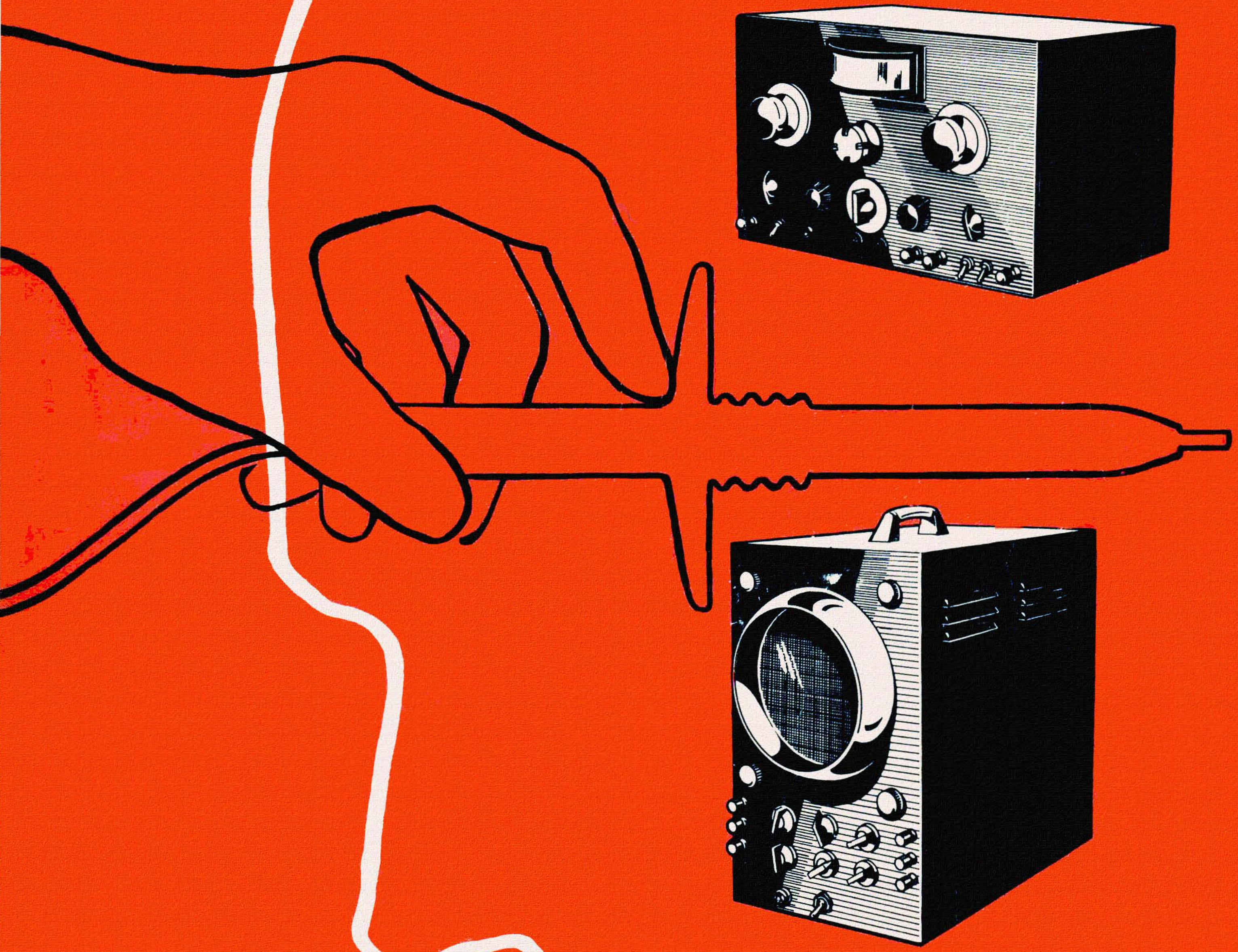
HOW TO UNDERSTAND AND USE

# TV TEST INSTRUMENTS

(TN-1)



by MILTON S. KIVER

A Howard W. Sams PHOTOFACT PUBLICATION

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# TV TEST INSTRUMENTS

*by* MILTON S. KIVER

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# PREFACE

A test instrument is the serviceman's best friend. Properly applied, it will tell him when a set is defective, why it is defective, and even where it is defective. But like every other friendship, a certain amount of mutual understanding must exist. In this instance, since the instrument cannot think for itself, it must rely on its service companion to do its thinking for it. An instrument will do great things if it is permitted to do so; it will do little or nothing, and may even confuse, if it is not properly understood.

It is the purpose of this book to promote a full understanding between test instruments and their service friends in the conviction that from such an understanding will arise a more alert, a more aggressive, and a more successful service industry.

January, 1953 | Milton S. Kiver

## PUBLISHER'S NOTE

To further enhance the useability of this, the second printing, of "How to Understand and Use TV Test Instruments", full page size illustrations of test equipments referred to in the text material have been included. Specific features of these popularly employed instruments will be more readily apparent. Text material remains identical to that of the first printing.

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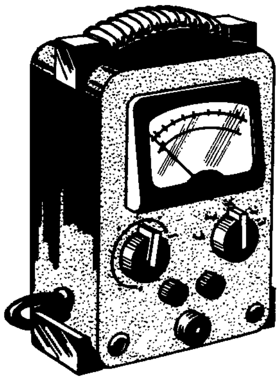

# section one

## The Vacuum-Tube Voltmeter

If someone were to ask which instrument in the radio or television shop is the most useful, the answer would undoubtedly be - the VTVM, or vacuum-tube voltmeter. With this meter in its most basic commercial form, volts (AC and DC) and ohms can be measured. Provision for measuring current may be available also, but in the lower priced units, this feature frequently is omitted. By the addition of suitable probes, a VTVM can be employed to measure high-frequency voltages up to several hundred megacycles.

The usefulness of the VTVM lies in the fact that most of the work in servicing is centered about voltage and resistance measurements. When a stage in a receiver becomes defective, the first step normally taken consists either in checking the tube or in substituting another one. If the trouble does not lie within the tube, then usually voltage measurements are made next, followed in turn by a resistance check. Thus, two out of the three servicing steps most frequently taken are made with the VTVM. In addition, as will be discussed in some detail later, there are a variety of other jobs which this instrument can perform. These range all the way from aligning an FM discriminator, to the tracing of a signal through a television receiver. The VTVM is truly an instrument that keeps the serviceman in business.

For a number of years, there were no popular-priced vacuum-tube voltmeters and the only comparable instrument available to the serviceman was the so-called multimeter, or multitester. In fundamental scope of usefulness, the multimeter performs as many functions as the VTVM. That is, it will measure AC and DC volts, current, and resistance. These meters are still very much in use today, but the VTVM, because of its higher input impedance, its ability to function at very high frequencies, and its greater sensitivity, has generally replaced the multimeter as the primary test instrument in the service shop. While the discussion in this section is completely devoted to the vacuum-tube voltmeter, many of the applications outlined can be performed with a multimeter, especially one possessing a 20,000 ohm per volt movement. Cheaper multimeters utilizing 1,000 ohm per volt movements are more limited in application. For example, they cannot be used in low voltage, high impedance circuits, nor are they suitable for measuring high voltages when the current drain must be kept low.

OPERATION OF THE VTVM

There is no denying the fact that when a man understands the operation of an instrument he is called upon to use, his results will be more accurate and his applications more extensive than without this knowledge. Toward that end, we will try, as far as space will permit, to indicate the basic operation of the various types of instruments described in this book. For information concerning the circuit or operation of any specific instrument, reference to instruction manual of that unit is suggested.

The basic circuit which is most widely employed in vacuum-tube voltmeters is the balanced bridge circuit shown in Figure 1. The current through each tube flows in the path indicated by the various arrows. Thus, for V1A, the current ($I_1$) flows from the plate through part of R3 to B+ and from ground through R1 back to the cathode of the tube. This current, in flowing through R1, develops a certain voltage drop which places point A at some positive value above ground.

Now, if the grid of V1A is grounded (to place it at the same potential as the grid of V1B), then we might expect the potentials at points A and B to be equal and no current would flow through meter M. If the currents in both paths are not identical, then some difference in voltage will exist between points A and B. In this case, current will flow through meter M and its needle will deflect. To "zero the meter" and thus bring about a balance between both branches of this circuit, variable resistor R3 is provided. Through its adjustment, the currents through V1A and V1B can be varied until points A and B possess identical positive potentials. R3 is the knob on the front panel of the VTVM which is labeled "Zero Adjust".

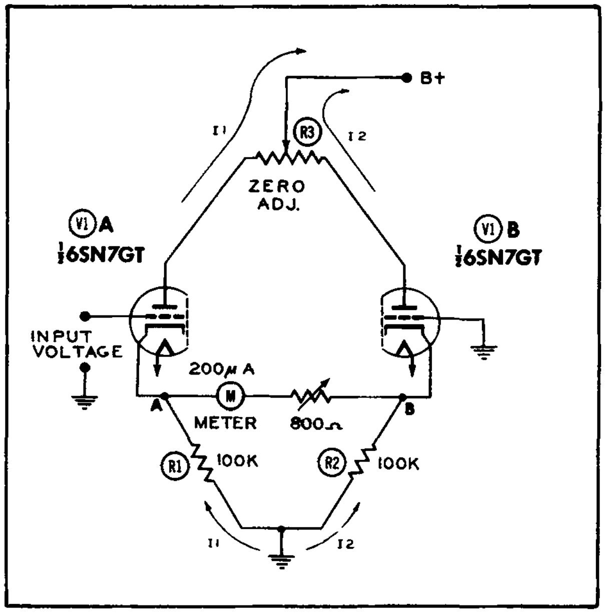


Figure 1. The Basic Circuit of a Modern VTVM.

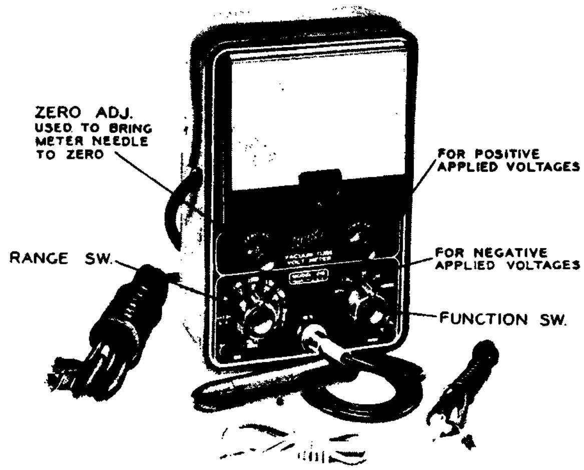


Figure 2. The Front Panel Controls on a Typical VTVM. Courtesy of Hickok Electrical Instrument Co.

To employ this circuit for the measurement of voltages, a voltage is applied between the grid of V1A and ground. If this voltage is positive, the current through V1A will increase, and point A will become more positive than it was. Point B, on the other hand, will remain unchanged since the grid of V1B is grounded.

With a very definite difference of potential existing now between point A and point B, current will flow through meter M from B to A. Just how much current will flow will depend upon the value of voltage applied to the grid of V1A. Consequently, the meter dial can be calibrated directly in volts.

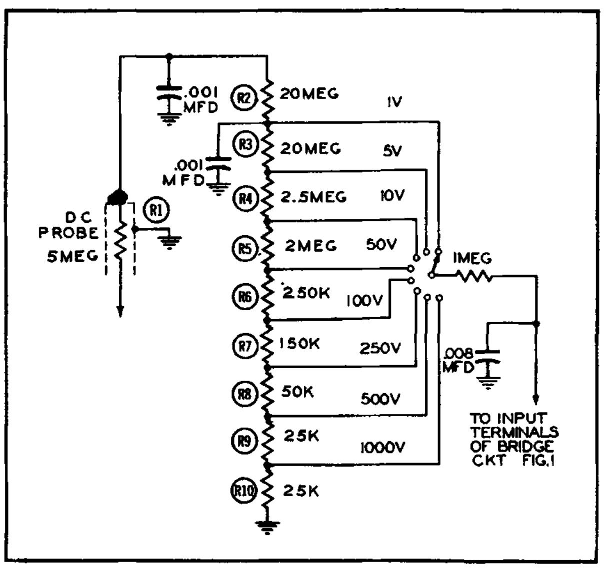


Figure 3. A Voltage Divider Network Across VTVM Input.

When a negative voltage is applied to the grid of V1A, the currect through this tube decreases, causing point A to become less positive and now current will flow through meter M from point A to point B. This will force the meter pointer to move from zero toward the left. Since on most instruments the zero position is already as far to the left as the pointer normally goes, applying a negative voltage to the VTVM would drive the pointer off scale. To overcome this limitation, we may either reverse the test leads or incorporate a switch which will accomplish essentially the same thing by reversing the meter connections.

This switch is known by a variety of names, but the most widely used is +DC and -DC. See Figure 2.

In order to permit the VTVM to measure a variety or range of voltages, a voltage divider circuit is placed across the input to the meter, as shown in Figure 3. The total value of the resistances in this string is 50 megohms and for the voltage ranges shown (i. e., 1 volt to 1,000 volts), 50 megohms in the input impedance of the VTVM. With an input impedance this high, it can readily be appreciated why the VTVM scarcely disturbs the circuit into which it is connected to measure voltages. This is one of the major advantages of the VTVM.

The smallest voltage which will give full scale deflection of meter M is 1 volt (in this arrangement). In practice, this will vary with the instrument, with other common values being 3 and 5 volts. When the meter is to measure voltages of 1 or less, the right hand switch is rotated to the line marked 1V. Figure 3 shows the schematic diagram for this condition and Figure 4 illustrates the settings of the switches on the front panel of a suitable VTVM. The right-hand range switch is set to the 1V. position and the left-hand function switch is set to +DC.V. The common lead of the meter (coming from the terminal marked

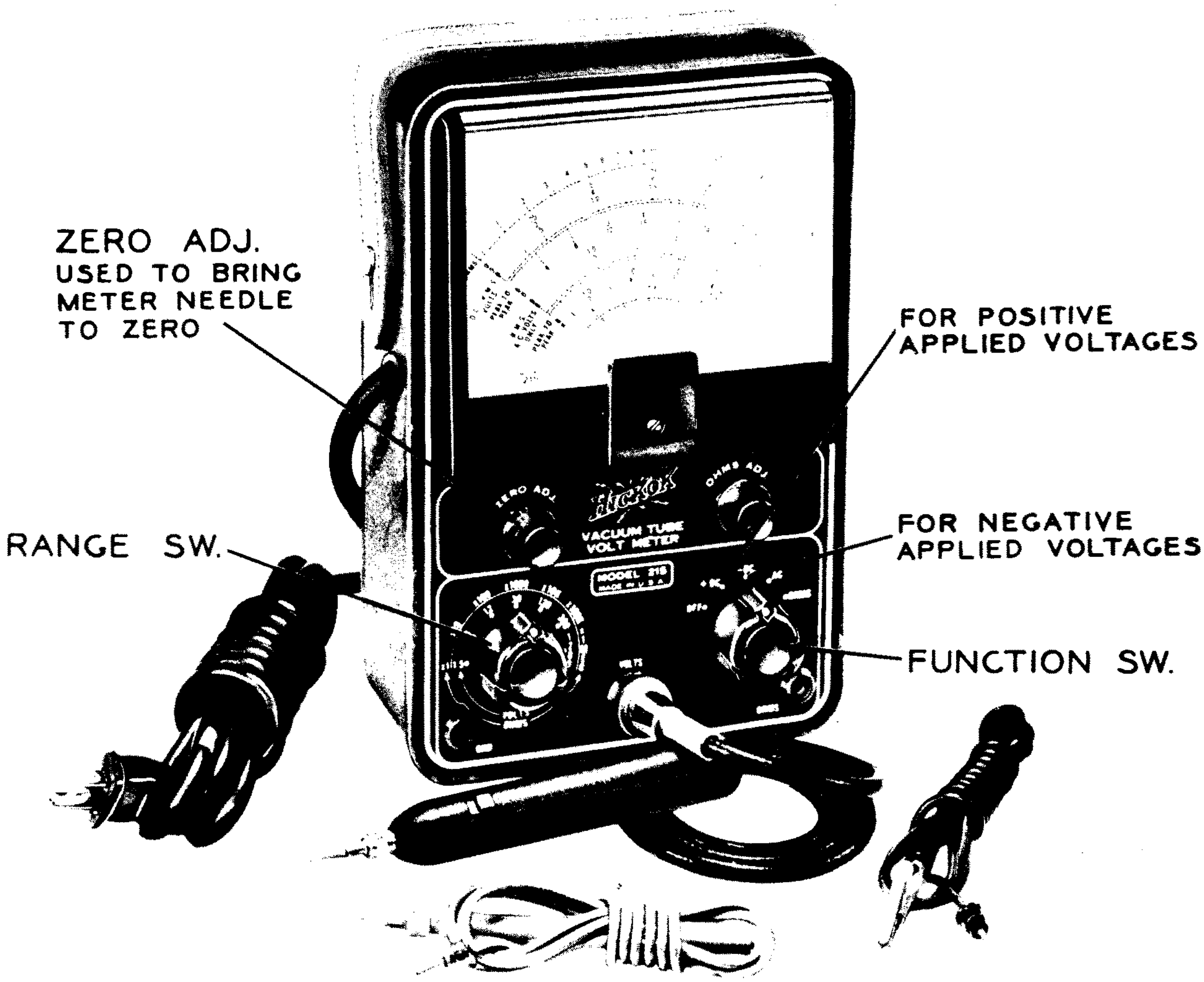


Figure 2. The Front Panel Controls on a Typical VTVM. (Model 215, Courtesy of Hickok Electrical Instrument Co.)

