start at the "front end." Identify the oscillator and the RF amplifier. Mark both the tube type number and the name of the stage on your chart.
    - (a) The "front end" will be mounted on a small subchassis in a cutout in the main chassis.
    - (b) The RF amplifier will be the tube nearest the twin line connection to the front end.
    - (c) The oscillator will be the tube toward the front of the cabinet in most cases.
    - (d) If three tubes are mounted on the sub-chassis you have either:
        - (1) Two RF amplifiers and an oscillator
        - (2) One RF amplifier, one oscillator and a separate mixer tube.
    - (e) If the oscillator is a dual triode, it is usually safe to assume one triode is used as a mixer and the other tubes on the "front-end" sub-chassis are RF amplifiers.
2. Locate the IF amplifiers next, and mark them on the chart.
    - (a) There will be three or four tubes mounted in a straight line.
        - (1) The line will originate very close to the tuner sub-chassis.
        - (2) All tubes in line will usually be of the same type.
        - (3) Tubes will be pentodes.

3. Identify video detector and note on chart.
    (a) Tube will be a diode, usually a 6AL5.
    (b) Tube will be physically very close to last IF amplifier.
    (c) If a duo-diode, other half may serve some other function. This is not readily determined without a schematic.
4. Locate the video amplifier and mark on chart.
    (a) The green or yellow lead from the picture tube socket often will pass through chassis close to the video amplifier.
    (b) This tube will be physically very close to the video detector.
    (c) If receiver is turned on, removing this tube will remove the picture, but a raster will still be present. Most common tubes used are 6AC7, 6AH6, 12BY7, 12AU7, or a 12AT7.
    (d) One of the terminals of the contrast control, located on the front panel, will usually be connected to the socket of this tube.
5. Locate the audio amplifier and sound output tube.
    (a) Follow leads back from the speaker to the chassis.
        (1) Audio output transformer is often on top of chassis, near the audio output tube.
        (2) If output transformer is mounted below chassis, speaker leads will usually enter chassis near the output tube.
        (3) Most commonly used tubes are 6V6GT, 6W6GT, 6K6GT, 6AQ5, 6BK5, and 25L6GT.
    (b) First audio tube will be close to the output tube. Most commonly used tubes are 6AV6, 6AT6, and one half of a 6T8.
6. Locate the sound IF and ratio detector and mark on chart.
    (a) The sound IF will usually be a pentode. In some cases it may be a triode.
    (b) Will usually have IF transformers or coils on two sides of it.
    (c) Working away from the video detector, you will see an IF transformer, then the sound IF tube, another IF transformer and then a miniature dual-diode. (Usually a 6AL5.)
        (1) This tube is the ratio detector, or a discriminator.
        (2) In some receivers part of this tube may be the first audio amplifier.
7. Identify the horizontal sweep tubes and mark on the chart. CAUTION! Be sure power line is disconnected from set before working near the high voltage cage. Voltages in this section can be lethal.
    (a) Horizontal oscillator will be either in the high voltage cage or just outside it.
    (b) Socket material of this tube may be different than that used in other octal sockets in set.
    (c) Socket may be mounted on spacers to keep it above or below chassis level.
    (d) Tube will usually be a dual triode. (Usually a 6SN7GT, 12SN7GT, 12AU7, 12AT7, or a 12BH7.)

8. Locate horizontal-output tube.

   (a) Nearly always located inside high voltage cage. See Fig. 1.

      (1) If outside cage, it will generally be the only tube outside the cage with a plate cap on top of the tube.

Fig. 1. The Horizontal-Output Amplifier, Damper, High-Voltage Rectifier, and Sometimes the Horizontal Oscillator are Placed in Special Cage.

      (2) Tube will often have a "G" size envelope. If tube is "GT" size, it will usually be taller than other GT tubes.

   (b) Tube is usually designed specifically for this function.

      (1) Common tubes used are 6BG6G, 6BQ6GT, 19BG6, 6CD6G, and 6CU6.

      (2) In some sets, this tube does not employ a top cap for the plate. Common tubes used in this case are 6AU5GT and 6AV5GT.

9. Locate the high voltage rectifier.

   (a) The tube type number will usually begin with the figure "1."

      (1) Most commonly used tubes are 1B3GT, 1X2, and 1X2A.

   (b) The socket will be on spacers to keep it well off the chassis.

      (1) Spacing of one inch or more from socket to chassis is quite common.

   (c) The high-voltage lead from the picture tube will often go directly to this tube socket.

10. Locate the damper tube and mark on the chart.

   (a) Will usually be the only tube left in the high-voltage cage.

(b) Most commonly used tubes are a 6U4GT, 6W4GT, or 6AX4GT.

(c) In some sets, this tube will be a miniature with a cap on top and will be a 6V3 type of tube.

11. Find the sync amplifier or amplifiers and mark on chart.

(a) This tube will be mounted in a position where they can feed the horizontal and vertical sync pulses to both sweep sections rather easily. This tube will usually be a 12AU7, 12AT7, 6SN7, and in some sets, it may be a 6BE6, 6CS6, or a 6BN6.

(b) If receiver is turned on, removing this tube from its socket will not remove the picture from the screen, but the picture will be out of synchronization both vertically and horizontally.

12. Locate the vertical oscillator and output tube, and mark on chart.

(a) Start by locating the output tube which will be located near the output transformer.

(1) One wire from a terminal on the vertical linearity control, usually located on the rear apron of the chassis, will be connected to the socket of this tube.

(b) Common tube types used are 6SN7GT (part of this tube may be used as the vertical oscillator), 6W6GT, 6V6GT, 6K6GT, 6S4, 12B4, and 12BH7.

(c) The vertical oscillator tube will be located near the output tube. If the oscillator is of the blocking oscillator type, it will be near the blocking transformer. Common tube types used are 6SN7GT, 12BH7, 6C4, and in some cases one-half of a 6U8.

13. Locate the LV rectifier tube and mark on chart.

(a) This tube will be located near the power transformer or sometimes it is located on top of the transformer.

(1) Most commonly used tubes are 5U4G, 5V4G, and 5Y3GT.

(b) If receiver does not use a power transformer, the LV rectifiers will consist of two selenium rectifiers, which are normally located on the bottom side of the chassis.

TUNING THE TELEVISION RECEIVER

Objective:

To become familiar with the proper method of tuning a television receiver, and the function of the various controls.

References:

Material Required:

Television Receiver.

Antenna

Schematic diagram of receiver being used.

A. Related Information

The installation of a TV receiver includes the placement of the unit in the desired location, the erection and attachment of the antenna, as well as the adjustment of the various operating and maintenance controls so that the set will function properly. The rear-panel controls will seldom need adjustments once they are adjusted properly.

B. Suggested Procedure

1. Connect the antenna lead-in to the antenna terminals on the receiver.
    a. A( ) B( ) C( ) D( ) The type of antenna system you are using is a: (A) dipole; (B) folded dipole; (C) rabbit-ear; (D) straight wire.
2. Turn the brightness and contrast controls fully counterclockwise.
3. Insert the AC plug of the receiver into an AC receptacle.
4. Turn the receiver ON.
    a. A( ) B( ) C( ) D( ) The power ON-OFF switch is located on the: (A) brightness control; (B) volume control; (C) front panel by itself; (D) contrast control.
5. List the channel numbers, the station call letters, and the channel frequencies of the stations received in your area.
6. Set the channel selector for the desired channel number.
    a. T( ) F( ) The RF, mixer, and oscillator circuits are pre-tuned for desired stations, and by setting the station selector to the channel number, the three tuned circuits are connected into their proper circuits.

b. Channel 7 has channel frequencies from 174 mc to 180 mc, therefore:

(1) A( ) B( ) C( ) D( ) The video carrier has a frequency of: (A) 167.25 mc; (B) 171.75 mc; (C) 175.25 mc; (D) 179.75 mc.

(2) A( ) B( ) C( ) D( ) The sound carrier has a frequency of: (A) 167.25 mc; (B) 171.75 mc; (C) 175.25 mc; (D) 179.75 mc.

VOLUME CONTROL

7. Set the volume control for desired sound volume.

a. A( ) B( ) C( ) D( ) This control is electrically located in the: (A) diode load; (B) power supply; (C) AF amplifier tube circuit; (D) sound IF stage.

BRIGHTNESS OR BACKGROUND

8. Turn the brightness control clockwise until the screen glows faintly, and the raster or picture is just visible. This control governs the brightness of the scanning beam by varying the DC operating bias for the picture tube. The normal position of the control is such that, with no incoming signal, the raster is just visible.

a. A( ) B( ) C( ) D( ) The brightness control may be found in the following stages of the TV receiver: (A) RF-oscillator-mixer; (B) cathode-ray tube first anode; (C) cathode-ray tube grid or cathode; (D) video amplifier.

b. A( ) B( ) C( ) D( ) This control governs the: (A) cathode-ray tube variable bias; (B) cathode-ray tube first anode voltage; (C) gain of the video amplifier; (D) amplitude of the deflecting voltage.

c. A( ) B( ) C( ) D( ) If this control is set too high, the beam saturates easily and the image appears (A) dark-thin-snowy; (B) bright-thin-watery; (C) very dark and thin; (D) snowy.

d. T( ) F( ) If this control is set too low, the general appearance of the image is dark.

e. T( ) F( ) The normal position of the control is such that with no incoming signal, the scanning raster is just visible.

CONTRAST OR PICTURE

9. Turn the contrast or picture control clockwise until a signal appears on the picture tube screen. This control regulates the amplitude of the video signal, thereby establishing the contrast between the light and dark portions of the image.

NOTE: It may be necessary to rotate the antenna and fine tuning controls when adjusting the contrast control, in order to obtain a picture.

Adjustment of the hold controls, as outlined in steps 12 and 13, may be required to obtain a stationary image.

a. A( ) B( ) C( ) D( ) The contrast control will be located in the: (A) sound IF amplifier; (B) local oscillator; (C) video amplifier; (D) RF amplifier.

b. A( ) B( ) C( ) D( ) This control regulates the: (A) IF value; (B) light area of the image; (C) dark to light area of the image; (D) amount of deflection.