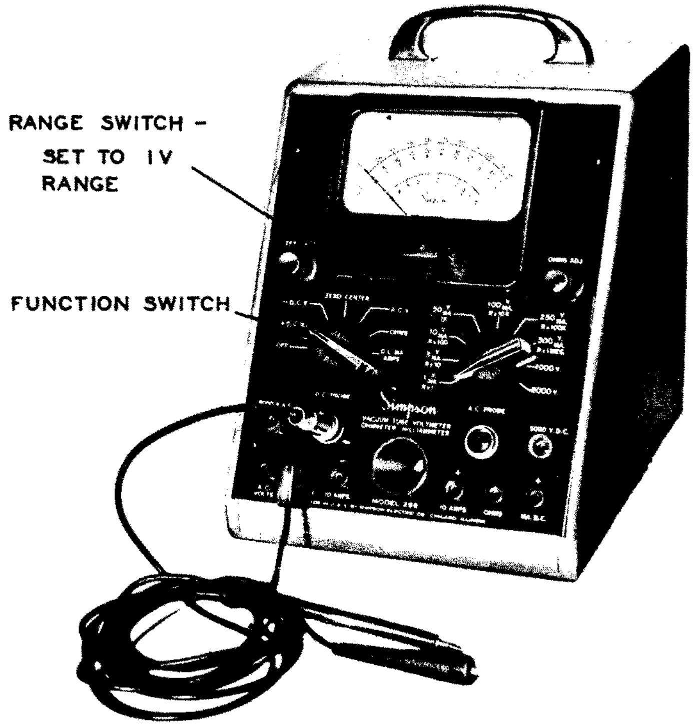


Figure 4. The Simpson Model 266 VTVM Set up to Measure Positive DC Voltages of 1 Volt or Less. Pay Particular Attention to the Range and Function Switches. (Courtesy of Simpson Electric Co.)


Figure 5. VTVM of Figure 4 Set up to Measure Voltages up to 500 Volts DC. Nothing Has Changed Except Setting of Range Control. (Courtesy of Simpson Electric Co.)

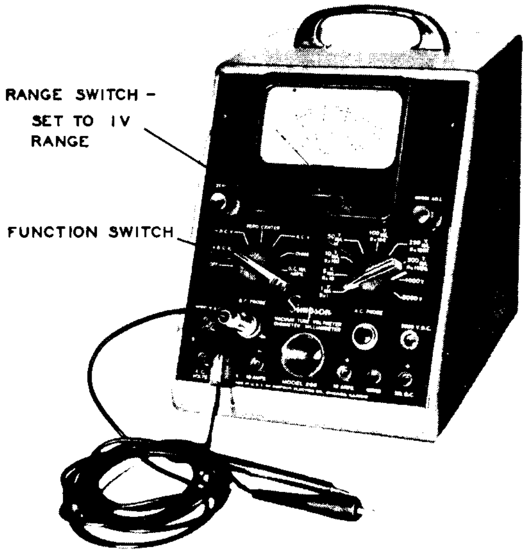


Figure 4. The Simpson Model 266 VTVM Set up to Measure Positive DC Voltages of 1 Volt or Less. Pay Particular Attention to the Range and Function Switches. Courtesy of Simpson Electric Co.

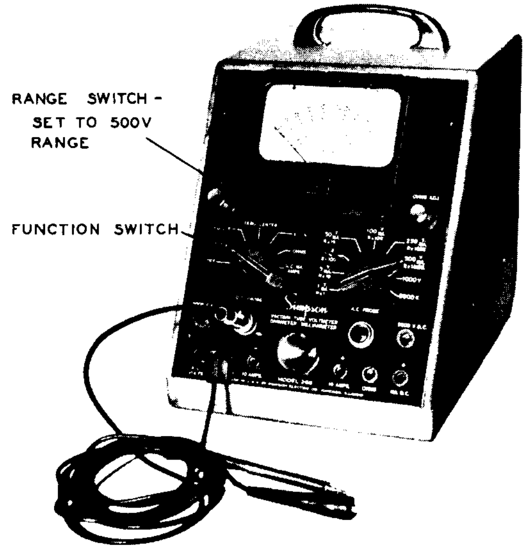


Figure 5. VTVM of Figure 4 Set up to Measure Voltages up to 500 Volts DC. Nothing has Changed Except Setting of Range Control. Courtesy of Simpson Electric Co.

"Common") is connected to the negative side of the voltage to be measured and the DC probe is touched to the positive side of this voltage. (In most instances the negative side is the circuit chassis, although in transformerless sets the chassis need not be B-.)

If the voltage to be measured had been negative with respect to ground or to the chassis, the measurements could have been accomplished in one of two ways.

1. Connecting the voltage probe to ground or chassis and using the common lead as the probe.

2. Or, the leads could have been employed as they normally are, but the meter reversing switch changed from +DC.V. to -DC.V. This is the preferred method.

To measure voltages greater than 1 volt, the right-hand selector switch of the meter would be turned to the proper scale. Thus, Figure 5 illustrates how the meter would be set up to measure voltages up to 500 volts. Actually nothing has been done except to rotate the range switch so that it now points to the 500 volt marking. Measurements are made using the DC probe and the common lead in exactly the same manner as previously outlined. It's as simple as that.

The selection of the proper voltage scale to make a certain measurement frequently puzzles the beginner. The best scale to use is the lowest one which permits you to obtain a reading without having the needle go off scale. However, when you first start to measure an unknown voltage, use the highest meter scale available. Generally this means 1,000 volts unless you have reason to believe that the voltage is even higher than this. In most television receiver circuits (excepting the high voltage circuit) the DC values seldom exceed 400 - 500 volts.

A zero adjust control is provided on the front panel of vacuum-tube voltmeters to enable the operator to balance the meter bridge circuit and to compensate for any changes that may have occurred to upset this balance. After the meter has been placed in operation (by turning on the power) and the circuit selector switch turned to the desired voltage measuring position, the "Zero Adj." knob should be rotated to the right or left until the pointer is directly over the zero indication on the meter scale. When making this adjustment, the DC probe and the common lead are shorted together. This is to prevent the probe from picking up stray voltages and causing the meter to give a false indication. This is especially important when the lowest DC scale is to be used.

The zero adjustment should be checked whenever the range is changed. A number of vacuum-tube voltmeters contain provision for placing the needle at the center of the scale. Internally this is accomplished by unbalancing the bridge circuit until the current flowing through the meter moves the needle to the mid-point of the scale. See Figure 6. If the VTVM is now employed to measure voltages, it will be found that applied positive voltages will cause the meter needle to swing to the right of center and negative voltages will swing it to the left of center.

Zero center reading vacuum-tube voltmeters usually have a separate small scale on the dial face marked with zero in the center. Whether or not this particular scale contains any markings is usually unimportant since the meter in the "Zero Center" position is not employed to indicate specific voltages, but merely to reveal whether the circuit under test is balanced. This is illustrated by a discriminator

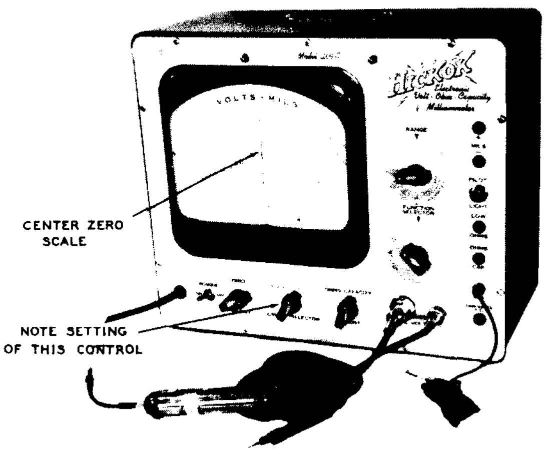


Figure 6. A VTVM With a Special Zero Center Scale. Courtesy of Hickok Electrical Instrument Co.

where a balanced condition will result in a zero center indication while an unbalanced condition will cause either a positive or negative deflection. This particular application will be considered in detail in a subsequent section.

## AC VOLTMETER -

The measurement of AC voltages with a VTVM is based on the rectification of the AC voltage by a rectifier (usually a diode but sometimes a copper oxide rectifier), and the subsequent application of this voltage to the grid of the input triode of the bridge, causing the bridge circuit to function. In the AC position, the meter will indicate the rms value of the voltage.

A simplified schematic of the AC voltmeter circuit of a VTVM is shown in Figure 7. The AC voltage is applied to a diode where it is rectified and

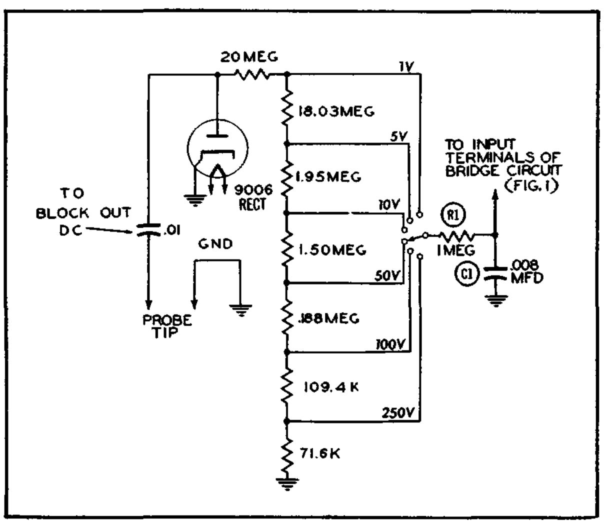


Figure 7. A Simplified Schematic of the AC Voltmeter Circuit of a VTVM.

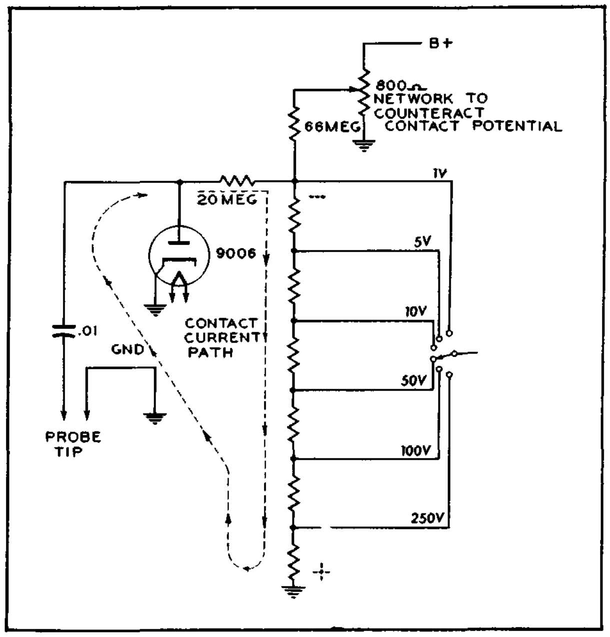


Figure 8. To Counteract the Negative Potential developed by the Contact Potential, a Small Positive Voltage is Fed Into the Circuit.

converted into pulsating DC. This voltage is then applied to the control grid of one of the bridge triodes through the appropriate resistors in the input voltage divider string. The voltage is indicated on the VTVM meter in the same manner as an applied DC voltage. Additional filtering is provided by R1 and C1.

When a diode tube is used for the rectification of the AC voltage, an additional internal adjustment is required. A diode tube will be found to conduct current even with no voltages applied to the plate or cathode, but with the filament heated. This minute current flows from cathode to plate of the diode, through the external resistors to ground and thence back to the cathode again. See Figure 8. The voltage developed across the resistors will be negative with respect to ground and is known as the contact potential. To counteract this negative voltage, an equiva-

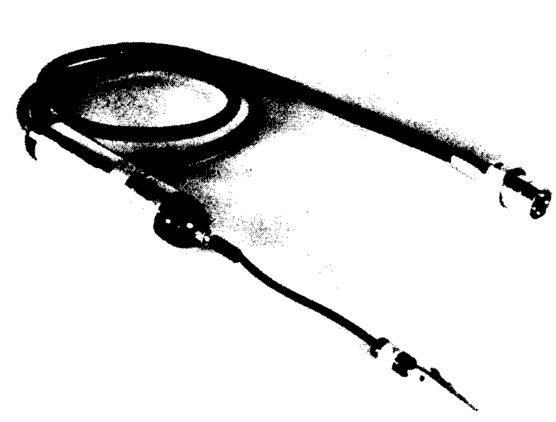

Figure 9. An AC Probe Which Contains the Rectifier Diode. Courtesy of Hickok Electrical Instrument Co.

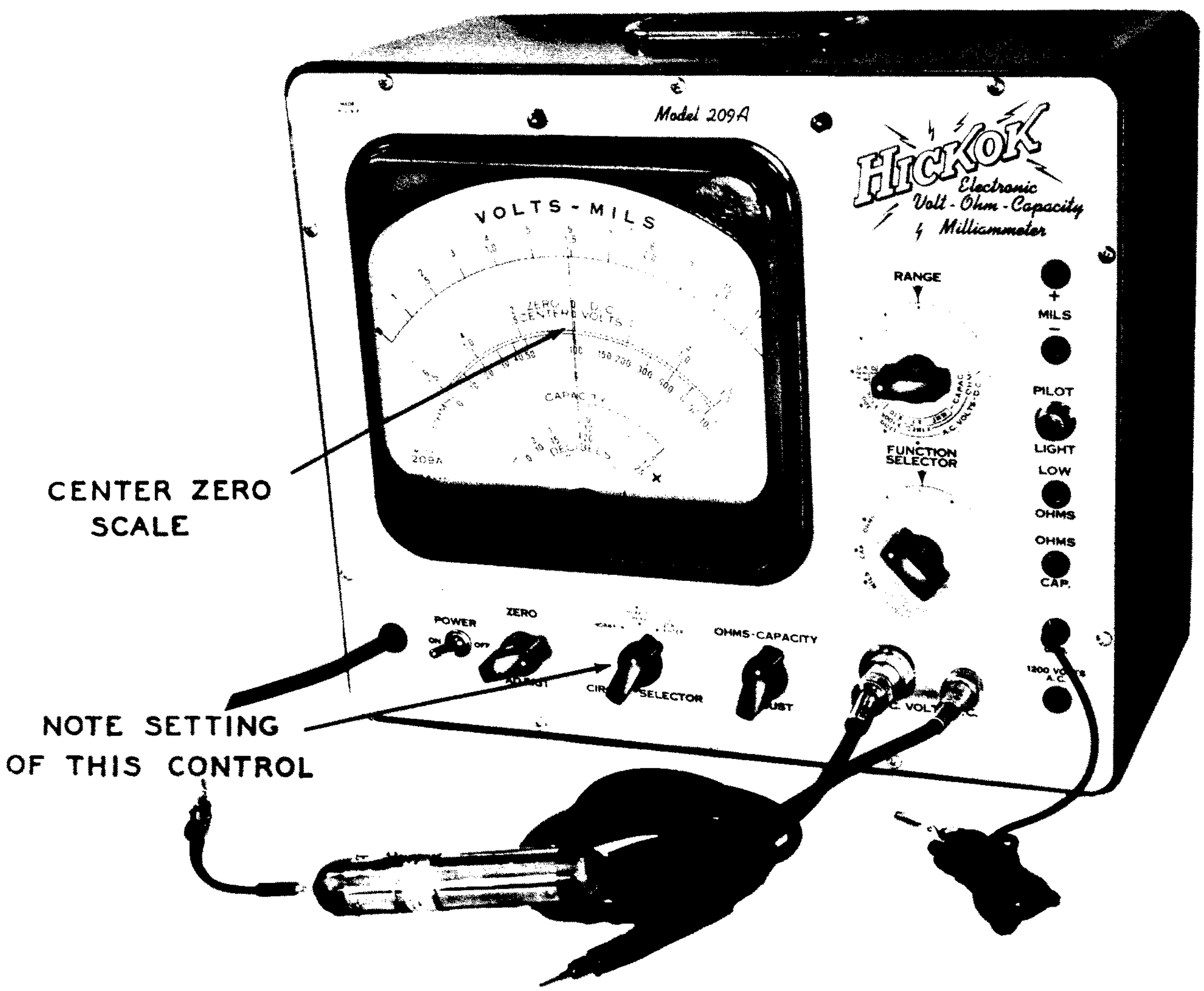


Figure 6. A VTVM with a Special Zero Center Scale. (Model 209A, Courtesy of Hickok Electrical Instrument Co.)

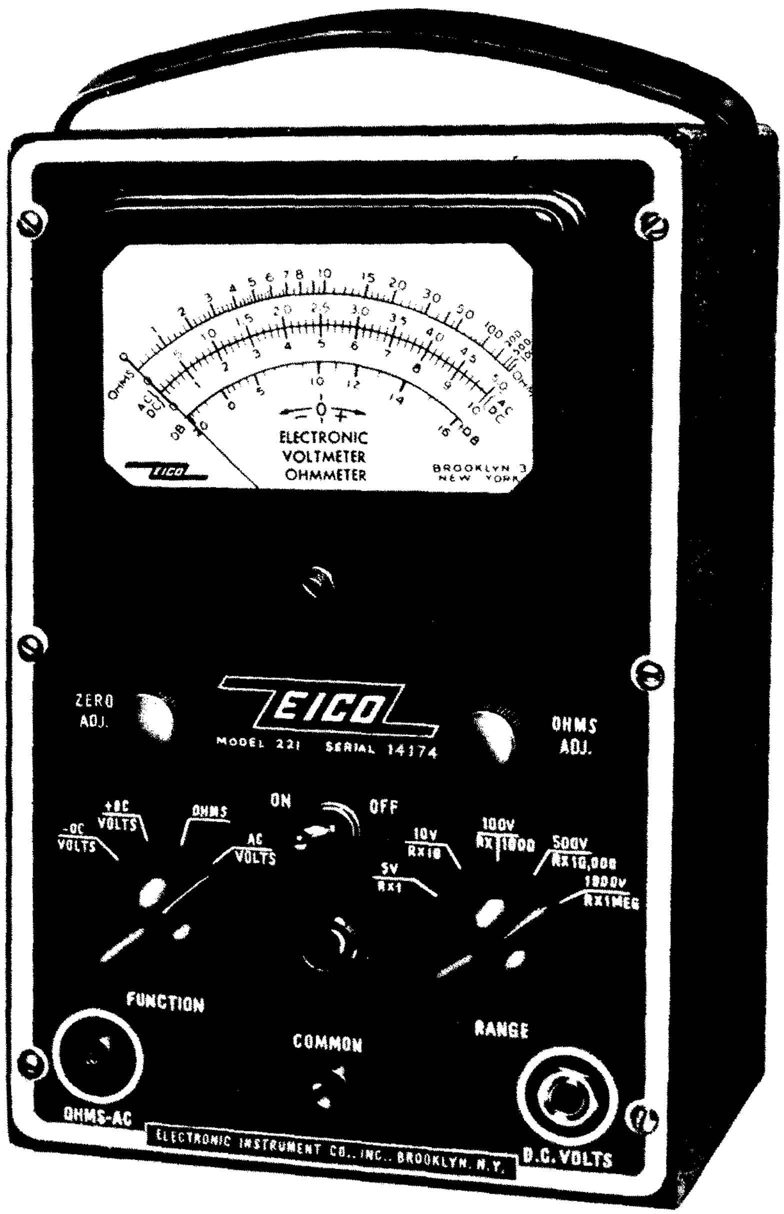


Figure 10B. An Eico VTVM Instrument Is Set up to Measure AC Volts. Note Function Switch Is Set to AC Volts Position; Setting of Range Switch Is Dependent on Voltage to Be Measured. (Model 221, Courtesy of Eico.)

lent positive voltage is taken from the power supply and fed into the circuit. The adjustment of this positive voltage is made in the factory and should not be required in the field.

The rectifier diode may be contained in a special probe (such as the unit shown in Figure 9) or it may be situated within the instrument case and a conventional test prod or probe* used for the AC measurements. In some meters there is a separate plug-in jack to which AC voltages are applied and a separate plug-in jack to which DC voltages are applied. In other models, both voltages are brought in through the same terminal. See Figure 10A. Note, however, that in all vacuum-tube voltmeters the range switch has a separate position for the AC and a separate position for the DC.

The measurement of AC voltages follows exactly the same procedure as that of DC voltages. The only precautions to observe is that the proper probe is being used and that the selector switch has been shifted from DC volts to AC volts. See Figure 10B.

The zero adjustment should be checked on all AC ranges just as it was on all DC ranges.

It may be noted in passing that whenever a VTVM is capable of measuring AC voltages beyond 1,000 volts (approximately), that it contains separate pin jacks to which this higher voltage must be applied. Thus, in Figure 4, there is a separate terminal for all AC voltages beyond 1,000 volts (1,000 - 5,000 volts). The unit in Figure 6 has a separate jack for AC volts from 300 to 1,200 volts. (The pin jack is labeled 1,200 volts AC but this represents the highest AC voltage which can be measured.)

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* The names "test prod" and "test probe," or just plain "prod" and "probe," are used interchangeably by most instrument manufacturers and by servicemen. This same practice will be followed here.

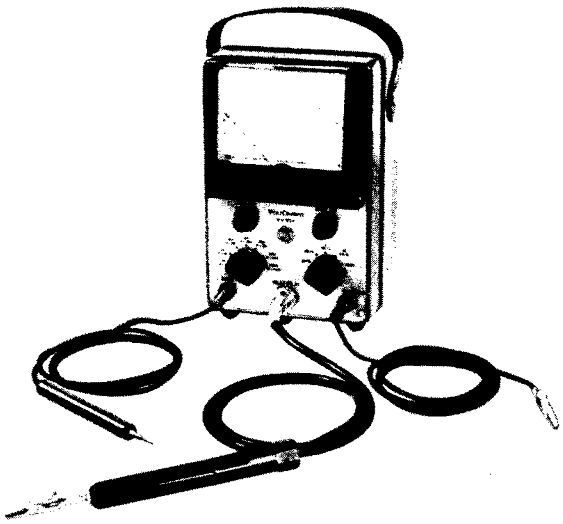


Figure 10A. A VTVM in Which AC and DC Voltages are Fed to the Same Terminal. Courtesy of RCA.


Figure 10B. An Eico VTVM Instrument is Set up to Measure AC Voltages. Note: Function Switch is Set to AC Volts Position; Setting of Range Switch is dependent on Voltage to be Measured. Courtesy of Eico.

PEAK-TO-PEAK READINGS. In servicing the deflection systems in a television receiver, it is frequently necessary to measure the peak-to-peak value of the voltages developed. To accomplish this, some vacuum-tube voltmeters contain a voltage doubling circuit of the form shown in Figure 11A. The peak-to-peak value of the applied voltage is developed across C2 in the following manner:

Assume that the positive half-cycle of the applied wave is present at the input terminals to the meter. Under these circumstances, current will flow from the cathode (Pin 5) to the plate (Pin 2) and thence to the right-hand plate of C1. An equivalent number of electrons will then flow from the left-hand plate of C1 through whatever circuit is attached to the input terminals of the meter and down to ground. From ground the electrons will flow back to the cathode (Pin 5) of the tube again. In this current flow, C1 will have developed across it a voltage equal to the peak value of the positive half of the applied voltage, regardless of its wave shape.

During the following negative half-cycle of the applied wave, the polarity across the input meter terminals is reversed. See Figure 11B. If we now compare the polarity of the voltage across C1 with the negative polarity of the applied voltage, we see that they are in series with each other. Further tracing shows that the most negative end of the two series voltages is applied to the cathode of the second diode (Pin 1 in Figure 11B), while the most positive end of the series voltages is at ground potential. Since the plate of the second diode (Pin 7) is essentially connected to ground through capacitor C2, we have a situation here where current will flow through this second diode, charging C2 to the peak potential of both applied voltages. Then, whatever voltage is developed across C2 will be applied to the voltage divider chain and from the appropriate point on this

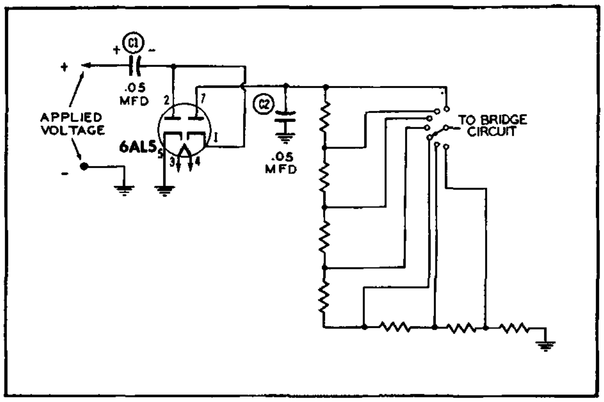



Figure 11A. A Voltage Doubler Circuit for Peak-to-peak Measurements. The Positive Peak Voltage Appears Across C1. See Text.

string fed to the control grid of one VTVM bridge tube.

It is important to note again that the arrangement shown in Figure 11B will provide an indication of the peak-to-peak value of the input wave, irrespective of its shape. This is most important because the rms or average value of a wave will change with its waveform and any peak-to-peak value obtained by relying on rms or average values will be incorrect unless the meter is calibrated for that particular waveshape and the waveshape is kept constant for all measurements (which it very seldom is).

When a VTVM is equipped to measure peak-to-peak values of any wave, it will usually have a separate selector switch position (or perhaps a separate probe other than the normal AC probe) for it. See Figure 6. Be sure to set the switch to this position. Also check to see whether the meter contains a separate peak-to-peak scale. Some units do, some do not. Where there is no separate scale, simply use the existing AC scale. The value indicated by the needle for any applied voltage will be the full peak-to-peak value of that wave.

As an illustration of the procedure to follow when using the instrument of Figure 6 to measure normal AC voltages and peak-to-peak voltages, here are the instructions as given by the manufacturer.

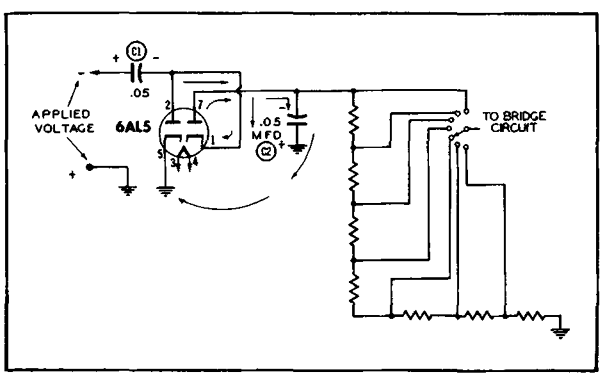



Figure 11B. The Full Peak-to-peak Voltage Is Developed Across C2. See Text.

A. For measuring normal AC voltages (i. e., to obtain rms values):

1. Turn the "Power" switch ON.

2. Connect the AC probe to the outlet provided for it.

3. Connect the black unshielded test lead to the "GND" jack.

4. Turn the "Function Selector" switch to VOLTS AC.

5. Turn "Circuit Selector" switch to NORMAL.

6. Turn the "Range" switch to the range which will cover the voltages to be measured. If this is unknown, choose the highest range.

7. Check the meter for zero setting. Adjust to zero with the "Zero Adjust" control.

8. Connect the AC probe and the black test lead to the voltage to be measured.

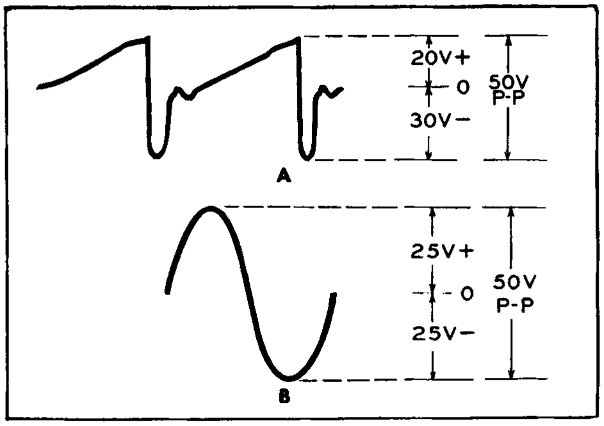
9. Read the numerical value from the scale directly and apply the multiplying factor for the position of the "Range" switch.

B. For measuring peak-to-peak voltages:

1. Procedure for AC peak-to-peak measurements is identical to that outlined above with the exception of Step 5 which, in this case, should be changed to "Peak-to-Peak."

On some vacuum-tube voltmeters there is no special probe or selector switch position for peak-to-peak voltages, but still a separate peak-to-peak scale will be found on the face of the meter. See Figure 2. The markings on this scale are designed to indicate the peak-to-peak value of sine waves only. (In a sine wave, the peak-to-peak value is 2.83 times the rms value.) This type of meter will not correctly give you the peak-to-peak value of any other shaped wave because each marking on this peak-to-peak scale is 2.83 times the corresponding value on the AC scale just above it and this factor of 2.83 does not apply to waves other than a sine wave.