10. Adjust the fine tuning control for loudest and clearest sound, along with a well defined image.

This control varies, within narrow limits, the frequency of the heterodyning oscillator. This is necessary to compensate for the slight drift in oscillator frequency during operation.

a. T( ) F( ) This control is located electrically in the sweep oscillator of the TV receiver.

b. T( ) F( ) This control is a variable capacitor.

FOCUS

11. Adjust the focus control for clearest definition by observing the width of the scanning line on the raster. The width of the line should be as small as possible.

The focus control on some receivers may be a control on the rear panel of the set, on other receivers it consists of a permanent magnet located on the neck of the picture tube.

a. A( ) B( ) C( ) D( ) The adjustment of the focus control governs the: (A) length of a scanning line; (B) number of scanning lines; (C) width of a scanning line; (D) picture height.

b. T( ) F( ) If the picture appears blurred, proper adjustment of the focus control should clear up the picture.

VERTICAL HOLD

12. Adjust the vertical hold control until the picture is vertically stationary. The vertical hold control varies the free-running frequency of the vertical-sweep oscillator. It is adjusted until the image is locked-in with the vertical synchronizing pulses of the incoming signal.

a. A( ) B( ) C( ) D( ) This control governs the sweep oscillator: (A) free-starting frequency; (B) free-running frequency; (C) sync pulse frequency; (D) free-locking frequency of the sync pulse.

b. T( ) F( ) The vertical hold control sets the sweep oscillator frequency to correspond to the frequency of the vertical sync pulse.

c. T( ) F( ) When the picture rolls from top to bottom or bottom to top, the horizontal hold control must be adjusted.

d. T( ) F( ) The hold controls are more common in electrostatic deflection.

HORIZONTAL HOLD

13. Adjust the horizontal hold control until the picture is stationary horizontally.

The horizontal hold control varies the free-running frequency of the horizontal sweep oscillator. It is adjusted until the image is locked-in with the horizontal synchronizing pulses of the incoming signal. Tearing of the picture is due to misadjustment of this control.

a. A( ) B( ) C( ) This control governs the sweep oscillator: (A) free-starting frequency; (B) free-running frequency; (C) sync pulse frequency.

b. T( ) F( ) The horizontal hold control sets the sweep oscillator frequency to correspond to the frequency of the vertical sync pulse.

c. T( ) F( ) The horizontal hold control is adjusted until the image is locked-in with the horizontal sync pulses of the incoming signal.

d. T( ) F( ) When the picture tears from side to side the vertical hold control is adjusted.

REAR PANEL ADJUSTMENTS AND ADJUSTMENTS ON THE NECK OF THE PICTURE TUBE.

Objective:

To learn to set up the back panel adjustments on a commercial television receiver.

Reference: Lessons 11, 12, 22, and 23

Material Required:

One commercial television receiver in good operating condition.
Schematic diagram of receiver being used.

A. Related Information

In order for a receiver to operate properly, the rear panel adjustments, and adjustments on the neck of the picture tube must be properly adjusted. The purpose of this job is to enable the student to perform these adjustments and note the effect of the adjustment on the picture.

B. Suggested Procedure

1. Turn the set on and tune in a TV station.

2. Have an instructor change the adjustments on the back panel and the neck of the picture tube.

3. Start by getting a raster on the face of the tube.

   a. Turn the brightness control to maximum (fully clockwise rotation).

   b. Move the ion trap (small magnet located around the neck of picture tube) slowly back and forward while rotating it at the same time.

      (1) Leave it in the position which gives maximum brightness.

      (2) You may now have only a portion of a raster with a rounded corner.

4. Adjust the centering control or controls.

   a. If a permanent magnet is used for focusing, there will be a metal tab sticking out of the focus assembly (see Fig. 1) which can be moved toward or away from the neck of the picture tube as well as rotated around the neck.

      (1) Adjust this control and readjust the setting of the ion trap. These two components will have an effect on each other.

      (2) In some sets there will be two positions of maximum brightness for the ion trap. If this is so in your set, use the position nearest the picture-tube socket.

b. If your receiver uses an electrostatically-focused picture tube (refer to lesson 20), the centering magnet will be composed of two circular rings with integral control tabs , as shown in Fig. 2.

   (1) When the tabs are 180 degrees apart mechanically, the raster location is not affected.

   (2) As the tabs are moved closer together, the centering of the raster will be altered. Adjust these tabs until the raster is properly centered.

c. If a focusing coil is used in the set, it will be mounted so it can be moved in practically all directions.

   (1) Tighten or loosen the mounting bolts and observe whether the picture (or raster) centering improves or not. Work slowly until you get the "feel" of this adjustment. Be careful to avoid undue strains on the neck of the tube.

Fig. 1. Permanent Magnet Focus and Centering Assembly.

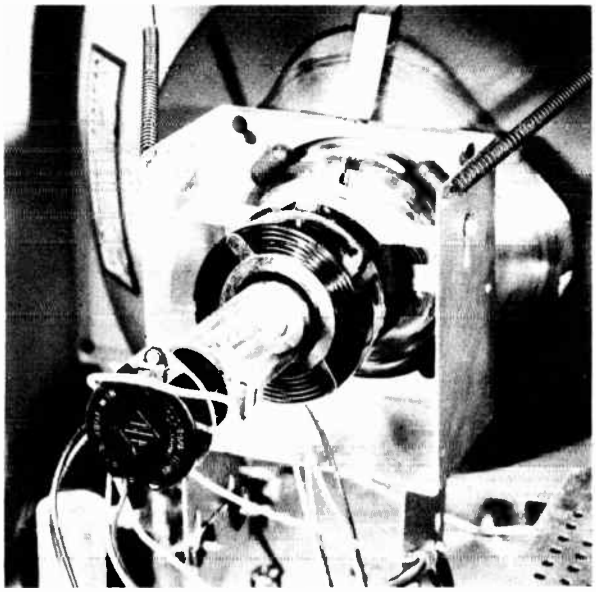


Fig. 2. Magnetic Centering Device Used On Electrostatic Focused Picture Tubes.

5. Adjust the horizontal sweep controls.

   a. There are four types of horizontal oscillator circuits used in present day receivers. Adjustment procedures for each type of circuit are presented in the following paragraphs. Determine the type of circuit your receiver employs and follow the adjustment procedures for that circuit.

      (1) The Saw-Tooth AFC System. See Fig. 3.

         (a) Turn the receiver on, and tune in a local station. Adjust the horizontal hold control to the mid-position of its range.

         (b) Adjust the horizontal frequency slug (B1), located on the back panel, until the picture locks in horizontally.

            (i) When the horizontal oscillator is out of adjustment, there will be sloping lines diagonally across the picture tube.

            (ii) As you adjust toward the proper setting, you will have a smaller number of these lines and they will get wider.

(c) If the picture is moving up or down on the face of the picture tube, stop the motion by adjusting the vertical hold control. (This control is usually a front panel control.)

(d) Turn the horizontal drive control (B2) clockwise until white bars or compression near the center of raster appears. Then turn B2 counterclockwise until white bars or compressions disappear.

(e) Adjust the width control for a picture slightly wider than necessary to fill the picture mask horizontally.

(f) Adjust the horizontal linearity control for a symmetrical picture from left to right.

(2) The synchroguide AFC system. See Fig. 4.

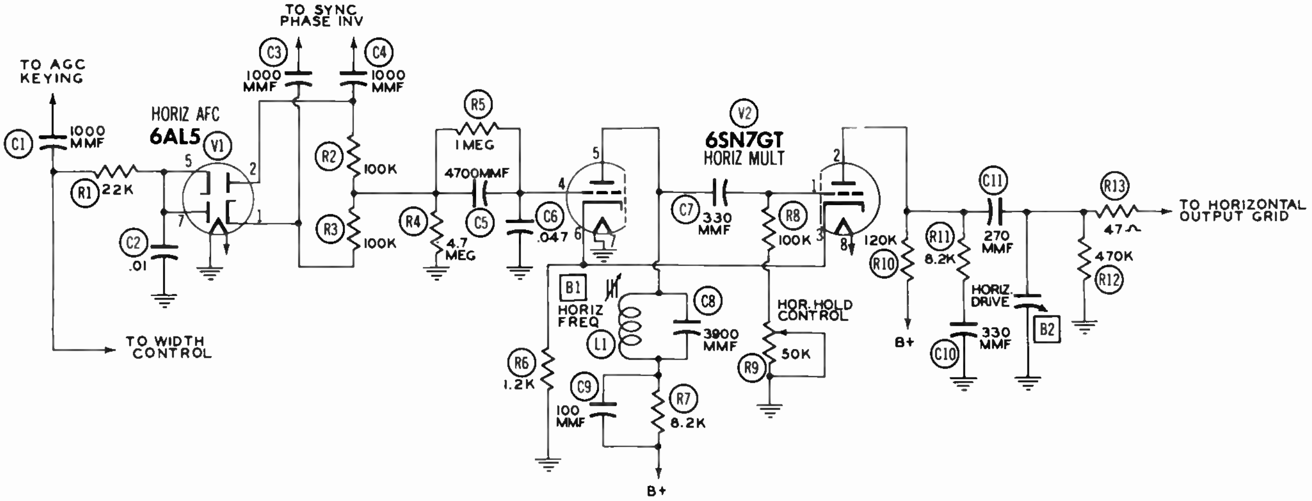


Fig. 3. Schematic Diagram of the Saw-Tooth AFC System.

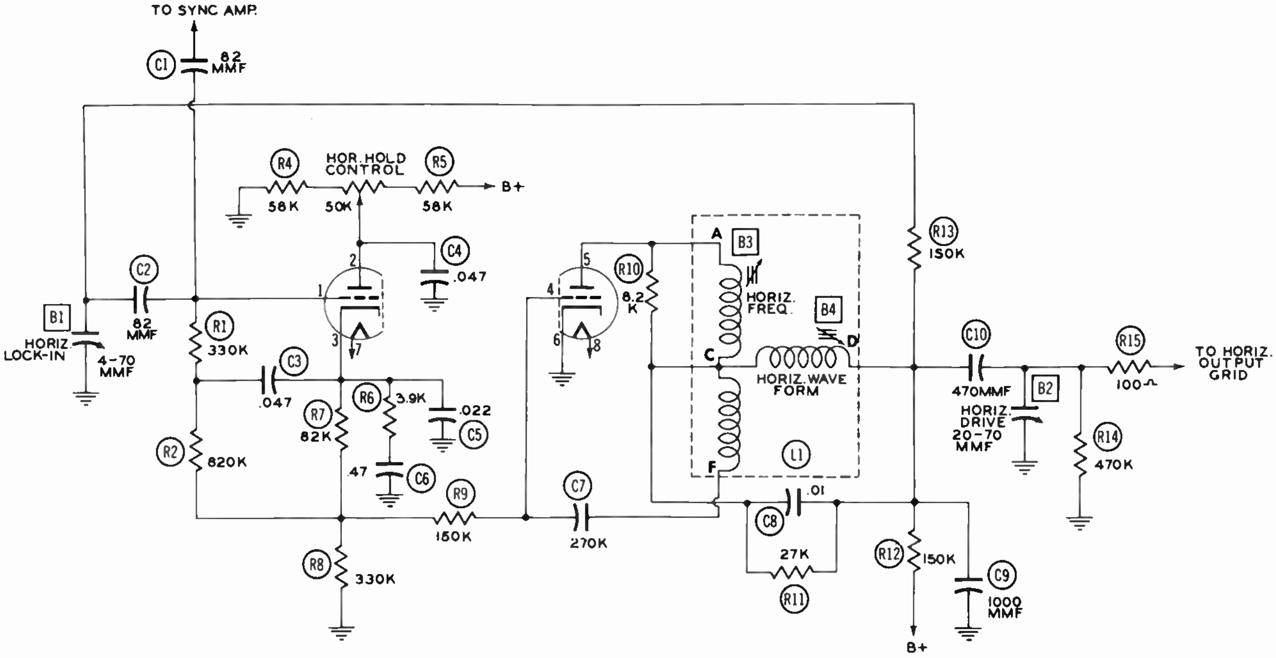


Fig. 4. Schematic Diagram of the Synchroguide AFC System.

(a) Preset the horizontal lock trimmer (B1) one turn counterclockwise from tight and the horizontal drive trimmer (B2) two turns counterclockwise from tight. Turn the set on and tune in a TV station, preferably a test pattern.

(b) Horizontal Frequency Adjustment

(i) Rotate the horizontal hold control over its entire range. If picture does not remain in sync over most of its range, adjust the horizontal frequency slug (B3) for best synchronization.

(ii) If unable to adjust B3 for proper horizontal hold range, adjust the horizontal waveform slug (B4) (located on bottom side of chassis), and repeat adjustment of the horizontal frequency slug. The picture should remain in horizontal sync; if not, continue with Horizontal Waveform Adjustment.

(c) Horizontal Waveform Adjustment.

(i) Short together terminals C and D of the horizontal oscillator coil (L1).

(ii) Set the horizontal hold control to its maximum counterclockwise position.

(iii) Adjust B3 until picture just locks in horizontally.

(iv) Remove short from terminals C and D of L1. If picture loses sync, adjust B4 until picture falls into sync.

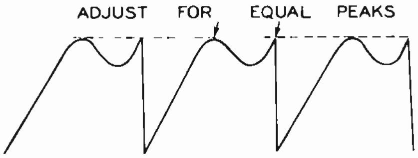


Fig. 5. Waveform Present at Terminal C of L1.

(v) Connect the vertical input leads of an oscilloscope to terminal C of L1. Adjust waveform slug B4 until the broad and narrow peaks are of equal amplitude as shown in Fig. 5. While adjusting B4, keep the picture in sync by turning the horizontal hold control clockwise. Disconnect scope from receiver.

(vi) Set the horizontal hold control fully clockwise and adjust B3 until picture remains in sync while switching off channel and back. With the horizontal hold control at mid-position, the picture should fall in sync when switching off channel and back again.

(d) Horizontal Lock Adjustment

(i) Set the horizontal hold control fully clockwise, switch off channel and back again. Picture should remain in sync.

(ii) If not, SLIGHTLY adjust B3 clockwise until picture falls out of sync with diagonal lines sloping to the left.

(iii) Turn the horizontal hold control counterclockwise. If more than three bars are present just before picture falls into sync, adjust the horizontal lock trimmer (B1) clockwise. If less than two bars are present, adjust B1 counterclockwise. The picture should now remain in sync while rotating the horizontal hold control over its full range and switching off channel and back again.

(3) The Reactance Tube AFC System. See Fig. 6.

(a) Turn the set on and tune in a TV station, preferably a test pattern.
Turn the horizontal drive control clockwise as far as possible without crowding the center of the picture or causing a vertical white line to appear.
Adjust the width control for a picture slightly wider than necessary to fill the picture mask horizontally.
Adjust the horizontal linearity control for a picture that is symmetrical from left to right.

(b) Remove the discriminator tube (V1), Fig. 6, from its socket.
Turn the horizontal hold adjustment (B1) until the picture moves back and forth across the screen with blanking bar vertical.
Replace V1 in its socket.

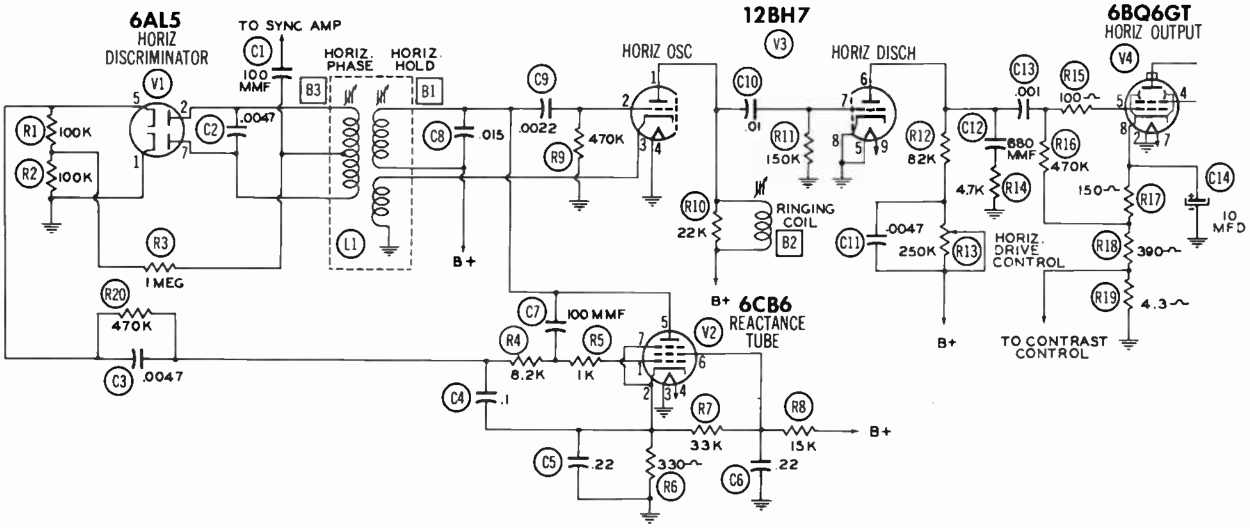


Fig. 6. Schematic Diagram of the Reactance-Tube AFC System.

(c) If the horizontal sync is unstable, perform the phasing adjustment as follows:

(i) Turn the core of the ringing coil (B2) fully counterclockwise. Short out peaking resistor R14. Repeat adjustment of horizontal drive control as above.

(ii) Remove the discriminator tube V1 from its socket.

(iii) Adjust B1 until picture moves back and forth across screen with blanking bar vertical.

(iv) Replace V1

(v) Adjust the phasing slug (B3) until approximately 1/4 inch of blanking is visible at the right edge of picture. In order to see the blanking it may be necessary to reduce the contrast to minimum and adjust the brightness control.

(vi) Remove the short from R14 and readjust the horizontal drive control as described previously. Turn B2 clockwise until approximately 1/4 inch of blanking is visible on the right edge of picture.

(vii) Slowly adjust B1 in either direction until the picture falls out of sync, with a number of diagonal bars present. Turn B1 to decrease the number of bars and note the least number present just before picture synchronizes. The number should not be less than three, nor more than six. Turn B1 in opposite direction from the first until picture loses sync, then back again, noting the least number of bars present just before synchronization. Again there should be not less than three, nor more than six. Repeat steps ii, iii, and iv.

(4) The Gruen AFC Circuit (See Fig. 7.)

(a) Turn the set on and tune in a TV station preferably a test pattern. Set the horizontal hold control at mid-position, and adjust the horizontal frequency slug (B1) until the picture synchronizes horizontally.