As an illustration, consider the deflection wave shown in Figure 12A, and assume its peak-to-peak voltage is 50 volts. Within its circuit, this wave extends for 20 volts in the positive direction and 30 volts in the negative direction. If we employed an rms reading VTVM, it would indicate a value of about 14 volts. This is because the AC voltmeter section of a VTVM uses a diode which responds only to the positive portion of the applied wave, becoming non-conductive throughout the negative portion. (See Figure 7.) Conventional vacuum tube voltmeters are calibrated to read an rms value which is .707 times the peak-positive value of the applied voltage. (Providing the applied voltage is a sine wave.) If now we multiplied 14 by 2.83, we would obtain the erroneous peak-to-peak value of 39.6 volts.



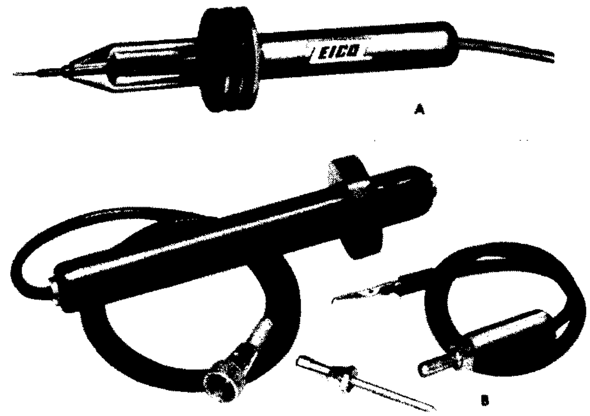

Figures 12A and B. The VTVM Must Contain a Special Circuit to Indicate Correctly the Peak-to-peak Value of Waves Other Than Sine Waves. See Text.

If we had a sine wave with the same 50 volts peak-to-peak value (Figure 12B), 25 volts would extend in the positive direction and 25 volts in the negative direction. The VTVM, responding to the peak of the positive half cycle, would record an rms value of 25 x .707 or 17.7 volts. On an adjacent peak-to-peak scale, this 17.7 multiplied by 2.83, would yield the correct 50 volts (approximately) peak-to-peak value. But note again that this occurs only because the meter is designed around the .707 factor which is derived from sine wave relationships.

HIGH-VOLTAGE MEASUREMENT -

The top DC voltage range of 1,000 volts found on most vacuum-tube voltmeters is more than sufficient for the measurement of any of the low DC voltages ordinarily encountered in television receivers. However, the cathode-ray picture tube operates at an accelerating potential of from 9,000 to 25,000 volts and some method should be available to the technician for measuring these high potentials. Fortunately the input impedance of the conventional VTVM is so high that by means of special probes, any VTVM can have its DC voltage range extended to 25,000 or 50,000 volts. (Some high-voltage probes extend the VTVM range only to 10,000 or 15,000 volts, but the majority of probes go higher than this.)* The low current drain, arising from the high input impedance, is important because the high-voltage power supplies in television receivers normally deliver less than half a milliampere (500 microamperes) and any meter which would draw more current than this would load the circuit down sufficiently to kill the high voltage.

The physical appearance of two high-voltage probes are shown in Figures 13A and B. Each probe is long and on each there is a safety flange to protect




Figures 13A and B. Two High-voltage Probes Designed for Use With Vacuum-Tube Volt-Meters. (A) Courtesy of Eico and (B) Courtesy of Hickok.

the serviceman from coming in contact with the high voltage to be measured and also to protect him from arcing or corona. Either of these can be just as harmful as direct contact. Within the probe is a very large series resistor across which the bulk of the applied high voltage is dropped. For example, if a probe is designed to measure 25,000 volts, then 24,000 volts might appear across the probe internal resistors and only 1,000 volts actually applied to the VTVM itself.

To employ the high-voltage probe, its connector cable is inserted in the DC volt terminal of the VTVM. The common lead of the meter is securely fastened to the television receiver chassis. In transformerless television receivers, an isolation transformer should be inserted between the receiver and the AC line. If this is not done, and you connect the meter common (or meter ground) to the receiver, you may very well be placing a short across the AC power line, with accompanying disastrous results. (If an isolation transformer is not available, make the measurement as outlined, but keep the meter case and chassis from making direct contact with any ground, such as an electric conduit pipe on the bench.)

The next step is to set the VTVM selector switch to the proper setting. In most instances this is the highest DC voltage range, say 1,000 volts. Just how much each value of this range must be multiplied (say 10, 15, or 30 times) depends upon the resistance of the high voltage multiplier. Which brings up a very important point. The high voltage multiplier that is used with a specific VTVM should be designed expressly for that VTVM. Just how much multiplication is required for a certain scale when the high-voltage probe is attached will depend upon (a) the internal resistance of the VTVM and (b) the resistance of the dropping resistor in the body of the high-voltage probe. Any change in the resistance at either point (probe or VTVM) will alter the voltage distribution and, with it, the amount indicated by the meter.

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* High-voltage probes are also available for 20,000-ohm per volt multimeters. A 1,000-ohm per volt meter cannot be used for high-voltage measurement because the current it would draw would reduce the high voltage considerably below its normal operating value.

It is quite evident, therefore, that unless you use a high-voltage probe designed specifically for your VTVM, the meter readings will be incorrect unless you know the proper multiplying factor.

Along these lines, it is not safe to assume that two different model vacuum-tube voltmeters marketed by the same manufacturer utilize the same high-voltage probe. As an illustration, consider the Simpson Model 266 VTVM and Model 303 VTVM. The probe for the Model 266 has an internal resistance of 1205 megohms. To use this probe, the Model 266 meter selector switch is set to the 1,000-volt scale, but when readings are taken, you note where the meter needle is along the 250-volt scale and then multiply this by 100.

However, to measure high-voltage with the Model 303 VTVM, you use another probe having an internal resistance of 991 megohms. Also, on this meter, you set the selector switch to the 1,000-volt scale and then multiply whatever reading you obtain on this scale by 100.

If you should happen to know what the probe resistance should be for your VTVM, then, of course, you may use any probe having this value of internal resistance. But in the absence of such information, do not interchange probes.

Finally, it is a good rule to keep one hand in your pocket when making high-voltage measurements. And the other hand, which holds the high-voltage probe, should be kept as far away from the contact end as possible. See Figure 13C.

In a television receiver, the only place where the high-voltage probe is normally employed is at the accelerating anode of the picture tube. If the voltage is measured with the high voltage lead disconnected from the tube, then the setting of the brightness control is unimportant. However, if the measurement is made with the high-voltage applied to the tube, it is advisable that the brightness control be turned down so that the screen is not illuminated.

Figure 13C. How to Use High-Voltage Probe Properly.

This is done because the power possessed by the high-voltage supply is quite small and any increased drain will cause the voltage to drop rather sharply. Normally, the picture tube draws several hundred microamperes; however, when the probe is also brought in contact with the high voltage, its added drain may be enough to cause this potential to drop, leading to an erroneous reading. By turning down the brightness control, we remove the tube drain and thereby permit the meter to record a truer value of the existing high voltage.

R. F. PROBES -

The outstanding advantage of the VTVM as a measuring device is its ability to perform this function without appreciably disturbing the circuit in which the measurements are made. For DC circuits and in low-frequency networks (up to approximately 15 kc) we can employ a pair of ordinary leads with the VTVM to make whatever measurements are needed, without unduly disturbing the operation of the circuit under test.

As the operating frequency of the circuit rises, the disturbing influence of the leads increases. Alternating voltages, we have seen, are measured by bringing them to a rectifier in the VTVM where they are converted into pulsating DC and from this, the rms value of the voltage is obtained. Now, as the operating frequency of the circuit rises, we know that the capacitance and inductance in that circuit decreases. Another way of looking at this is to say that with frequency increase, a circuit becomes more sensitive to capacitance and inductance changes. Moving a wire only one-quarter of an inch in a 200 mc circuit will cause a greater frequency disturbance than moving a wire several inches in a low-frequency circuit.

Because of this sensitivity, measurements in high-frequency circuits must be made with an instrument which introduces far less extraneous capacitance and inductance than a pair of test leads. Toward that end, special RF or high-frequency probe attachments for VTVM instruments have been designed wherein the rectifying element is brought as close to the voltage to be measured as is feasible. This reduces shunting capacitance to a minimum and, at the same time, keeps the amount of lead inductance extremely low.

Two types of rectifiers have been used in these probes: miniature diodes and crystal rectifiers. The diode is advantageous because it is capable of measuring higher voltages than a crystal. Its disadvantage lies in the fact that it requires filament voltages and these must be brought to the tube through the leads connecting the probe to the VTVM proper. The construction of the crystal probe is simpler (no heating power is required), but to date the voltages which it can safely measure seldom exceed 20 volts. It is partially possible to by-pass the voltage limitation of

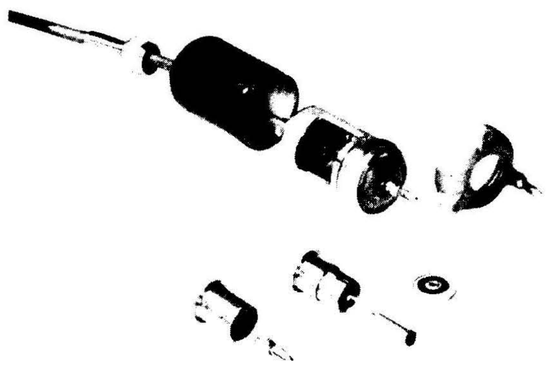

Figure 14A. Exploded View of Diode High-frequency Probe. Courtesy of General Radio.

the crystal with capacitive voltage dividing networks, but these introduce additional shunting capacitance that is not desirable.

Exploded views of a diode probe and a crystal probe are shown in Figure 14, A and B. The diode probe (here) uses a 9005 acorn tube, chosen especially for its low input capacitance (1.0 mmf.) and small lead inductances. The crystal probe uses one of the many germanium crystal units commercially available.

Precautions to be observed when using the RF probe are first, to know the maximum voltage which can safely be applied to the probe without injury and second, the frequency range throughout which its indications can be relied upon. These specifications are either indicated in the instruction sheets provided with the probe or they can be obtained from the manufacturer. While the voltage limitation of diode probe units is seldom serious, their frequency limitations can be - especially in view of the forthcoming use of the UHF band for television reception.

When using the high-frequency probe to make measurements, place the probe end directly on the point whose RF potential is to be measured. The grounding lead of the probe should be kept short and grounded close to the measuring point.

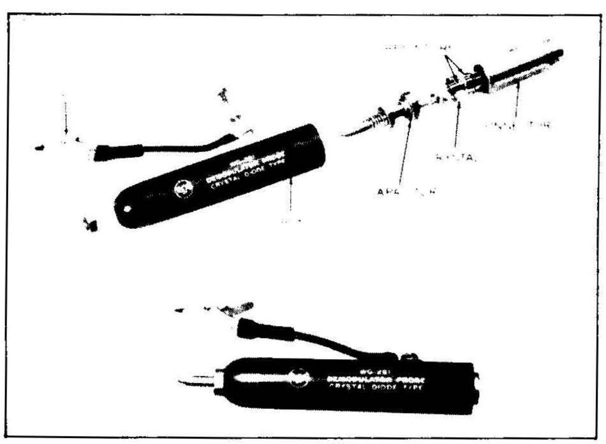

Figure 14B. A Crystal-diode Probe and its Internal Construction. Courtesy of RCA.

Circuit components should be disturbed as little as possible when making RF measurements; also, keep your hand and other parts of your body as far away from the circuit as possible. Above all, do not indiscriminately push leads and components aside in order to get at the point where the voltage is to be measured. Pick your way through the circuit carefully.

## OHMMETER -

The ohmmeter section of a VTVM is shown in Figure 15. A small battery (such as the Mallory RMBZ4, 1.34V unit) is used to supply the potential. This potential, when applied to the grid of one triode section of the 6SN7 tube is sufficient to cause full scale deflection of the meter. A variable control, marked "Ohms Adj." on the front panel, permits the operator to accurately position the meter needle so that it stops directly over the final right-hand marking of the "Ohms" scale. This is done with no resistor connected between the "Ohms" and "Common" terminals of the meter and with the leads from these terminals NOT touching. The needle position at the other end of the scale should also be checked by the procedure previously outlined, i. e., with the meter leads shorted together. The "Zero Adj." knob is used this time to bring the needle directly over the zero line.

When the resistance under test is connected between the "Common" and "Ohms" test leads, a voltage divider circuit is produced consisting of the 1.34V battery in series with one of the standard resistors R1 to R7 and the resistor under test. The voltage across the unknown resistor is proportional to its resistance. This voltage is applied to the grid of one section of the bridge circuit which produces a meter deflection proportional to the unknown resistance.

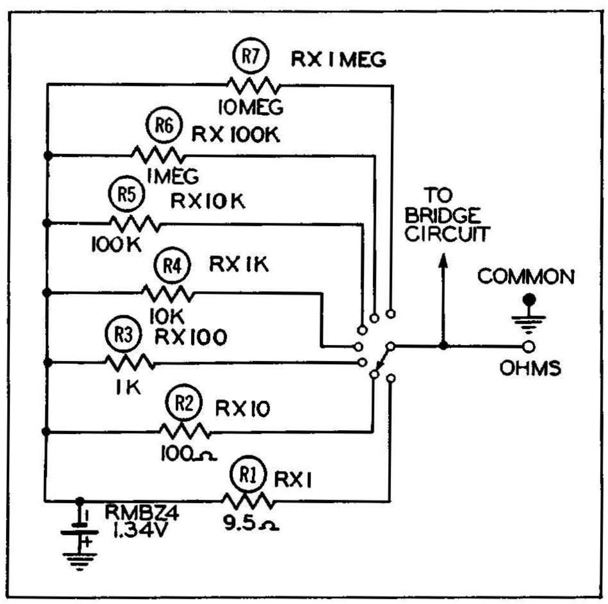


Figure 15. The Ohmmeter Section of a VTVM.

Modern vacuum-tube voltmeters are capable of measuring resistances up to 1,000 megohms (some units even go beyond this). This is 1,000,000,000 or one billion ohms and is more than sufficient for any normal service work.

When the ohmmeter is not in use, the meter needle remains at the extreme right-hand side of the scale at the "Inf." mark. This is opposite to its resting position when in use on other scales, such as volts or milliamperes. (An exception to this is the VTVM shown in Figure 16, where the zero position for volts is at the center.*)

The most important fact to remember when measuring resistance is, first, to remove all voltages from the circuit in which the resistor whose value is to be checked is located. Secondly, zero the meter at the low end (using the "Zero Adj." control) and position it accurately at the upper end of the scale (using the "Ohms Adj." control). At the low end, the meter leads are shorted together; at the high end, they are kept apart. Also, use the scale that brings the needle into the less congested portion of the scale. On vacuum-tube voltmeters, this is the center and left-hand section of the scale.

The greatest difficulty that the serviceman may encounter when using the ohmmeter is to measure the value of a resistor while this resistor is still in its circuit. Simply placing the ohmmeter leads across the resistor will not necessarily give you the true value of this resistor. It all depends upon whether or not there are other resistors in the circuit shunting the one under test. To illustrate, suppose the value of R1 in Figure 17 is to be determined. Actually, if you glance at this circuit, the value in-

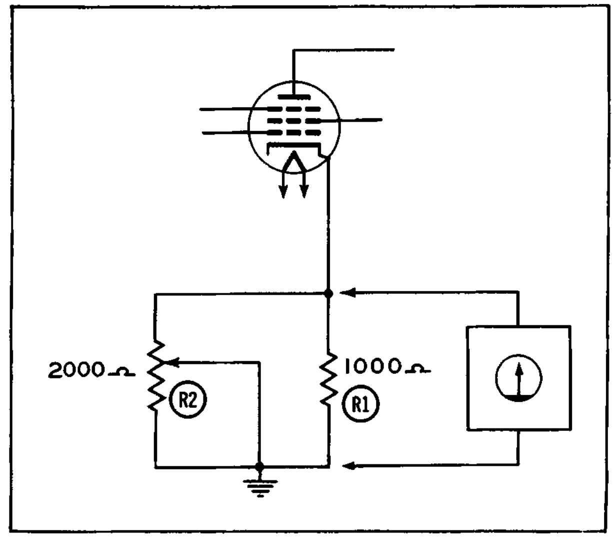


Figure 17. The Measured Value of R1 (Without Removing From Circuit) Is Dependent Upon a Center Arm Setting of R2.

dicated by the ohmmeter can be anywhere between 667 ohms and zero and any of these values would be entirely correct. R1, you see, is shunted by a variable 2,000 ohm resistor, R2. When R2 is set so that its entire resistance is in the circuit, the 1,000 ohms of R1 is shunted by the full 2,000 ohms of R2 and the resultant value is:

$$R \text{ (resultant)} = \frac{R1 \times R2}{R1 + R2}$$

$$= \frac{1000 \times 2000}{3000}$$

$$= 667 \text{ ohms (approximately)}$$

On the other hand, when R2 is taken completely out of the circuit, by moving the grounded center arm to the top of the resistor, R1 is likewise grounded out and the total resistance value is zero.

Since there is no way to determine the true value of R1 while it is in the circuit, the only thing to do is to unsolder one end of this resistor and then measure its value.

Only when it is definitely known that a resistor is not shunted by other resistances may its true value be determined without removal from the circuit.

Another difficulty which is frequently encountered by the serviceman is the measurement of resistances in circuits where large valued capacitors are shunted across the resistor under test. To understand what will happen in these circuits when the ohmmeter leads are placed across a resistor, two facts must be known. First, as we have noted above, the ohmmeter circuit in the VTVM contains a small battery and it is the voltage drop developed across the resistor under test that determines how much resistance the VTVM will indicate. Secondly, when a voltage is applied to a circuit containing resistance and capacitance, the voltage across the capacitor does not immediately rise to its full value. Some

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* The zero center volt scale in this instrument eliminates the need for a polarity reversal switch and minimizes possibility of meter overloading when measuring voltages of unknown polarity.

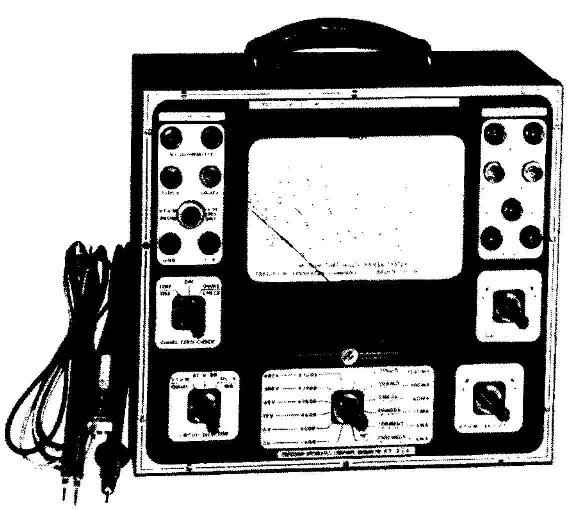


Figure 16. A VTVM With Zero-center Volt Scale. Courtesy of Precision Apparatus Co.

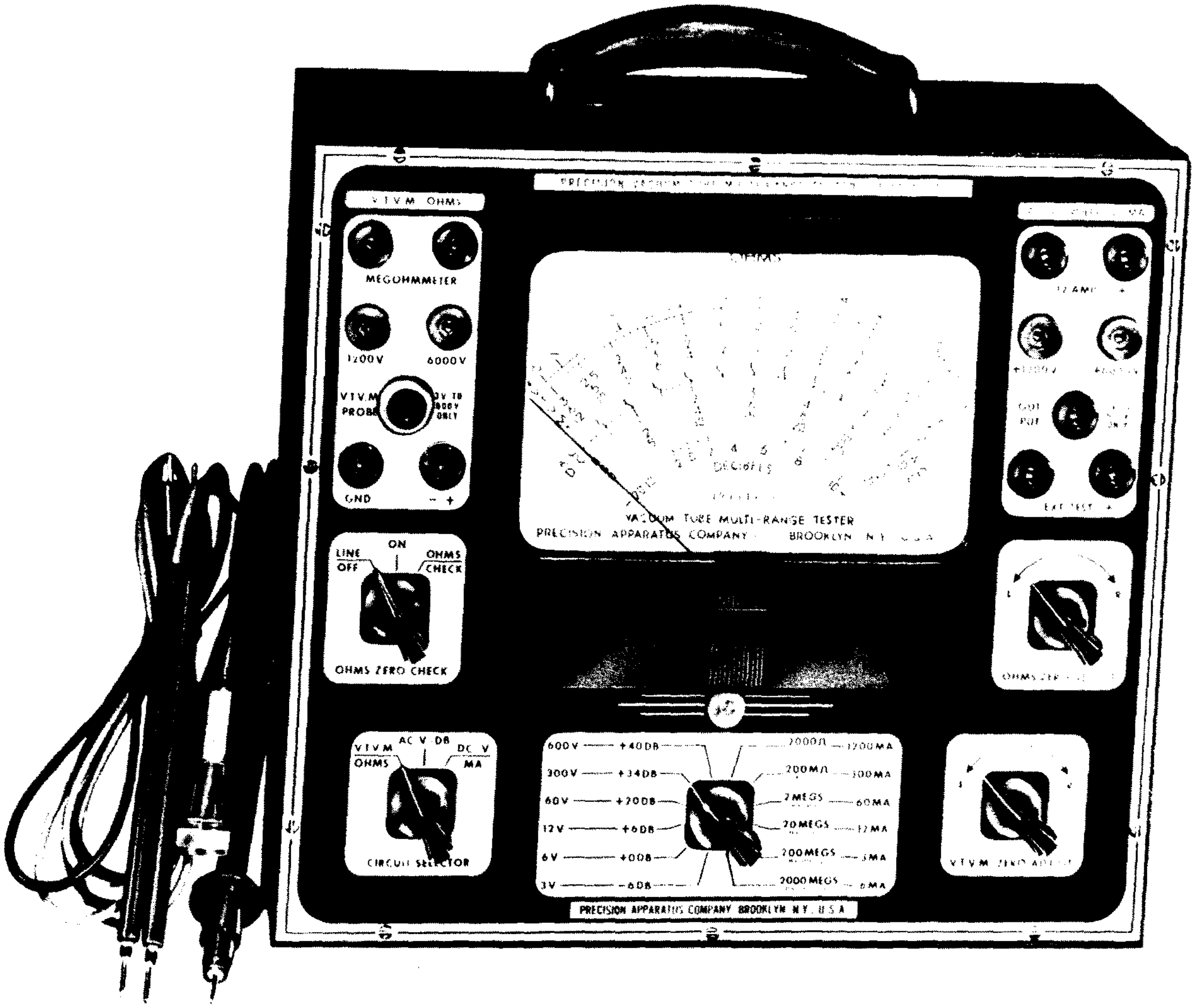



Figure 16. A VTVM with Zero-Center Volt Scale. (Model EV-10, Courtesy of Precision Apparatus Co.)

definite time must elapse before this can occur and the length of time depends upon the amount of resistance and capacitance present in the circuit. When the resistance value is low and a relatively small capacitor is used, then the time required by the capacitor to charge may be so short as to appear instantaneous. In this case the serviceman will not be aware of any time lag between the time he places the probe in the circuit and the time he glances at the meter for a reading. However, if the resistance and/or capacitance values are high, then he will see the meter needle move up gradually, taking several seconds, or longer, before it comes to a complete stop.

Consider, for example, the circuit shown in Figure 18A. When the ohmmeter leads are connected across this circuit, the meter pointer will initially jump up to 1 megohm and then slowly and gradually work its way up to 4 megohms. If we assume that the 20 mfd. capacitor is uncharged at the start, then when the ohmmeter is connected across the circuit, the capacitor acts as a short circuit across points A and B. The meter thus initially sees only 1 megohm and that is all the resistance it indicates on its scale. Gradually, however, as the capacitor charges up, more and more of the current flows through the 3 megohm resistor. When the capacitor has become fully charged, no current (or at least very little) will be diverted away from the 3 megohm resistor and now the ohmmeter will indicate the full 4 megohms of resistance present in the circuit.

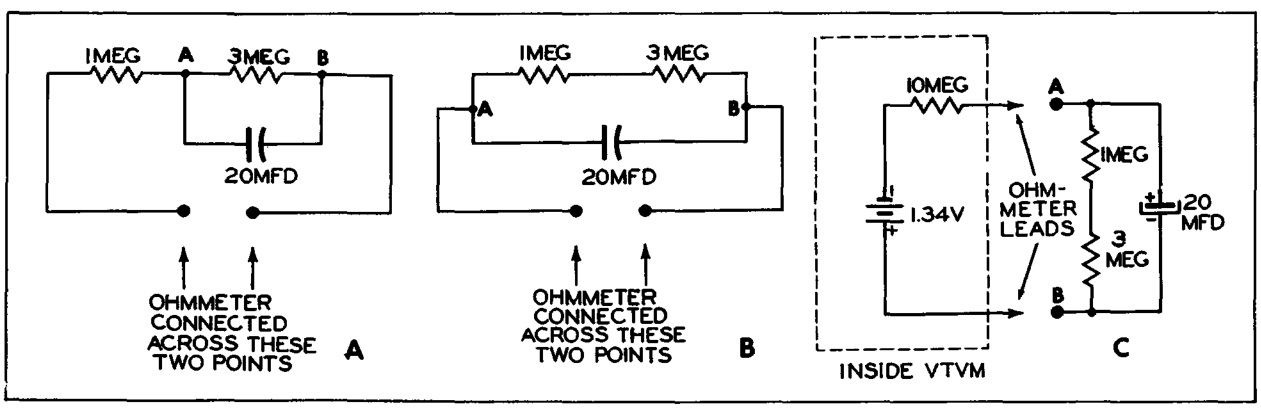
If the 20 mfd. capacitor shunted both resistors, as in Figure 18B, then initially the meter needle would go down to zero and then slowly rise back up until it reached a value of 4 megohms. At this point it would stop.

This concept of an uncharged capacitor acting as a short circuit when a voltage is applied across it follows quite logically from capacitor action. Electrons flow from the negative side of the battery into the nearest capacitor plate and an equivalent number of electrons leave the other plate and flow toward the positive side of the battery (or power supply). Since the capacitor offers no electrical opposition at the start, the amount of current flowing through the circuit will be limited solely by any resistance that may be in series with the capacitor. With continued current flow, however, a charge develops across the capacitor which acts in opposition to the applied voltage, gradually reducing the amount of current flowing through the capacitor. When the capacitor becomes fully charged, all current flow through it ceases.

Keep in mind that the charging time is governed by the values of the resistances and capacitors in the circuit. This includes whatever resistance is present in the meter, too. Thus, consider the ohmmeter circuit in the VTVM of Figure 15. When the meter selector switch is set for Rx1 megohm, the 1.34 volt battery has a 10 megohm resistor in series with it. This 10 megohm resistor plus the 20 mfd. capacitor in the external circuit causes the voltage across the capacitor to rise slowly and in consequence the meter needle will also move up the scale slowly. And until the capacitor reaches a value which, in Figure 18C, is 4/14 of 1.34 volts, the VTVM meter needle will continue to move slowly up the scale.

Were it not for the presence of the 20 mfd. capacitor, the current flow (and hence, voltage distribution) in the circuit would be instantaneous and the full meter indication would be obtained as soon as the meter leads were connected across the circuit. It is only when large capacitors are introduced into the circuit that the slow rise of the meter needle occurs.

Sometimes other complicating factors enter the picture just outlined. Thus, if the leakage resistance of the 20 mfd. capacitor (which is of the electrolytic type) is quite high, as it is in a good unit, then the action described will take place, as the serviceman may determine for himself. However, if the electrolytic capacitor has been in use for some time, its leakage resistance may be low enough to produce a final meter reading of less than 4 megohms. This is another pitfall that the technician will have to guard against when he measures resistances without removing them from the circuit. All in all, a lot less trouble is encountered if one end of the resistor is disconnected from the receiver circuit before its value is measured.




Figures 18 A, B and C. Circuits to Illustrate Why Meter Needle Will Rise Slowly on Some Resistance Measurements.

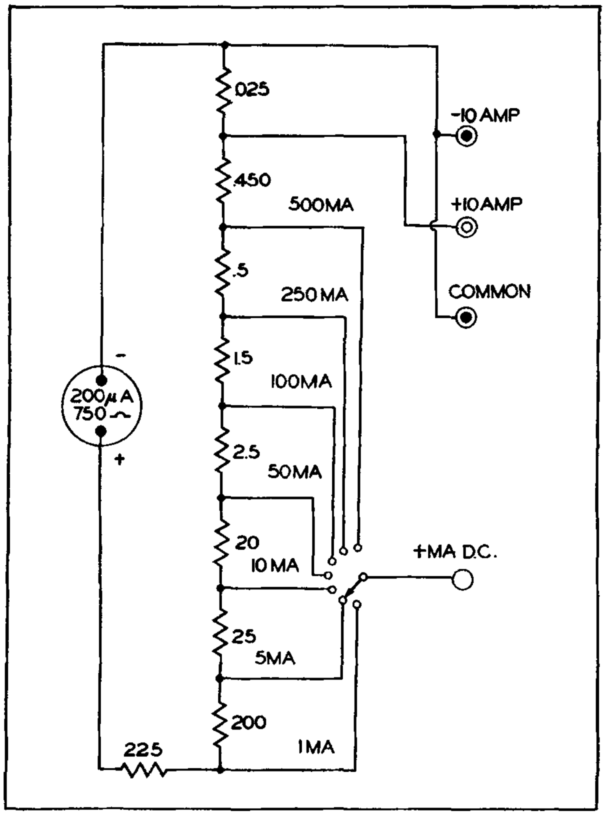



Figure 19. A Simplified Milliammeter and Ammeter Circuit Used in a VTVM.

CURRENT MEASUREMENTS -

In comparison to the number of times the voltmeter and the ohmmeter sections of the VTVM are used, there are relatively few occasions when current is measured. For this reason some of the vacuum-tube voltmeters on the market do not contain any provision for current measurement. However, for those units which do, the circuit shown in Figure 19 is typical of the arrangement employed. On examination this is seen to consist simply of a sensitive meter (200 microamp movement) with a suitable array of shunting resistors. The shunt resistors are arranged so that for full scale deflection in each range, a current of 200 microamperes flows through the meter. The balance of the current is directed through the associated shunt resistors. When large currents are to be handled, say on the order of 10 amperes or more, special terminals are employed on the front panel. There is one positive terminal and one negative terminal. Heavy wires capable of handling large currents connect these terminals to the meter. Since the vacuum-tube circuits do not enter into current measurement, there is no need to plug the VTVM into the power line. Merely set the function Selector Switch to the "MA" position and connect the meter leads into the circuit where the current is to be measured. The "Range" switch is used for low currents but large currents (10 amps or more) are never shunted through the switch.

A good precaution to observe when measuring large currents is never to remove the pin jacks from the meter terminals while the current is flowing through the circuit. Breaking the circuit while this much current is present will produce a sizeable arc at the pin. This may not injure the meter, but it will cause the terminal jack to char in time.