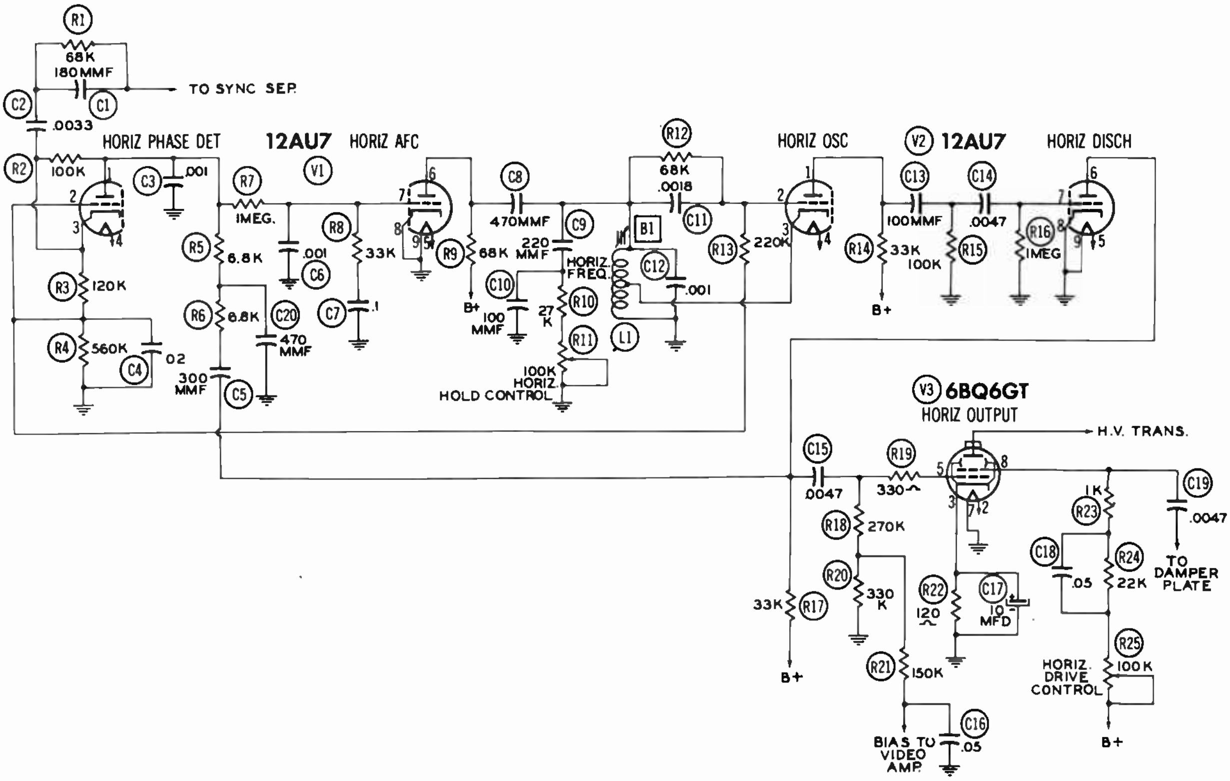


Fig. 7. Schematic Diagram of the Gruen AFC System.

(b) The horizontal drive control should be rotated in a counterclockwise direction as far as possible without compression of the center of the picture, or presence of a vertical white line.

(c) The width control should be adjusted for a picture slightly wider than necessary to fill the picture mask horizontally.

(d) Adjust the horizontal linearity control for a picture that is symmetrical from left to right.

6. Adjust the vertical sweep controls.

a. A test pattern should be used for these adjustments, if possible. The vertical linearity (usually marked VERT LIN) and the height control (sometimes called the vertical size control) should be adjusted simultaneously to provide proper picture height consistent with good vertical linearity.

b. If the top or bottom portion of the picture must be run off the screen to bring a picture to either edge, and the picture is nonlinear, touch up the centering adjustments and repeat the linearity and height adjustments.

c. The height and linearity controls will affect each other. Keep working between these controls until you are satisfied with the picture.

IDENTIFYING CIRCUITS IN A TELEVISION RECEIVER

Objective:

To gain experience in identifying parts and circuits of a television receiver using service literature as a guide.

Reference: Lessons: 11 through 23

Material Required:

1. Television receiver
2. Schematic diagram of the set.
3. Unlabeled layout diagram as seen from bottom of chassis.

A. Related Information:

1. This shop job is divided into several sections. Each section covers one specific part of the TV Receiver.
2. After the job is completed the student should be able to readily locate any of the tubes, controls, or adjustments of the receiver. He should also be able to identify any part of a receiver when shown its symbol on the schematic. He should likewise be able to give the symbol for any part shown.
3. This job is very important for future field servicing because a visual check will quite often reveal a loose connection which can disable a set. Even if the visual check does not locate the trouble it will help to speed servicing by isolating the circuit which needs attention.
4. Sometimes production changes are made after the service literature is published. On a separate sheet of paper note any differences you see between the set and schematic diagram.

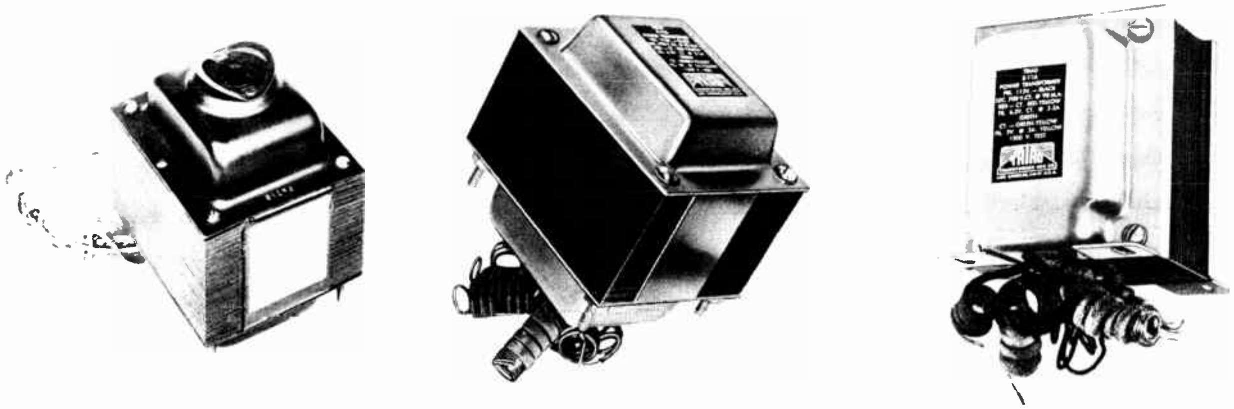


Fig. 1. Power Transformers Used in TV Receivers.

B. Suggested Procedure:

1. Power supply

   a. Is the rectifier a vacuum or selenium type? ________________

   b. Does the set have a power transformer? If so, locate it and be prepared to point it out to the instructor. (See Fig. 1.)

   c. Trace the lead from the cathode of the rectifier to the input filter capacitor. (The cathode of a vacuum tube can be located by referring to the tube manual. The cathode of a selenium rectifier is marked by a red dot or a plus (+) sign or a letter K. (See Fig. 2.)

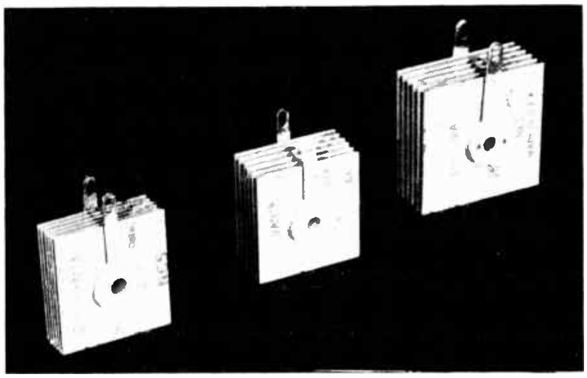


Fig. 2. Typical Selenium Rectifiers Used in TV Power Supplies. Note the Cathode Markings.

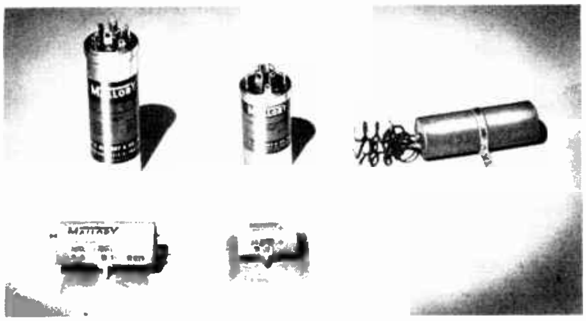


Fig. 3. Electrolytic Filter Capacitors Used in TV Receivers.

   d. Locate the filter choke and the output capacitor. (See Figs. 3 and 4.)

   e. Are the tube filaments connected in series or parallel? ________________

   f. Label all parts of the power supply which are shown on layout diagram.

2. High-Voltage Section

   CAUTION: The voltages developed in this part of the receiver are dangerous. Do not turn the set on with high voltage cage open AT ANY TIME.

   a. Locate and identify the high voltage transformer (see Fig. 5). Be prepared to point it out to the instructor.

   b. The high voltage winding of the high voltage transformer is connected to the plate of the ________________ which is a ________________ tube type.

Fig. 4. Typical Filter Choke.

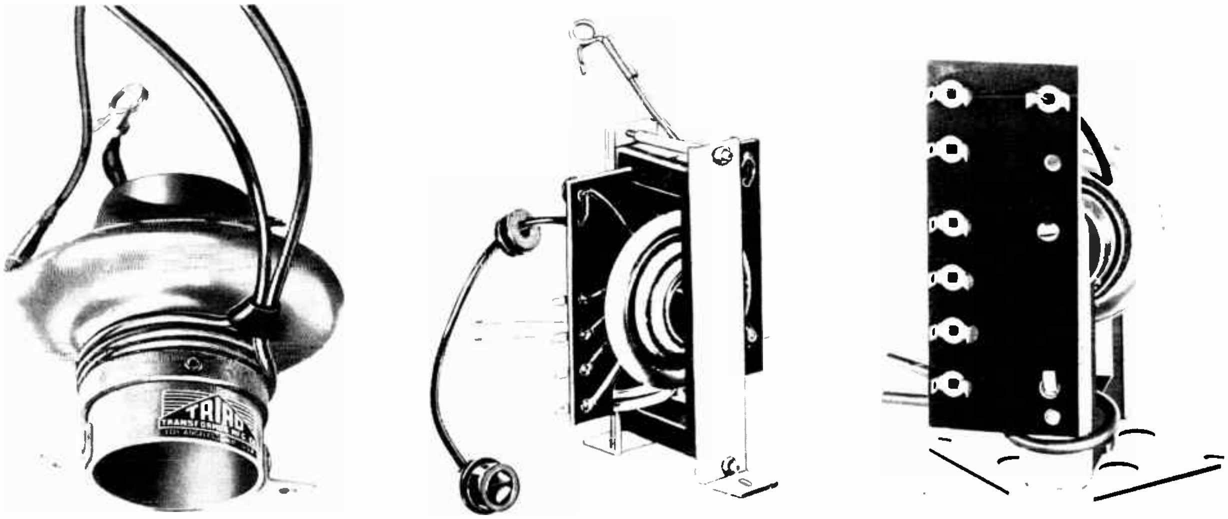


Fig. 5. Typical TV High-Voltage Transformers.

c. Locate and identify the high voltage filter capacitor and be ready to show it to the instructor. (See Fig. 6.)

d. Does the set you are working on have width and horizontal linearity controls? (See Fig. 7.) Locate and identify the width and horizontal linearity control (if present) and be prepared to show them to the instructor.