DECIBEL (DB) MEASUREMENTS -

A number of vacuum-tube voltmeters contain a decibel range with which comparative measurements may be made in the audio section of a receiver. The decibel scale in most vacuum-tube voltmeters is so calibrated that it will read 0 db when .006 watts (or 6 milliwatts) is being dissipated in a 500-ohm line. If you are using this meter to determine the db level at a certain point in the audio amplifier system of a receiver, the impedance should be 500 ohms if you wish to obtain a correct comparative reading. If the load impedance is any other value, conversion to the new impedance will be necessary. Suitable conversion tables are furnished either by the manufacturer of the instrument or are available in textbooks or technical magazines.

The principal application of db meters is that of a power level indicator of AC voltages across known impedances in audio circuits, and consequently the selector switch of the VTVM is set to the AC Volts position. (Some manufacturers include a db notation with the AC Volts on the selector switch, and some do not.) The setting of the range switch depends on the design of the instrument and recourse to the instruction booklet is necessary. Also, for different decibel scales in the same instrument, different settings of the range switch are necessary.

Note that since the 0 point on the meter db scale is based on a certain standard, less power than this will cause the needle to stop to the left of the 0 mark. This position on the db scale is marked off in negative units, such as -5, -10, -15, etc. Where the power is greater than the standard, the db indication will be positive.

If you are going to make any use of the db scale in your VTVM, note again that its markings are of value only if the load impedance across which the measurements are being taken is equal to that used in the calibration of this particular scale. It is also well to keep in mind that while most vacuum-tube voltmeters have a db scale based on 0 db = 6 mw, some are based upon a zero level of 1 mw across a 600 ohm line. The readings of the two, while capable of being converted from one to the other, are not the same when taken directly from their respective scales.

OTHER MEASUREMENT SCALES -

A small number of vacuum-tube voltmeters, like the one shown in Figure 6, are also capable of measuring capacitances. In the instrument of Figure 6 (and in all other vacuum-tube voltmeters possessing similar provision) the theory of the capacity measurement resembles that of the ohmmeter, with the impedance of the unknown capacitor replacing the unknown resistance. However, since an AC voltage is needed to measure capacitance, and since only DC can be applied to the input grid of the bridge tube, some means must be used to rectify the AC. This is accomplished by using (in this instance) one diode section of a duo-diode tube. The output of this rectifier is then fed to the input grid of the bridge tube.

It is difficult to make any but the most general statements with regard to the exact procedure to follow when making capacity measurements since each instrument has its own method of approach. The only advice that can be given is to refer to the instruction booklet for the instrument.

DEFECTIVE CAPACITOR TESTS. In the servicing of radio and television receivers, it is generally more important to determine whether a capacitor is good rather than what its value is. If a capacitor checker is available, it may do the job. But in the absence of such an instrument, certain tests can be performed with a VTVM which will give you a fair idea whether or not the unit is faulty.

If a coupling capacitor is suspected of being leaky, a DC voltage measurement from grid to ground of the following tube should reveal the trouble. See Figure 20. Normally, all stages which are capacitively coupled in a radio or TV receiver operate with negative bias. If the coupling capacitor is leaky, current will be able to flow through it, developing a voltage drop across Rg. To insure that any positive voltage noted across Rg is not a result of a gassy tube, the tube can be removed or another one, known to be good, substituted in its place.

Another method which has been employed successfully to determine the condition of a capacitor is to disconnect one side of the capacitor from the circuit and then measure its resistance. A good paper or mica capacitor will show a slight deflection on the R x 1 meg range and the reading will quickly approach full scale. The smaller the capacitance value of the capacitor, the smaller the needle deflection, leading ultimately to an inconclusive test when the capacitance becomes too small.

An electrolytic capacitor may be checked the same way, with observance of polarity. That is, the lead connected to the negative terminal of the battery which is located inside the VTVM should go to the negative lug on the capacitor and the other, positive, lead to the capacitor positive lug. Since an electrolytic capacitor will charge more slowly (because of its value), it is recommended that these be checked on the R x 10K range.

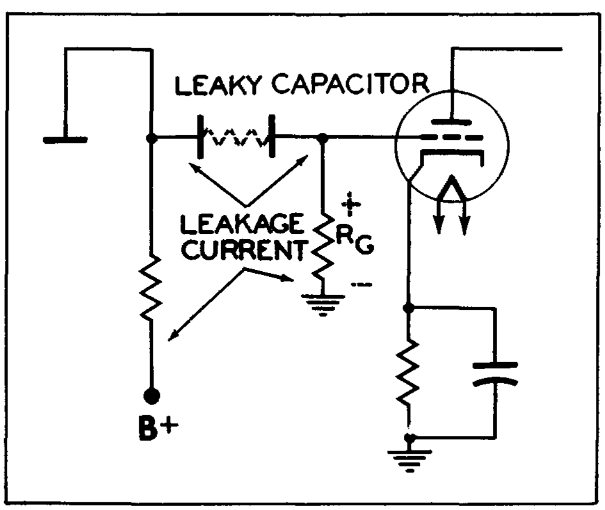



Figure 20. A Leaky Coupling Capacitor Will Place a Positive Potential at the Grid of the Following Tube.

An open capacitor of any type will not give any meter deflection from the full scale point. A faulty capacitor will have a resistance value far below the megohm range.

The foregoing ohmmeter tests are useful but it must be recognized that with them we are testing the capacitor at a very low voltage. Frequently a capacitor becomes faulty only when its normal, higher voltage is applied. Hence, if the tests were carried out at the higher voltage, a truer picture concerning the condition of the unit would be obtained. A method of performing these tests at the rated voltage of the capacitor is as follows:*

In the method to be described, a high DC potential is applied to the capacitor in series with the proper DC Volts range (VTVM) to determine whether or not it has low insulation resistance or abnormal leakage.

The necessary DC potential can be obtained from an external high voltage DC power supply or from the power output tube socket of a radio receiver. In the latter instance, the plate prong position of the socket will be the positive high voltage lead, and the negative return or ground will be the negative lead.

PROCEDURE:

1. Measure and adjust the DC voltage obtainable from the DC power supply. Then select the proper meter range that would indicate full scale deflection for the voltage there available and in keeping with the capacitor rating.

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* This method and the one to follow are described in the Precision Model EV-10A VTVM instruction booklet.

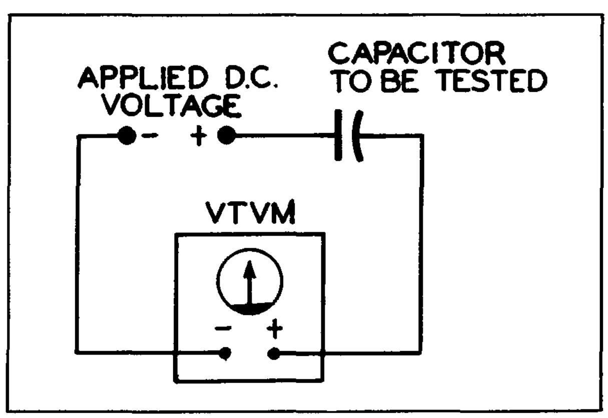



Figure 21. Set up to Check Leakage Resistance of a Paper Capacitor.

2. With the power supply OFF, insert the capacitor to be tested in series with one of the meter test leads. See Figure 21.

3. Turn ON power supply. An instantaneous deflection due to the charge of the capacitor will be indicated on the DC meter.

(A) In case of a good capacitor, the needle pointer will recede to (or VERY close to) the zero voltage mark.

(B) If the meter pointer remains noticeably above the zero mark, this indicates that the capacitor has abnormal leakage.

(C) If the meter pointer remains at the indicated value of the voltage measurement obtained primarily, then the capacitor is "shorted".

(D) If no meter deflection is obtained, it indicates that the capacitor is "Open" or that the capacity is too low in value to indicate an instantaneous noticeable meter deflection when charged.

NOTE: After this test is completed, always FIRST disengage the negative test lead from circuit BEFORE turning off power supply to prevent slamming of needle pointer due to discharge of capacitor under test.

This method of using a relatively high DC potential in series with a DC VTVM to qualitatively check paper capacitors is superior to a simple high range ohmmeter check because the high potential tends to "search out" capacitor defects which could cause breakdown at operating potentials. The low battery voltage of the ohmmeter circuit (1-3 volts) is insufficient to perform the "searching" function.

The foregoing test is designed for paper or mica capacitors; it is not to be used with electrolytic capacitors. For the latter, the best test to perform is a leakage test and this requires that the VTVM be capable of measuring current.

MEASUREMENT OF LEAKAGE IN ELECTROLYTIC CAPACITORS. The leakage in an electrolytic is measured in terms of direct current (per microfarad) flowing through the capacitor, when rated DC voltage is applied.

All electrolytic capacitors contain an inherent leakage. However, if leakage above an allowable amount is present, it can then be termed as poor. Allowable current leakage is dependent upon such factors as age and manufacturers' specifications of a capacitor, design of power unit, filter system and rectifier tube of the receiver in which the capacitor is incorporated. In general, considering an 8 mfd. capacitor THAT HAS BEEN IN USE (rated at 450 volts) the maximum allowable leakage is approximately .5 ma. per microfarad or 4 ma. total.

The following will serve as a basis for computing approximate leakages:

1. For capacitors rated at 300 volts or more, leakage of approximately .5 ma. per microfarad is permissible.

2. For capacitors rated between 100 to 275 volts, permissible leakage is approximately .2 ma. per microfarad.

3. For capacitors rated below 100 volts, permissible leakage is approximately .1 ma. per microfarad.

CAUTION: WHEN OBTAINING ELECTROLYTIC LEAKAGE MEASUREMENTS, HIGH VOLTAGE IS EMPLOYED. IT IS THEREFORE EXTREMELY IMPORTANT THAT THE FOLLOWING INSTRUCTIONS BE ADHERED TO IMPLICITLY TO PREVENT DAMAGE TO METER.

PROCEDURE:

With capacitors disconnected from radio receiver circuit, check capacitors for short with ohmmeter using 0-200,000 ohms range. Polarities must be observed.

In some instruments the negative terminal of the ohmmeter battery is grounded while in others it is the positive terminal. A check of the schematic diagram of the instrument (in the instruction manual) will reveal the answer, or, it may be determined by connecting another voltmeter across the ohmmeter leads. Once this information is obtained, the negative lead goes to the outside can or negative terminal of the capacitor while the positive lead connects to the anode (positive) terminal of the capacitor. A decided low resistance reading indicates that the capacitor is shorted and should be rejected without further testing.

When an electrolytic incorporated in a receiver is to be tested, the necessary rated voltage is automatically applied and the following connections are made for "forming" and measuring the current leakage, after being (ohmmeter) tested for short.

1. Set "Function" switch to the "MA" position and rotate the "Range" switch to the "600 MA" position.

2. Remove the lead in the receiver which goes to the positive terminal of the capacitor and, instead, connect this wire to the positive (+) "MA" tip jack on the meter in series with a proper limiting resistor. (Where voltage applied to capacitor is above 100 volts the limiting resistor should be approximately 1,000 ohms. When the applied voltage is below 100 volts, the value of the limiting resistor should be approximately 300 ohms. This limiting resistor is very important and should not be omitted.)

3. Connect the negative (-) "MA" pin jack (this is usually meter "GND." jack) to the positive terminal of capacitor. (From the above connections it can be seen that the meter tip jacks, limiting resistor, capacitor terminals and the voltage source are in series connection.)

4. After series connections are made, turn on switch of the receiver. The meter pointer will now deflect to near full scale and then gradually recede to the zero mark or near zero, after the expiration of about three minutes. This procedure is known as "forming" the capacitor.

NOTE: A steady meter pointer indication without receding to or near zero (after forming process) indicates a shorted or leaky electrolytic and should be rejected without further testing.

5. After "forming", short out the limiting resistor and read current leakage of capacitor under test directly on the 120 ma. scale. If meter reading is under 30 ma., set "Range" switch to a lower position for a better indication. Divide the meter reading by the capacitor value and then check with the rules given previously to determine if capacitor leakage is within acceptable limits.

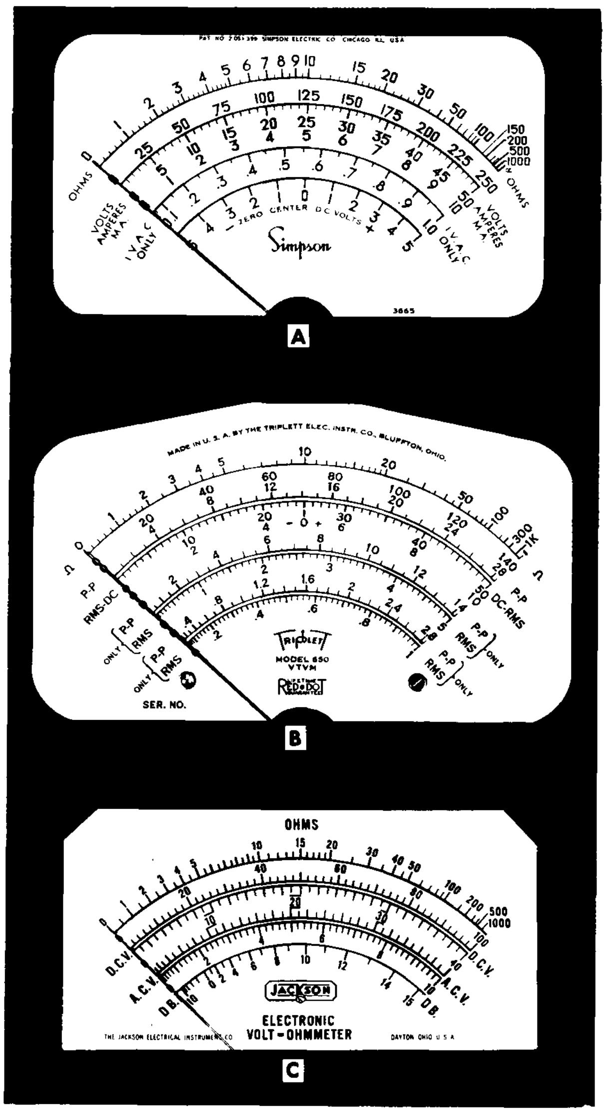



Figure 22. The Meter Scales of Several Vacuum-Tube Volt-Meters. (A) Courtesy of Simpson Electric Company. (B) Courtesy of Triplett Electrical Instrument Company. (C) Courtesy of Jackson Electrical Instrument Company.

## HOW TO READ METER SCALES

The VTVM, we have seen, is designed to perform a number of functions covering a wide range of voltage, current, and resistance values. Due to the varied nature of these functions, the meter dial face contains a number of different scales, some of which are shown in Figure 22. No two are alike, each differing from the other in some detail. All the vacuum-tube voltmeters, however, are designed to be used in essentially the same manner.

Now, to obtain the proper results from a vacuum-tube voltmeter requires not only that the serviceman knows how to connect the meter into the circuit and how to adjust the panel controls, but that he also knows how to correctly read the meter scale. And this latter job is far from being as simple as many technicians believe it to be.

The correct reading of a meter scale depends upon knowing three things:

1. The proper scale to read.

2. The value of the markings on that scale.

3. The amount by which each value on the scale must be multiplied.

The first step is to determine which scale to read for the measurements being made. This, in turn, will depend upon the manner in which the instrument is set up. The placement of the function switch tells you what electrical units the meter is in position to measure, whether it be volts, ohms, milliamperes, etc. The other control on the front panel (the range control) will indicate how much of this quantity the meter will measure. Thus, one control will indicate what is to be measured, while the other will tell you how much.


Figure 23. VTVM Simpson Model 303.