(NOTE: On some sets one or both of these controls may be omitted. The linearity control is most commonly a coil located in series with the cathode circuit of the damper tube. The width control is generally a coil connected across part of the high-voltage transformer secondary.)

e. Label all parts of the high-voltage section that appear on the layout diagram.

3. The Deflection Circuits.

a. Trace the circuit from the horizontal hold control to the horizontal oscillator. On this set the horizontal hold control is a ______________(resistor, capacitor, coil) in the ______________ (cathode, plate, grid) circuit of the horizontal oscillator. It is on the ______________(front, back) of the chassis.

Fig. 6. High-Voltage Filter Capacitors.

Be prepared to point this control out to the instructor and to trace the lead from it to the oscillator.

b. The horizontal drive control is a variable ____________ (resistor, capacitor, coil) located on the ____________ (front, back, top) of the chassis.

c. Trace the circuit from the vertical hold control to the vertical oscillator. This control is a ____________ (resistor, capacitor, coil) in the ____________ (cathode, plate, grid) circuit on the ____________ (front, back, top) of the chassis. If this circuit is a blocking oscillator locate the blocking oscillator transformer. See Fig. 8.

d. Does the set have a height and vertical linearity control? If so, locate them and be ready to point them out to the instructor.

e. Locate the vertical-output transformer. (See Fig. 9.)

f. Label all parts of the deflection circuits that are shown on the layout diagram.

4. The IF Strip:

a. On some sets the entire IF strip can be removed as one unit. Is this provision made on your set? ____________

b. Trace the B+ lead of the IF strip.

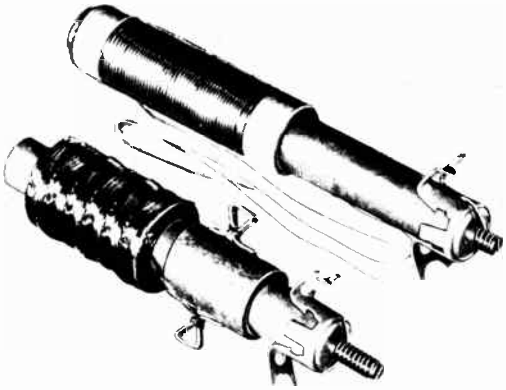


Fig. 7. Linearity and Width Controls.

Fig. 8. Blocking Oscillator Shielded-Type Transformer.

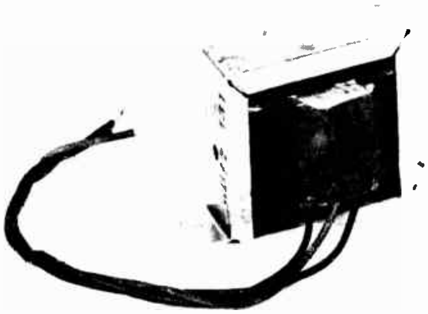


Fig. 9. Typical Vertical-Output Transformer.

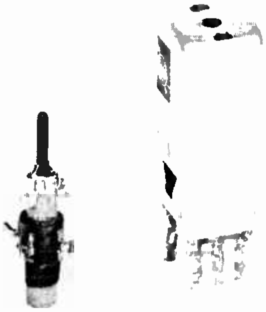


Fig. 10. Video IF Transformers — Shielded and Unshielded Types.

c. Locate and identify the IF Transformers. (See Fig. 10.) Are they above or below the chassis?________ Are they shielded?________

d. On many sets decoupling networks are provided in the B+ circuit of the IF strip. They are usually RC circuits. A typical decoupling network is shown in Fig. 11.

On what IF stage does your set have decoupling networks?________

e. Often the filaments are bypassed by using capacitors, RF chokes, or both. A filament circuit is shown schematically in Fig. 12. A filament choke is pictured in Fig. 13.

Usually the filaments of the IF tubes are between pins 3 and 4. Trace the filament circuit and locate any bypass components. Be ready to point them out. There are ________ capacitors and chokes in the IF filament circuit of your set.

f. Trace the AGC line of the IF strip. To which IF stages is the AGC line connected? ________. Point the AGC line out to the instructor.

g. Locate and identify the sound IF circuit (tubes, transformers, etc). How many stages of sound IF amplification are provided?________. Locate the discriminator transformer. (See Fig. 14.)

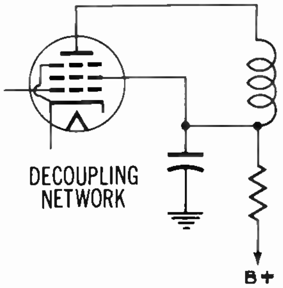
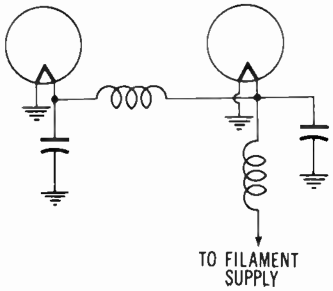


Fig. 11. (Left) IF B+ Decoupling Network.

Fig. 12. (Right) Typical Filament Decoupling Circuit.



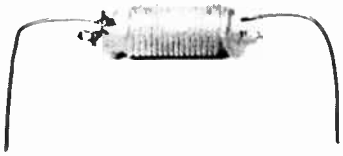


Fig. 13. Filament Choke.

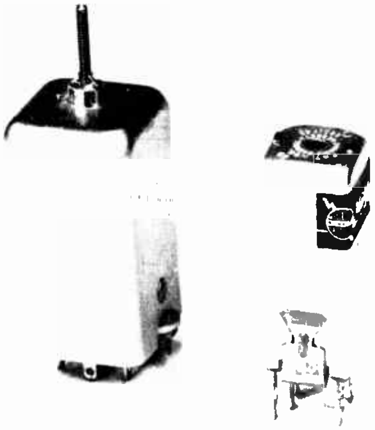


Fig. 14. Two Types of Discriminator Transformers.

Fig. 15. Typical Audio-Output Transformer.

h. Label all parts of the IF circuit that appears on the layout diagram.

5. The Audio Circuit

a. What is the value of the coupling capacitor from the volume control to the grid of the first audio stage? ______. What is the value of the coupling capacitor from the first to the second audio stage? ______.

b. Does the audio output tube have a bypassed cathode resistor? If so, what is the value of the resistor? ______ What is the value of the bypass capacitor? ______.

c. Does the set have a detector output jack, for connecting to an external amplifier? ______ If so, locate it.

d. Locate the audio-output transformer. (See Fig. 15.)

e. Label all parts of the audio circuit shown on the layout diagram.

6. The Video Detector.

   a. Locate and identify the video detector. Be prepared to point it out. Is it a tube or a germanium diode?______________.

   b. Label the parts of the video detector that appears on the layout diagram.

7. The Video Amplifier.

   a. How many stages are in the video amplifier section? ______________. Locate the video amplifier tube (or tubes).

Fig. 16. Video Peaking Coil.

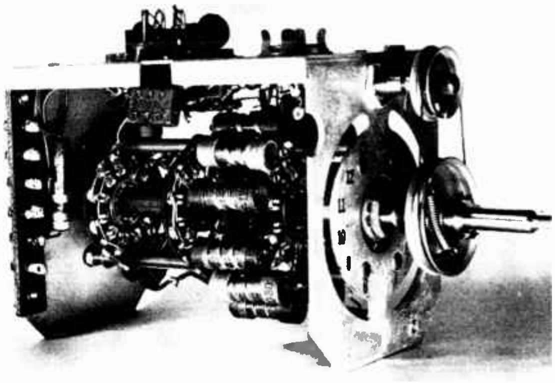


Fig. 17A. The Incremental Type RF Tuner.

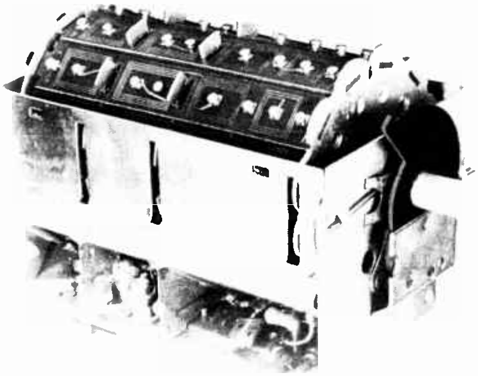


Fig. 17B. Turret Type RF Tuner Using Removable Channel Strips with Printed Circuits.

b. Locate the video peaking coils. (See Fig. 16.) Is shunt or series peaking used? ___________

c. Trace the circuit from the contrast control to the video amplifier.

d. Label the parts of the video amplifier that are shown on the layout diagram.

8. The Tuner (See Figs. 17 and 18.)

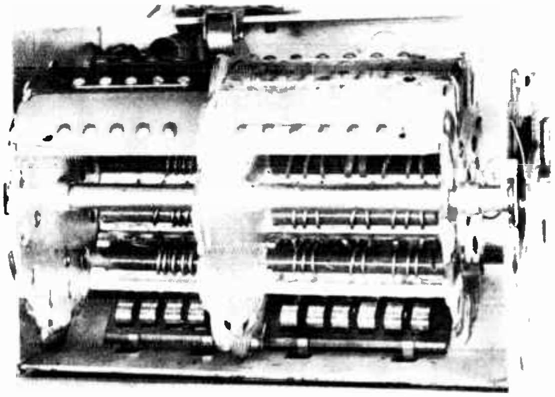


Fig. 18. Tuner Using Tuning Strips with Lumped Constants. Some Tuning Strips are Removed, Exposing the Wiring of Others.

Fig. 19. A Deflection Coil.

CAUTION: It is very easy to get a tuner out of adjustment. Do not touch the parts of the tuner.

a. How many positions are there on the tuner?_____________. Does it have a provision for UHF tuning?_____________ .

b. Is the bottom of the tuner shielded?_____________. If so, ask the instructor to remove the shield.

c. Does the tuner have removable channel strips? (See Fig. 18.)_____________.

d. Label all parts of the tuner which appear on the layout diagram.

e. Ask the instructor to replace any parts of the tuner which have been removed.

9. Parts on the Neck of the Picture Tube.

a. Locate the deflection yoke. (See Fig. 19.)

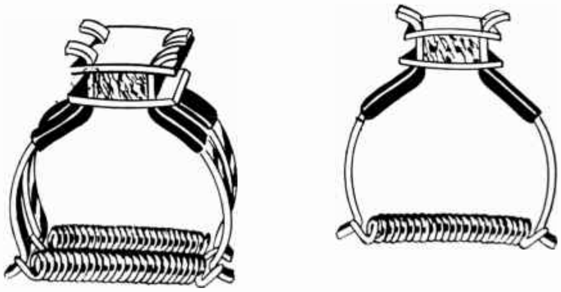


Fig. 20. Ion Traps — Single and Double Magnet Types.

b. Locate the ion trap. (See Fig. 20.) Is a single or double magnet ion trap used?__________.

c. Locate the focusing device. (See Fig. 21.) Does this set use electrostatic focusing? __________.

If electromagnetic, is the focusing device a permanent magnet or a coil? __________.

d. Locate the focusing control.

e. Locate the high voltage lead and connector.

f. The part located closest to the bell of the picture tube is the__________. The part located closest to the base is the__________. The__________ is located between the above mentioned parts.

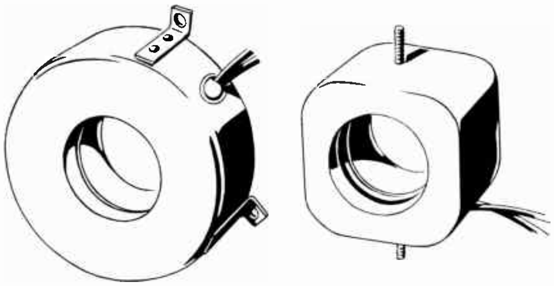


Fig. 21. Focus Coils.

STUDYING THE VIDEO DETECTOR AND AMPLIFIER STAGE OF A COMMERCIAL TV SET.

Objective:

To become acquainted with the video circuit used in a commercial TV set.

References: Lessons 17 and 18

Material Required:

1. Television set.
2. Set of service instructions for the set including the schematic, waveforms, and voltage readings.
3. Oscilloscope
4. VTVM
5. Several sheets of graph paper.

A. Related Information.

Essentially, a video amplifier is the same as an audio amplifier with a very wide range. To obtain the necessary range, the plate load resistor is reduced and peaking coils are added to the circuit. The steps taken to widen the range also reduce the gain. Therefore, a video amplifier is often multi-stage.

B. Procedure Steps.

1. Remove the TV set from its cabinet. Turn the chassis on one side and turn it on. Adjust the front panel controls for good picture and sound. Turn down the volume (sound) as you are not concerned on this job with the audio section of the receiver.
2. Locate the parts of the video detector and amplifier circuits.
   a. Is the video detector a tube or a germanium diode? ____________
   b. Is the signal taken from the cathode or plate of the video detector? ____________

NOTE: If the detector is a germanium diode, the cathode is usually marked CATH, or by the letter K. Some diodes will bear the marking + and -, the + sign being the plate and the - sign the cathode.

   c. How many stages of video amplification are provided? ____________
   d. Does the set have a DC restorer? ____________
   e. Is the video section direct coupled? ____________

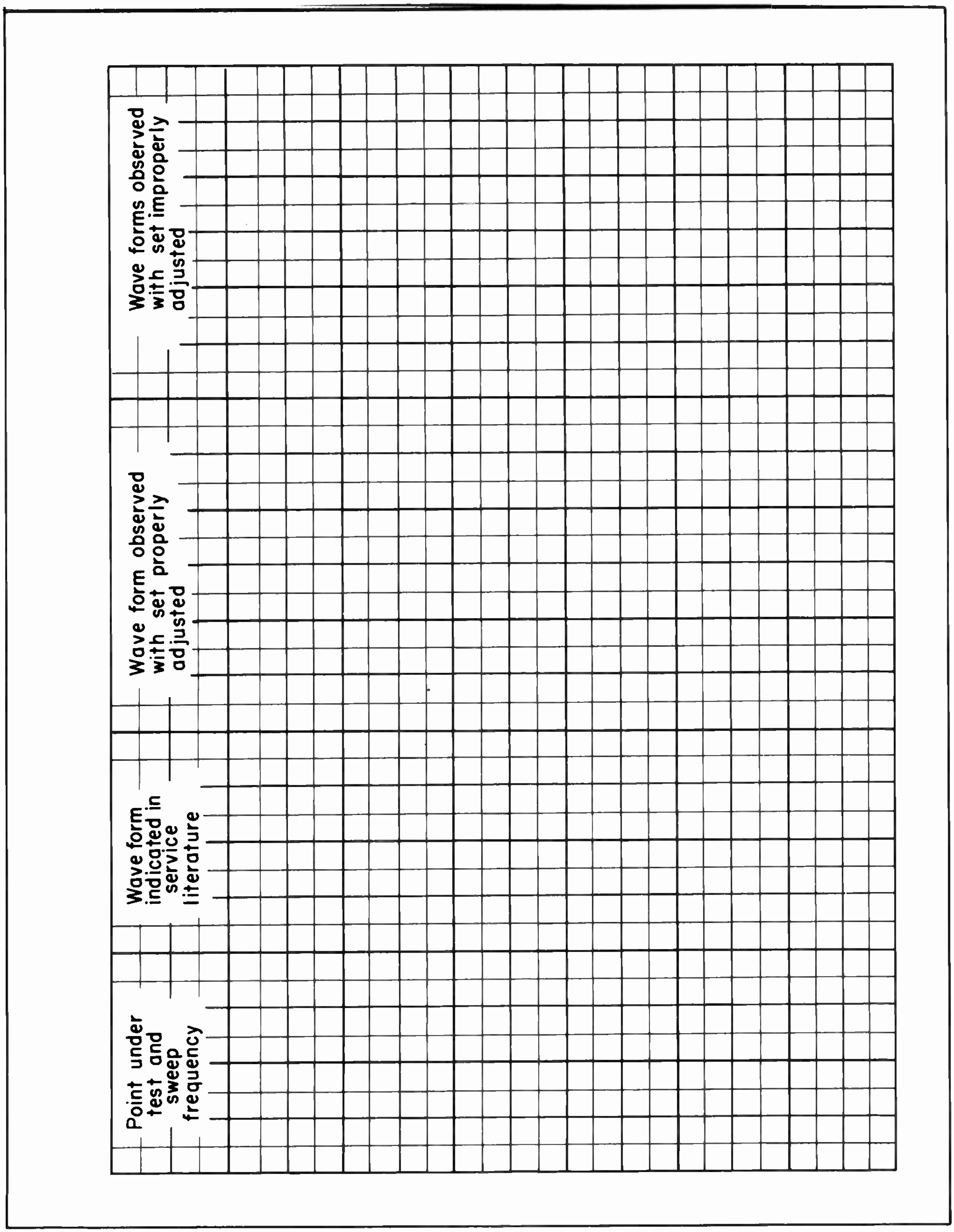


Fig. 1. Graph Paper Divided for Waveform Comparison.

f. Is the video signal fed to the grid or cathode of the picture tube? ______________

g. Where is the sound take-off point? ______________

h. Where is the sync take-off point? ______________

i. What type of peaking (series, shunt,or both) is used in each video stage?

3. Check all voltages whose expected values are given in the service manual and any others the instructor directs. Record the point measured, expected value, and observed value on a separate sheet of graph paper.

4. Lay out a piece of graph paper for comparison of waveforms, as shown in Fig. 1.

   a. Observe all waveforms of the video detector and amplifier that are shown in the service manual. On the graph paper record the point of observation, sweep frequency of scope, expected wave, and observed waveform.

   b. In addition to the waveforms observed in step a, look at the output of the video detector, also the input and output of each video stage. It is not necessary to record waveforms not shown in the literature unless directed to do so by the instructor.

   c. Repeat step b for any other points the instructor directs.

5. Investigate the effects of the brightness and contrast controls on the video signal.

   a. Connect the oscilloscope to observe the video signal fed to the picture tube.

   b. Change the setting of the brightness control and describe any changes in the video signal.
   ____

   Readjust to the correct brightness.

   c. Vary the contrast control and describe any changes in the video waveform.
   ____

6. Turn the set off and restore it to its original condition.

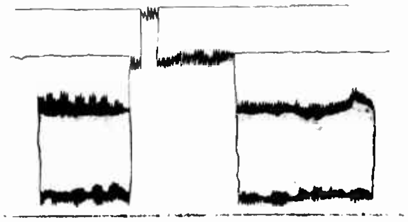


Fig. 2. Composite Video Waveform at Vertical Sweep Rate.

C. QUESTIONS

1. If the video detector is a germanium diode and if the output signal is taken from its cathode the picture information will be ____________ (pos. – neg.) with respect to the blanking and sync pulses.

2. Fig. 2 shows the composite video waveform from just before to just after the vertical retrace. Label the following:

   Picture information

   Black level

   Sync level

   Vertical blanking pulse

   Vertical sync pulse

3. Fig. 3 shows the composite video waveform for two horizontal lines. Label:

   Picture information

   Black level

   Sync level

   Horizontal blanking pulses

   Horizontal sync pulses

4. The ____________________(brightness, contrast) control determines the picture tube bias, and the ____________________(brightness, contrast) control varies the video signal amplitude.