To illustrate, in Figure 23, the right-hand knob is pointing to +DC and the left-hand knob to 60. With the controls in these positions the meter will read up to a maximum of 60 volts, DC. Your first job, after setting the controls, is noting the proper DC volt scale. On the meter in Figure 23, this is the scale labeled "Volts" and is second from the top. The right-hand value of this scale is 12 for the bottom row of figures, 60 for the middle row of figures, and 300 for the top row of figures. Each row of figures (12, 60, or 300) is divided into six sections. Thus, for the 0-12 row, we have 0, 2, 4, 6, 8, 10, and 12. In the second row, 0-60, we have 0, 10, 20, 30, 40, 50, and 60. Similarly, for the top row, there is 0, 50, 100, 150, 200, 250, and 300.

The row of figures from which you will obtain your readings will depend upon the setting of the left-hand (i. e., range) control. In Figure 23, the knob is turned to 60, which means that all readings are to be taken from the 0-60 scale.

We might digress here a moment and note that the left-hand control has five ranges for the "Volts" scale and yet only three ranges are shown on the dial face itself. Missing are the 1.2 volt range and the 1,200 volt range. The answer to this apparent "oversight," of course, lies in the fact that 1.2 volts is 1/10 of 12 volts and hence, whenever the control knob is turned to the 1.2 volt position, all readings are taken on the 12 volt scale and divided by 10.

By the same reasoning, when the control knob is turned to the 1,200-volt position, readings are again taken on the 0-12 scale and multiplied by 100. By utilizing one scale for several purposes, a "simplification" in the number of figures required on the meter face is achieved. But if you are unfamiliar with this practice, your readings can be far out of line. (Incidentally, this practice is extensively employed on other scales of the meter, especially the ohms scale. More will be said of this presently.)

Once it has been determined which scale to read, the next problem is the actual reading itself. In many respects this is the most difficult operation of all to perform and it is here that the greatest number of errors are made. The trouble seems to stem from the difficulty in determining the value of each marking. And yet the process, once learned, is no more difficult to perform than any other meter operation.

To start, consider the relatively simple scale divisions shown in Figure 24. The scale is uniform from one end to the other and contains numbers ranging from 0 to 10.

If you examine the scale closely, you will see that directly below each number is a dark heavy line. All the other lines on the scale are smaller and narrower in appearance. The longer and wider marks can be considered as the major divisions of the scale while the smaller, narrower lines as the minor divisions.

Between every two consecutive numbers, say, 4 and 5, there are four equally spaced markings. To ascertain the value of each marking, let us first determine the value of the entire space between 4 and 5. This is done by subtracting the smaller number from the larger one. Here, this means 5 minus 4 or 1. Thus, 1 must be equally divided into five parts because the four minor lines produce five spaces between 4 and 5. One divided by 5 (or 1/5) gives an answer of .2 and consequently each space (between 4 and 5) is .2. When you get to the end of the first space, just after the 4, the result, if shown on the scale, would be 4.2. At the end of the second space, at the second minor mark, the result would be 4.4. The third small marker is 4.6 and the fourth one is 4.8.

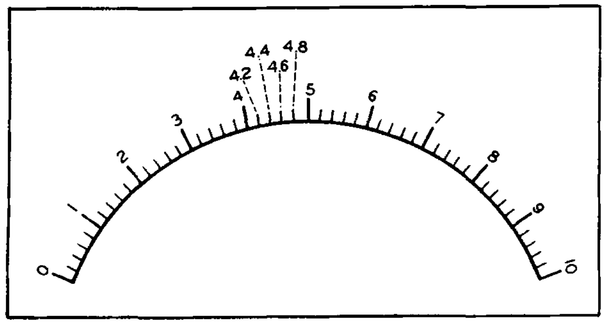



Figure 24. A Simple Scale Containing 10 Major Divisions.

The remaining minor divisions throughout this scale would have a similar value of .2. This means that the value of any individual minor line would be .2 higher than the line to the left of it and .2 lower than the line to the right. This particular relationship is true over the entire scale because all major divisions are equally spaced from each other and all minor divisions are equally spaced from each other also, (i. e., other minor divisions). This latter point is of considerable importance, although it is not always true, as we shall presently learn.

If the meter needle should, perchance, stop between two markers, its reading would be some value between those of the two markers. Thus, in Figure 25, the needle is between the second and third small lines, or between 4.6 and 4.8. If the needle is midway between the two lines, its value will be midway between 4.6 and 4.8 or 4.7. If the needle is closer to the 4.6 mark then it is to the 4.8 mark, you could assign a value of 4.65 to it, but it is problematical whether it would be wise to do so. Actually, in a situation such as this, you might very well assign

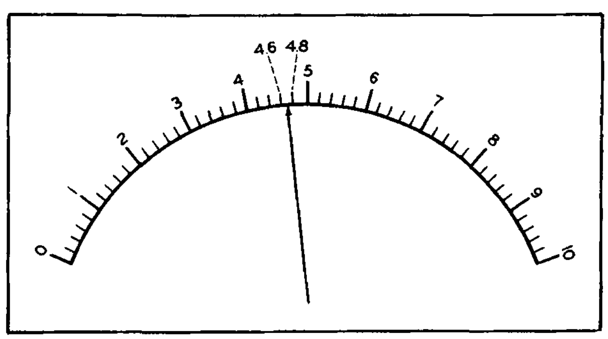



Figure 25. The Pointer Being Between 4.6 and 4.8 Would be Read as Indicating a Value of 4.7.

a value of 4.7 for most needle positions between 4.6 and 4.8. But if the needle came to rest slightly beyond 4.6, its value could be called 4.6; or, if the needle came close to 4.8, the reading could be called 4.8. Meters such as we find in the service shop do not usually possess an accuracy greater than 2 percent and it is seldom necessary to determine readings any more accurately than what has been noted above.

To recapitulate briefly, note first the major divisions on a scale and then the minor divisions. Major divisions are characterized by heavier and usually longer lines, and are frequently identified by numbers. Minor divisions seldom have any numbers placed above, below, or beside them.

To determine the value of each marking, count the number of minor spaces contained between the two adjacent major lines and then divide this number into the difference between the values of the two major indications. The result will be the value of each minor marking. In the above illustration, each minor line had a value of .2.

The scale shown in Figure 24 is probably the simplest type of scale you will encounter. A slightly more complex scale is the one shown in Figure 26A. This, too, contains major and minor markings, but some of the major lines are unlabeled, together with all of the minor divisions. Thus, the technician is called upon to determine more than just the values of the minor divisions. However, this complicates the problem only slightly.

On the scale shown in Figure 26A, the figures range from 0 at the extreme left-hand side, to 10 at the extreme right-hand side. Actually shown on the meter face are the numbers 0, 2, 4, 6, 8, and 10. As a first step, it is necessary to determine the value of all the unmarked major divisions or, in other words, all the longer, heavier lines. Starting at the left-hand side of the scale, the first unmarked major division occurs between 0 and 2. Hence, its value is 1. The next unmarked major division occurs between 2 and 4 and its value is 3. In similar fashion the values of 5, 7, and 9 for the next three unmarked major divisions can be ascertained. These are shown in Figure 26B.

Once the values of all the major divisions have been obtained, we can turn to the minor markings. In the scale of Figure 26, the minor divisions have the same values as those in Figure 24. In fact, once all of the major division numbers have been determined,

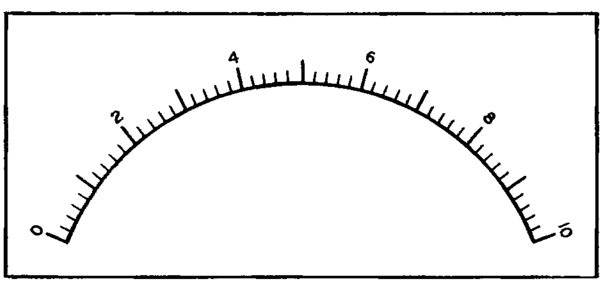



Figure 26A. A Scale Which Is Similar to the One Shown in Figure 24. Note That Only Alternate Major Lines are Numbered.

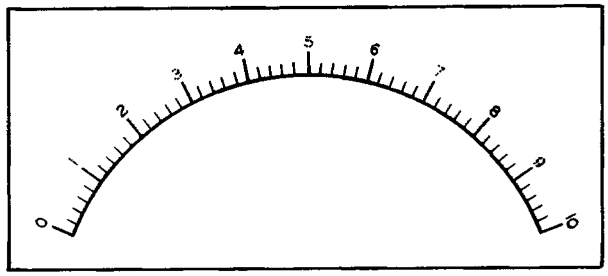



Figure 26B. The Values of the Unnumbered Major Divisions in Figure 26A, as Shown, Appear in Dotted Form.

it can be seen that this scale and that of Figure 24 are identical.

Where the same scale is used with several different sets of numbers, as it is in Figure 23, the severicman must be careful to change the value of the various minor divisions as he switches from one range to another. Thus, when the meter is set to operate on the 0-12 volt scale, each minor division has a value of .2. On the 0-60 volt scale, using the same set of markings, each minor division is equal in value to 1. (This follows from the fact that every mark on the 0-60 scale is 5 times its value on the 0-12 scale.)

Finally, on the 0-300 range, each minor marking possesses a value of 5.

The scale shown in Figure 27 has a gradation of markings different from those illustrated heretofore. Here the principal or major divisions are identified by the numbers 0, .5, 1.0, 1.5, 2.0, 2.5, and 3.0. The space between any two consecutive numbers is divided into 5 minor divisions and each minor segment, in turn, is further subdivided in half. For the purposes of this explanation, let us call the smallest divisions, sub-divisions, in contrast to the minor sections.

To tackle first the minor spacings, we note there are five between every two consecutive numbers. Also, the difference between each two major sections is .5. Hence, .5 divided by 5 produces a result of .1. This, then, is the value of each minor section. Thus, between .5 and 1.0 we have .6, .7, .8, .9, and finally 1.0.

Ascertaining the value of the sub-divisions now becomes quite simple since each sub-division line divides each minor section in half. Hence, .1

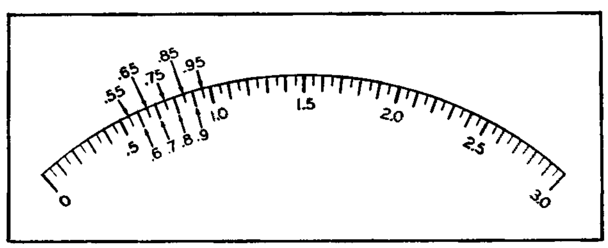



Figure 27. The Value of the Major and Minor Markings on Another Scale. See Text.

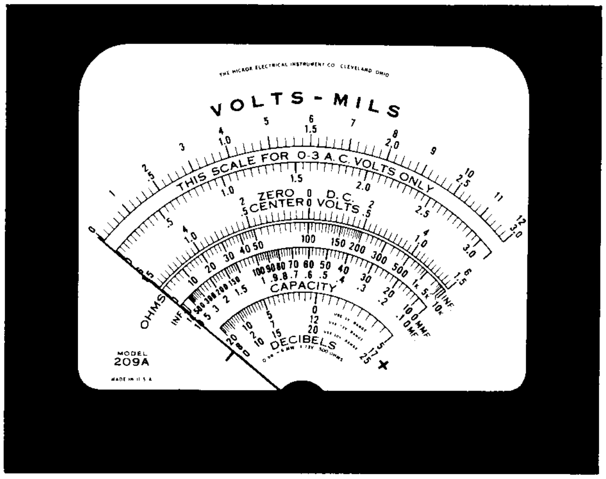



Figure 28. The Scale Used on the Hickok Model 209A VTVM. Courtesy of Hickok Electrical Instrument Co.

divided by 2 gives a result of .05 and this is the value of each sub-division.

On the Hickok Model 209A VTVM, the Volts-Mils scale used is shown in Figure 28. It is employed for volts (AC-DC) and for DC current. Two sets of numbers, 0-3 and 0-12 are found above this scale. The 0-12 is the easier one to figure out, so let's investigate it first. Each number is placed above a major marking; furthermore, between each two consecutive numbers there are five equal sections (produced by four equally spaced lines). Since there are five sections and the difference between two consecutive numbers is 1, each section must have a value of 1/5 or .2. Hence, for the 0-12 scale, each thin line marking possesses a value of .2.

What may prove somewhat confusing here is the fact that not all of the thin lines (minor markings) have the same height. The reason for this stems from the 0-3 scale. So far as the 0-12 scale is concerned, the height variation is not significant. All the minor divisions are equally spaced and all possesses the same value.

Now consider the 0-3 scale. Its major markings are 0, .5, 1.0, 1.5, 2.0, 2.5, and 3.0. Similar dark lines are placed midway between each set of numbers and so each of these other dark lines has an intermediate value. Thus, the dark line midway between .5 and 1.0 has a value of .75; the dark line between 2 and 2.5 is 2.25, etc.

Now the question is: Why are these intermediate dark lines used? Their values for the 0-3 scale are obviously not significant or at least not as significant as .5, 1.0, 1.5, etc.

The answer is that these intermediate dark lines are actually employed for the 0-12 scale, not the 0-3 scale. However, as long as they are present, their relationship with regard to both scales should be known.

The minor markings for the 0-3 scale fall into two categories. The longer lines could be considered

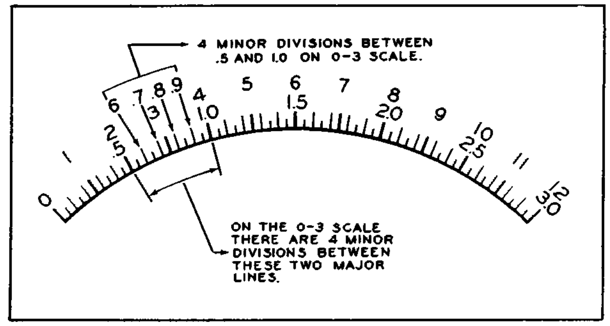



Figure 29. Further Elaboration of a Portion of the Scale Shown in Figure 28.

as the true minor divisions while the shorter lines could be classified as sub-divisions. If we consider the longer lines first, then between every two consecutive numbers there are four such lines. See Figure 29. This means that these four lines divide the space up into five sections and hence we must divide the difference in the two major markings (say 1-.5) by five. Doing this, .5/5, reveals that each of these minor divisions has a value of .1. Thus, between .5 and 1 we have .6, .7, .8, .9, and finally 1.0.

The values of the smallest thin lines, the so-called sub-divisions, can now be readily ascertained. Each sub-division line is seen to divide each minor space in two. Since each minor space has a value of .1, each sub-division has a value of .1/2 or .05. If we were now to write in the value of each dial marking, it would appear as shown in Figure 30.

NON-LINEAR SCALES -

Thus far we have dealt only with meter scales in which the distance between every two consecutive numbers was the same. Technically, this is known as a linear scale. However, there are a number of scales, principally those employed for the measurement of ohms and db, in which the spacings between numbers at different points along the scale varies. This means that the values of the minor divisions will depend upon the particular section of the scale in which they are located. To illustrate, consider the Ohms scale shown in Figure 31. At the left-hand side of the scale, the numbers are spread out and increase in value slowly. However, as we move toward the right, the spacing between numbers decreases and the values increase quite rapidly.

The problem is to determine the value of the minor divisions at various points along the scale. At

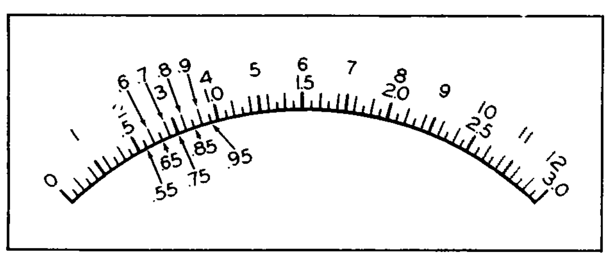



Figure 30. The Value of the Sub-divisions on the 0-3 Scale.