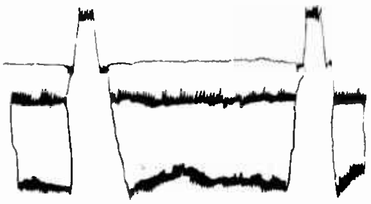


Fig. 3. Composite Video Waveform at Horizontal Sweep Rate.

STUDYING THE ACTION OF THE AGC SYSTEM

Objective:

To learn the normal behavior of an AGC system and to learn to recognize the symptoms of some of the more common troubles in this circuit.

References: Lesson 17

Material Required:

1 operating television receiver.
1 set of servicing information for this receiver.
1 vacuum tube voltmeter.
1 antenna.
1 defective (gassy) IF tube for receiver. (See note at end of job.)
1 resistor with alligator clips at ends of three inch leads (5K — 1/4 watt)

A. Related Information:

In strong signal areas, the receiver can easily be overloaded if the AGC system is not supplying enough correction. In very weak signal areas, the skilled technician sometimes modifies the AGC system to make the set as sensitive as possible. Almost all manufacturers recommend opening the AGC line and installing a fixed bias during alignment. It is evident, therefore, that a practical familiarity with these circuits is essential. In this job we will first check the operation of the circuit under normal conditions, then under trouble conditions.

B. Suggested Procedure:

1. Remove the chassis from the cabinet and turn up on one edge. Attach the antenna and tune in a local station. Be sure the set is in operating condition before starting.

2. Connect DC probe of a VTVM to the grid of the last IF amplifier which has AGC bias applied to it. Connect the common lead to B minus.

   a. The reading will be negative, so your meter should be set for minus DC volts.

   b. The meter should be on approximately the 10 volt range, depending on the range of scales on your particular meter.

3. Adjust the antenna and fine tuning control for the highest reading on the VTVM.

   a. The voltage reading is now ________________ volts.

b. The picture contrast is (check one)

_____ Too strong (Tends to smear.)

_____ Very good (A natural contrast between the light and dark areas.)

_____ Acceptable (Could be improved but is clearly defined.)

_____ Very poor (Very thin color tones with some retrace lines showing, but the set still synchronizes.)

4. Slowly rotate the antenna or fine tuning control. Leave these in the position which gives the lowest reading.

a. The voltage reading is now _____ volts.

b. The picture contrast is (check one)

_____ Very good (A natural contrast between the light and dark areas.)

_____ Acceptable (Could be improved but is clearly defined.)

_____ Very poor (Very "thin" color tones with some retrace lines showing but receiver synchronizes.)

_____ Picture lost (Will not synchronize or can not be seen because of snow.)

5. From the above results we can conclude that as the signal strength is increased the AGC voltage _________________ (increases or decreases), and the picture _____________ (improves or deteriorates) in quality.

6. Now return the antenna and fine tuning control to the position which originally gave you the maximum reading.

a. Read the voltage at each IF grid. (If your set has split-sound, check only the picture IF grids.)

Voltage at first IF grid _________

Voltage at second IF grid _________

Voltage at third IF grid _________

7. Do not disturb antenna or setting of any controls. Locate one of the capacitors connected from the AGC line to B minus. An AGC decoupling network is shown in Fig. 1. Connect the 5K-ohm resistor across it. Read the voltages at the grids again.

Voltage at first IF grid _________

Voltage at second IF grid _________

Voltage at third IF grid _________

a. What happened to the picture contrast? (increased or decreased) _________

b. Was the voltage affected at all grids, or only the one nearest the capacitor? _________

8. Remove the resistor you temporarily connected.

9. Replace the second IF amplifier tube with a gassy tube of the same type.

a. The picture is (check one)

_____Very good.

_____Tends to smudge.

_____Tends to pull or tear.

b. Check the grid voltages again. Are the grids still negative with respect to B minus?_____

Voltage at first IF grid __________

Voltage at second IF grid __________

Voltage at third IF grid __________

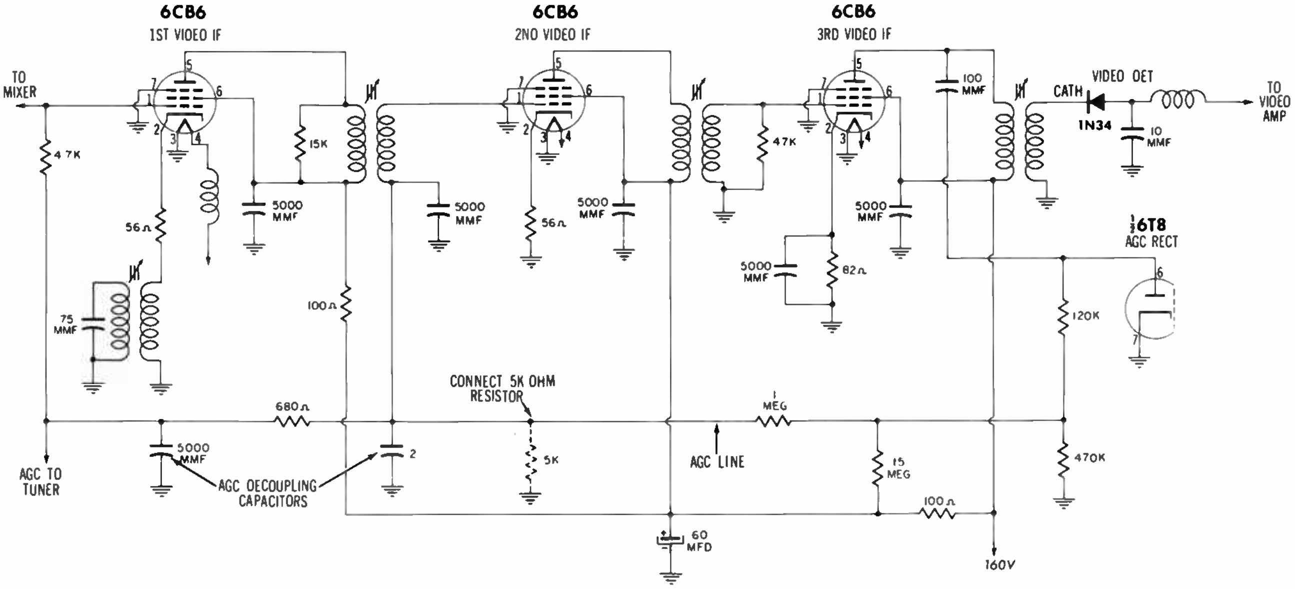


Fig. 1. Schematic Diagram of a Typical AGC Circuit.

10. Remove gassy second IF tube but do not replace with good tube. Measure the voltages on grids once more.

Voltage at first IF grid __________

Voltage at second IF grid __________

Voltage at third IF grid __________

11. Does removal of the gassy tube make all grids more negative, even though no signal is reaching the detector to develop an AGC voltage? __________

12. Put the good IF tube back in the socket and check to see if the set is in good operating condition, and call your instructor to check the job.

QUESTIONS:

(1) Does the set you are working on have an AGC amplifier? __________

(2) Is there a keyed AGC system used in this set? __________

(3) Does the AGC system control any tubes in the tuner (front end)? ____________

(4) Is a decoupling network used between all points where the grid returns connect to the AGC bus (line)? ____________

(5) Does a leaky AGC decoupling capacitor tend to increase or to decrease the receiver sensitivity? ____________

(6) Does a gassy tube tend to increase or decrease the sensitivity? ____________

(7) In normal operation, is the AGC voltage determined by the overall average signal level or by the level of the sync pulses only? ____________

(8) In an AM radio receiver we usually take the AVC voltage from the detector. In a television set, is the AGC voltage taken directly from the video detector? ____________

(9) In the set you used in this job, will the setting of the contrast control have any effect on the AGC voltage? ____________

(10) Does this set have a switch to change AGC sensitivity for local and distant reception?
____

NOTE: Your local TV service shops should be glad to give you gassy tubes since they must discard them in any case. If not, you can prepare your own by running the tubes too hot for a few minutes. Use about 200 volts on the plate and gradually decrease bias until the plate shows a dull red spot. Hold for about a minute, then check tube on a tester. If not yet gassy, repeat.

CHECKING WAVEFORMS IN THE SYNC AND DEFLECTION CIRCUITS

Objective.

To observe waveforms in a properly adjusted television receiver and to compare them with the waveforms given in the service literature.

References: Lessons 19, 21, 22, and 23

Material Required:

1. An operating television receiver.
2. Service literature pertaining to your receiver, and a schematic diagram with waveforms shown.
3. An oscilloscope.
4. A pair of test leads equipped with alligator clips on one end of each lead.
5. Several sheets of graph paper.

A. Related Information:

Servicing of the deflection and sync circuits of a television receiver is often done by use of an oscilloscope. The service literature provided by most manufacturers or by leading technical publishers, indicate the waveforms expected at certain important points in a TV set. By observing these waveforms, a defective component can be located and the set can be properly repaired.

In this shop job we will observe the waveforms in a set that is properly adjusted. After this, mis-adjustments will be introduced into the set and their effects will be studied.

The service literature usually indicates the oscilloscope sweep frequency beside the waveform expected at any given test point. If the frequency is given, it should be used. If the frequency is not given, use 30 cycles per second for the vertical circuits and 7,875 cps for the horizontal circuits. This will permit the observation of two complete cycles of the waveform being viewed.

B. Suggested Procedure

1. Check the receiver to be sure it is operating properly. There should be a good picture and sound. After the sound has been checked, turn the volume all the way down for the rest of the job.
2. Turn the set off, remove the chassis from the cabinet and turn it on one side to enable you to get at the points you wish to test.
3. Make a visual check of the sync and deflection circuits.
   a. Locate the deflection and sync tubes on the schematic. Looking at the underside of the chassis locate the sync and deflection tubes.
   b. Locate all controls and adjustments of the sync deflection circuits on the schematic and on the set.

c. Locate the vertical-integrator circuit. Printed circuits are often used in this application. (See Fig. 1.) Is the integrator network of your set a printed circuit?

4. Turn on the set and get a good picture. If you have not already done so, prepare your graph paper as shown in Fig. 2. The set can be warming up while you prepare the graph paper.

5. Check the waveforms of the horizontal-deflection circuit at all points for which a waveform is shown in the service literature, and draw them on the graph paper. (Note: The waveforms observed should be fairly close to those shown in the service literature.)

   a. Check any other points the instructor directs.

   b. What type of horizontal oscillator is used in this set? ____________

6. Check the waveforms of the vertical circuit.

   a. Check all points for which a waveform is shown in the service manual.

   b. Check any other points the instructor directs.

   c. What type of vertical oscillator is used in the set? ____________________

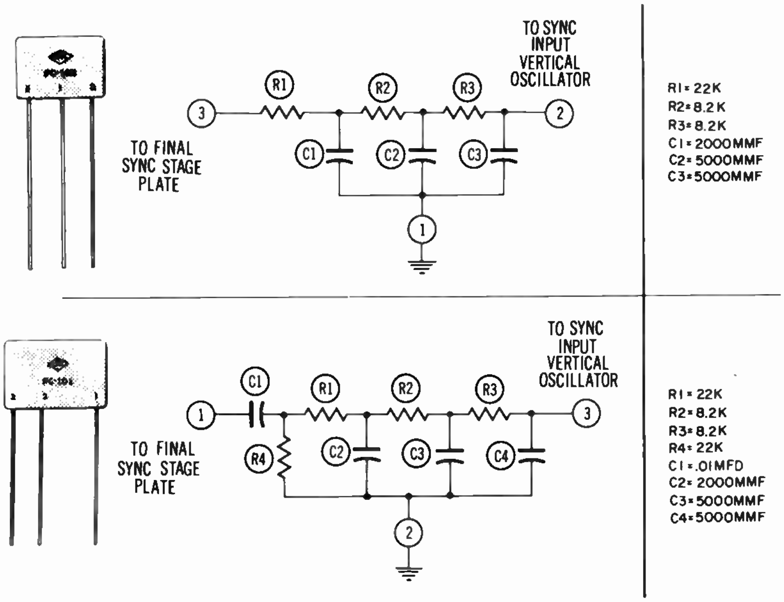


Fig. 1. Typical Printed Vertical-Integrator Circuits.

7. Check the waveforms of the sync circuit.

   a. Check all points for which a waveform is given in the manual.

   b. Check any other points the instructor directs.

   c. Where is the sync take-off point? ______________

(NOTE: The sync signal is usually taken off at the output of a video amplifier. It may be taken from the output of the video detector or the IF strip.)

Be prepared to point out the sync take-off point to the instructor.

   d. What type of horizontal AFC system is used in this set? ______________

8. Observe the effect on the sync circuit output when the input to the sync separator is varied.

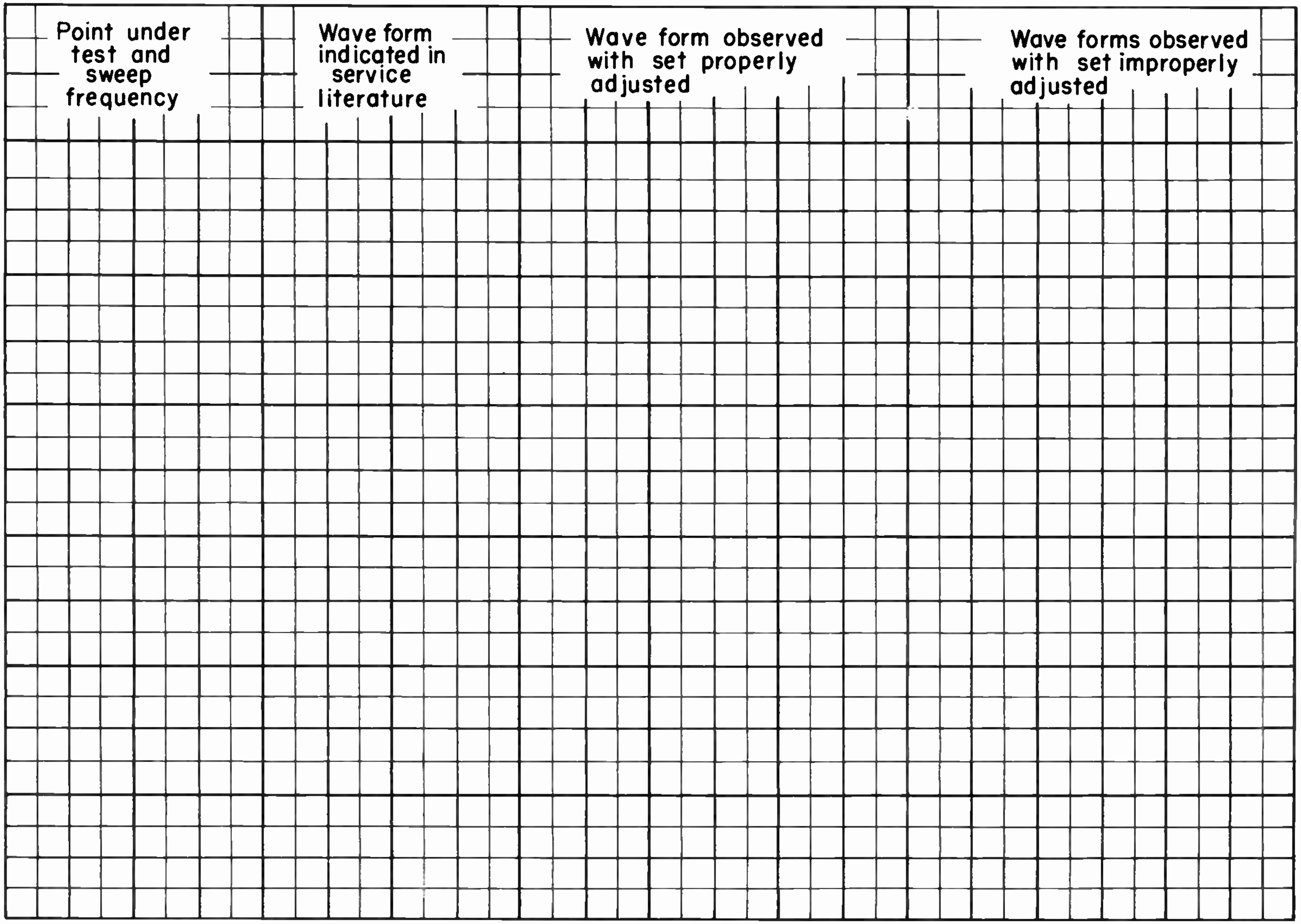


Fig. 2. Graph Paper Divided for Waveform Comparison.

a. Observe the output of the sync clipper (ahead of the vertical integrator and horizontal AFC circuits). Rotate the contrast control. Is any change produced in the sync pulse amplitude? __________ . Is it possible to make a noticable change in contrast without greatly affecting the sync pulse amplitude?

b. Observe the output of the sync clipper. If possible, switch back and forth between two stations of different signal strength, and observe the effect on the sync pulse amplitude. The effect is __________. (none), (slight), (great).

9. Effects of varying the controls of the deflection circuits.

a. Observe the waveform at the grid of the horizontal oscillator while the horizontal hold control is varied. Describe the results and illustrate with waveforms on the graph paper.

Return the horizontal hold control to its original position.

b. Observe the waveform at the grid of the vertical oscillator as the vertical hold control is varied. Describe and illustrate the results.

Return the vertical hold control to its original position.

c. Repeat steps (a) and (b) or any other controls the instructor directs.

10. Restore the set to the proper operating condition.

QUESTIONS

1. The circuit which removes the sync information from the video is the ____________. The sync information is amplified if necessary and fed to a ____________ .

2. An integrator circuit is shown in Fig. 3A. If the sync pulses, shown in Fig. 3B, are fed to the input of the circuit shown in Fig. 3A, the output waveform will resemble (Fig. 3C or 3E)?

   A differentiator circuit is shown in Fig. 3F. If pulses like those shown in Fig. 3D are fed to the input of Fig. 3F, the output of the circuit will resemble ____________. (Fig. 3C or 3E)?

3. In an integrating circuit consisting of RC components, the output is taken from across a ____________(resistor, capacitor). The output of a differentiating circuit is taken across a ____________(resistor, capacitor).

4. At the output of the sync section, the sync pulses are large and uniform in amplitude. They are fed through the ____________(differentiator, integrator) to the vertical oscillator and through the ____________(differentiator, integrator) to the horizontal AFC circuit.

5. Explain why grid leak bias is frequently used in a sync amplifier.

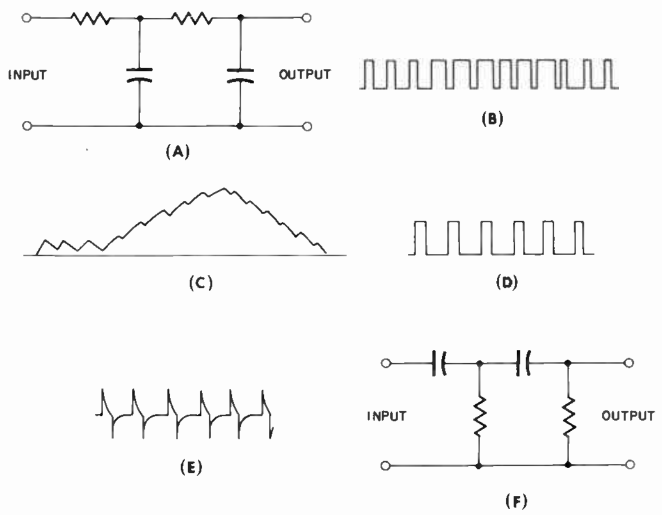


Fig. 3. Principal Steps in Producing Oscillator Synchronizing Voltages from the Composite Television Signal.