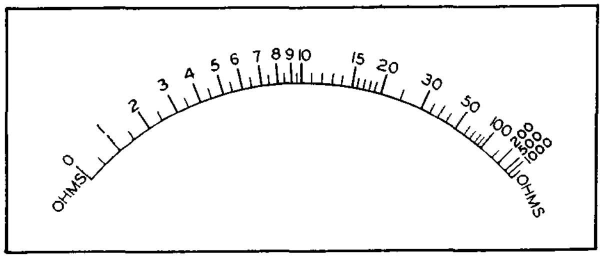



Figure 31. A Typical Ohms Scale.

the left-hand side of the scale each two consecutive major divisions have but one minor division between them and consequently the value of this minor division is midway between that of the two major marks on either side of it. Thus, the minor mark between 2 and 3 is 2.5; between 8 and 9 it is 8.5, etc.

Over the central portion of the scale, between 10 and 15 (or between 15 and 20), there are five spaces produced by four minor divisions. The difference between 10 and 15 is 5 and this, divided by the five spaces, results in a value of 1 for each of the four minor divisions. Thus, between 10 and 15 we have 10, 11, 12, 13, 14, and finally 15.

Between 20 and 30 there is but one mark and so this must be 25; between 30 and 50 there are several marks although these should cause no difficulty. The center mark, darker and longer than the rest, is obviously 40. The minor divisions on either side of it can then be seen to be 35 (at the left of 40) and 45 (at the right).

The scale at the extreme right-hand end becomes quite crowded and the values rise rapidly. Again, if any minor divisions appear between the larger markings, count the number of such marks, and divide this into the difference between the two flanking major divisions. This is the method we have employed heretofore.

Generally speaking one scale is employed for all ohms measurements and the serviceman must be careful, when using this scale, to note what positions his multiplier is in. If it is set for R x 100, then every value read on the ohms scale must be multiplied by 100; if the switch is in the R x 1,000 position, every value is multiplied by 1,000, etc. And, whenever use is made of this scale, the selector switch should be set so that the readings occur to the left-hand side of the scale. The markings here are much clearer and easier to read.

To conserve space, especially at the crowded end of the scale where the large numbers are found, 1,000 (and higher values in the thousands) is shortened by the use of the letters K or M. Thus, some manufacturers write 1,000 as 1K, 2,000 as 2K, etc. Others prefer the letter M; thus, 1,000 is printed 1M, 2,000 as 2M, etc.

In vacuum-tube voltmeters, the ohms scale starts at the left-hand side of the meter dial and extends to the right. In multimeters, the direction will vary with the instrument; some scales increase from left to right while others rise in the opposite direction. The methods of using both types of instruments are identical.

The AC scales in some meters will be non-linear but in most instruments it will be as linear as the DC scales. The difference is due to the manner in which the AC is rectified in the instrument. Other scales which are generally non-linear are the decibel (or db) and capacitance scales. No difficulty, however, should be encountered in reading these scales if the preceding discussion is fully understood.

To recapitulate, then, correct reading of a meter scale proceeds in three steps.

Step 1. Find the proper scale to read.

Step 2. Determine the value of the markings on that scale. In taking this reading, make sure your eyes are directly over the needle. If you are off to one side, the reading you get will be too high or too low, depending upon which side of the meter you are.

Step 3. Check with the range switch to see if the scale used should be multiplied by some factor. Multiplication of scale values is most extensively employed for resistance measurements, and to a lesser extent for the other electrical units. However, there is no set practice in this respect and each instrument should be carefully checked for multiplying factors before being used.

## USE OF THE VTVM IN TV SERVICING

The principal applications of the VTVM in television receiver service work consists in making voltage and resistance measurements. The low voltage checks are made with an ordinary probe. For high-voltages, a special probe is available, such as shown in Figure 13. An ordinary probe, too, is used for AC measurements (up to approximately 15,000 cycles). Beyond this, extending up for several hundred megacycles, a special RF probe is necessary. The high-voltage probe and the RF probe are generally additional accessories which are not included in the original pricing of the unit. Where the money is available they should be purchased because they do extend the usefulness of the meter.

While the VTVM is the work horse of the service shop, its usefulness for signal tracing, especially in the RF and IF sections of the receiver, is frequently overlooked.

Yet with a suitable RF probe and perhaps an AM generator to supply a strong signal, a considerable amount of testing can actually be carried out here.

To illustrate how the probe may be employed for signal tracing, consider a television receiver in which, for some reason, the incoming signal is not reaching the video second detector. The problem is to locate the break in the signal path. Tune the receiver to one of the local channels. Then disconnect the antenna and feed in the signal from an AM signal generator. Set the generator to the video carrier frequency for that particular channel. Do not modulate this signal; in other words, feed in an unmodulated signal.

Now, with the RF probe of the VTVM, check for an indication of this signal voltage at the plate of the RF amplifier. (Use the full output of the signal generator and adjust the fine tuning control of the receiver for peak indication on the meter.) Check for the RF signal at the grid of the mixer stage.

Continue the check at the mixer plate and at the grid and plate of each video IF amplifier from the mixer to the video 2nd detector. In each amplifier stage, the signal should be stronger at the plate than at the grid. The only exception to this might occur in the mixer tube, which is not operated as a conventional amplifier, but rather as a converter wherein the incoming signal is brought down from its RF value to the IF level. Further investigation should be directed to any amplifier stage where the signal either remains the same or actually decreases in going through the circuit.

The same probe can be employed to measure the RF output of the receiver oscillator. Remove all signals from the front end of the receiver. Then, with the power on, place the RF probe of the VTVM at the point where the oscillator injects its signal into the mixer circuit. (Ground the RF probe shield to the receiver chassis as close to the point of contact as possible.) Check the output of the oscillator by noting the reading it produces on the VTVM scale. Do this on every channel on which the receiver is used.

There are several features concerning the use of the RF probe for signal tracing with which the serviceman should be familiar.

1. For best results use an RF generator rather than the incoming signal as the voltage which the probe detects. The generator will provide a useable signal at most frequencies; incoming signals, unless they are exceptionally powerful, will not develop voltage in the first three or four stages of the receiver to give a useable indication on your VTVM.

2. As you go through the front end stages of the set (i. e., those in the tuner) you will find it easy to confuse the voltage fed by the oscillator into the mixer with the incoming signal voltage. The test for the oscillator voltage has already been given. To check for the signal voltage separately at the mixer, it will be necessary to disable the oscillator. Generally, this need not be done if you find a signal in the video IF stages since the presence of this signal indicates an interaction between the incoming signal and oscillator voltage in the mixer. However, when there is no IF signal at the grid or plate of the first video IF tube, then separate tests for the signal and oscillator output at the mixer are warranted.

In dealing with a television receiver, it must be remembered that if you wish to check directly any RF or IF signal (in their respective systems), that an RF probe will have to be used. The RF probe is a detector which takes the signal present at the point of measurement, converts it into pulsating DC, and then feeds this voltage to the meter where its rms value is recorded.

If you wait until the signal reaches the video second detector before measuring it, then only the DC probe of the VTVM need be connected to the video load resistor. In this instance the second detector tube takes the place of the RF probe.

As long as you keep the functions of the RF probe in mind, there will be no confusion regarding where it should or should not be used.

## ISOLATION TRANSFORMERS -

One statement in this section made reference to the use of an isolation transformer when using test instruments to service a transformerless receiver. Other references to this same practice will be found in many of the instructional booklets that come with test equipment. To those men who have not had much servicing experience, these references may appear puzzling since they are almost invariably given without any additional explanation.

The 100-117 volt power line, from which all electrical equipment operates, has one wire grounded and one wire energized. The grounded wire potential remains constant, while the potential of the energized wire, varies alternately above and below ground by 110-117 volts. (While it is common to refer to the power line potential as 110 volts, actually the exact value will vary with each locality. It is not unusual to find variations from 95 to 125 volts not only from place to place, but also within the same locality.)

Now, in a transformerless set, such as the AC-DC receivers so widely employed, the power line connects directly into the receiver low-voltage power supply circuit. See Figure 32. One side of the line becomes the B- for the receiver while the other side connects to the rectifier tube for the development of the B+ voltage.

To the receiver it makes little difference which of the two power line wires is the B- wire and which connects to the rectifier tube. If the grounded power line wire is the B- wire of the receiver, then, of course, the rectifier diode will conduct whenever the energized wire is positive. On the other hand, if the plug is reversed in the wall receptacle, the grounded power wire connects to the rectifier tube and the so-called "hot" or energized wire becomes the receiver B-.

Now, the question can be raised, "How does the set operate under these conditions?" The set does

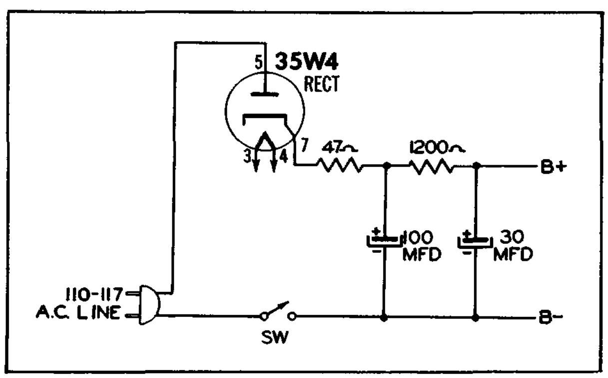



Figure 32. A Power Supply Circuit Common to Transformerless Receivers.

operate, we know, and the answer is to be found in the fact that when the energized wire becomes negative, the grounded wire is, by comparison, more positive. Since the rectifier tube is concerned only with the relative voltage between these two wires, it will conduct during this half cycle.

Thus, to the receiver itself, it makes no difference which power wire connects to B- and which goes to the rectifier tube.

Suppose, however, that the receiver B- is also connected to its chassis (which is frequently true) and that this chassis is resting against the electrical conduit pipe running along the bench. Since the pipe is at ground potential, one of two things can happen.

1. If the grounded wire of the power line connects to the receiver B-, then nothing will happen.

2. But if the energized wire of the power line is the one that reaches the receiver chassis, then you will be shorting this wire to ground. Result: A surge of current and one blown fuse. The blown fuse is readily replaced but the surge of current may easily damage the receiver On-Off switch and burn out pieces of metal on the receiver chassis or the conduit pipe.

Instead of backing the receiver up against the conduit pipe, suppose we connect a VTVM to the receiver for a series of voltage measurements. The common or ground lead of the VTVM goes to B-, while the voltage probe is placed at various points to determine the various potentials. Here, again, we have several interesting situations which can arise. If neither the receiver nor the VTVM chassis (and cabinet) come in contact with any ground conductor, nothing will happen. But if either of these units does

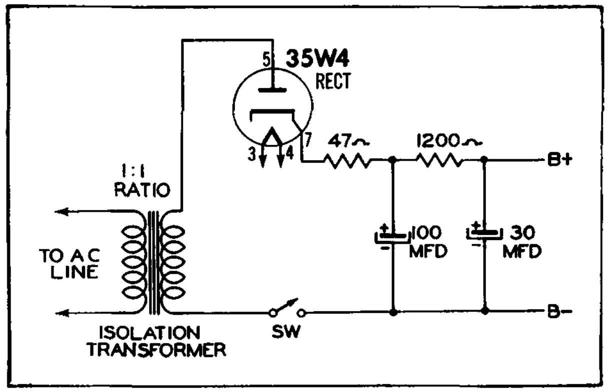
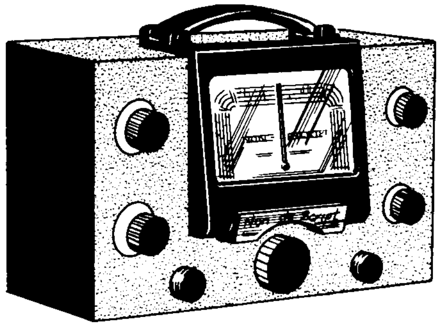



Figure 33. By Using an Isolation Transformer, There Is no Direct Connection Between the Power Line and the Receiver.

make contact with a power line ground and the energized power wire is connected to the receiver B-, the fuse blowing fireworks discussed will occur, this time with possible damage to the VTVM, or whatever other instrument is employed.

To prevent shorting the power line to ground, a 1 to 1 isolation transformer should be inserted between the power line and the transformerless receiver. See Figure 33. The isolation transformer removes the direct connection between the power line and the receiver and now we can ground the receiver chassis without disturbing its operation or that of the power line.

In transformer operated receivers, isolation is achieved by the set transformer itself and so, of course, no additional unit is required.



# section two

## AM Signal Generators

### INTRODUCTION

Despite the fact that television receivers contain broad bandpass circuits extending over a range of 3 to 6 mc, there are a considerable number of applications to which an AM generator be put. Thus, an AM generator can be employed for peaking the various coils in stagger-tuned video IF systems; they can be used to align the audio IF circuits; and, finally, AM generators find extensive application as marker generators. In this latter capacity, the AM generator provides an identification signal (or marker) which, when used in conjunction with a sweep generator, shows the operator the exact position of certain frequencies within the bandpass of the circuits under test. A complete and detailed discussion covering this very important application will be given in a later section.

The AM generator, wnatever frequency range it covers, consists basically of an RF oscillator whose output frequency can be varied over a certain range. This signal is available as is (i. e., unmodulated) or it may be combined with a low-frequency audio signal (i. e., modulated). To achieve this amplitude modulation, the generator also includes an audio oscillator, operating at a fixed frequency which is usually in the neighborhood of 400 cycles. Provision is always made to bring the modulation in, when desired, or, to cut it off when only the RF signal (or carrier) is needed. For direct testing of the receiver's audio system, the 400 cycle signal voltage is also available at a front panel jack.

### AM GENERATOR CIRCUITRY

The complexity of the AM generator, like that of the VTVM, depends upon the number of functions which the unit is designed to perform. One of the simplest commercial units available (in kit form) is shown in Figure 1. V1 (a 6C4) is operated as a Hartley oscillator. The output of V1 is resistance-coupled to a buffer tube, V2A. A four-step ladder attenuator and a variable potentiometer in the cathode circuit of the buffer stage control the output of the generator without loading the oscillator stage. (Loading changes in the most rigidly controlled oscillator will tend to cause a frequency variation.)

The second half of V2 (V2B here), 1/2 of a 7F7 tube, is connected as a 400-cycle audio oscillator. The modulated output then appears across the cathode of V2A, from which point it is fed to the output terminals of the signal generator.

Stability is all-important in any type of test instrument, and especially so in signal generators. To achieve a measure of stability in the circuit shown, a voltage regulator tube is connected across the output of the power supply. With this regulator, line voltage variations from 95 to 135 volts will not affect the generator accuracy. However, variations in the value of the other oscillator components will have an affect on the frequency. Just how immune the oscillator is to component value variations depends upon the quality of the parts used, and frequently this varies in direct proportion to the price of the instrument.

AM signal generators are one of the oldest pieces of test equipment employed by the radio serviceman. That they are more complicated now is due principally to the extension of broadcasting into newer (and higher) frequencies. Thus, where prewar signal generators were required to generate signals extending only to the end of the radio broadcast band, now they must cover this range plus FM and television, too. This means an extension up to 220 mc and, in time, even higher as the UHF bands are opened up to commercial broadcasting.

The front panel of the generator discussed in Figure 1 is shown in Figure 2. The dial face is seen to consist of a number of scales (here, 7), each scale devoted to a different set of frequencies. The lowest frequency scale is the outermost scale (labeled A). The frequencies across this scale range from 75 kc at the low end to 220 kc at the high end.

At this point, one might raise the question, "How do you know that the outer scale concerns the lowest generated freauencies of this instrument?"

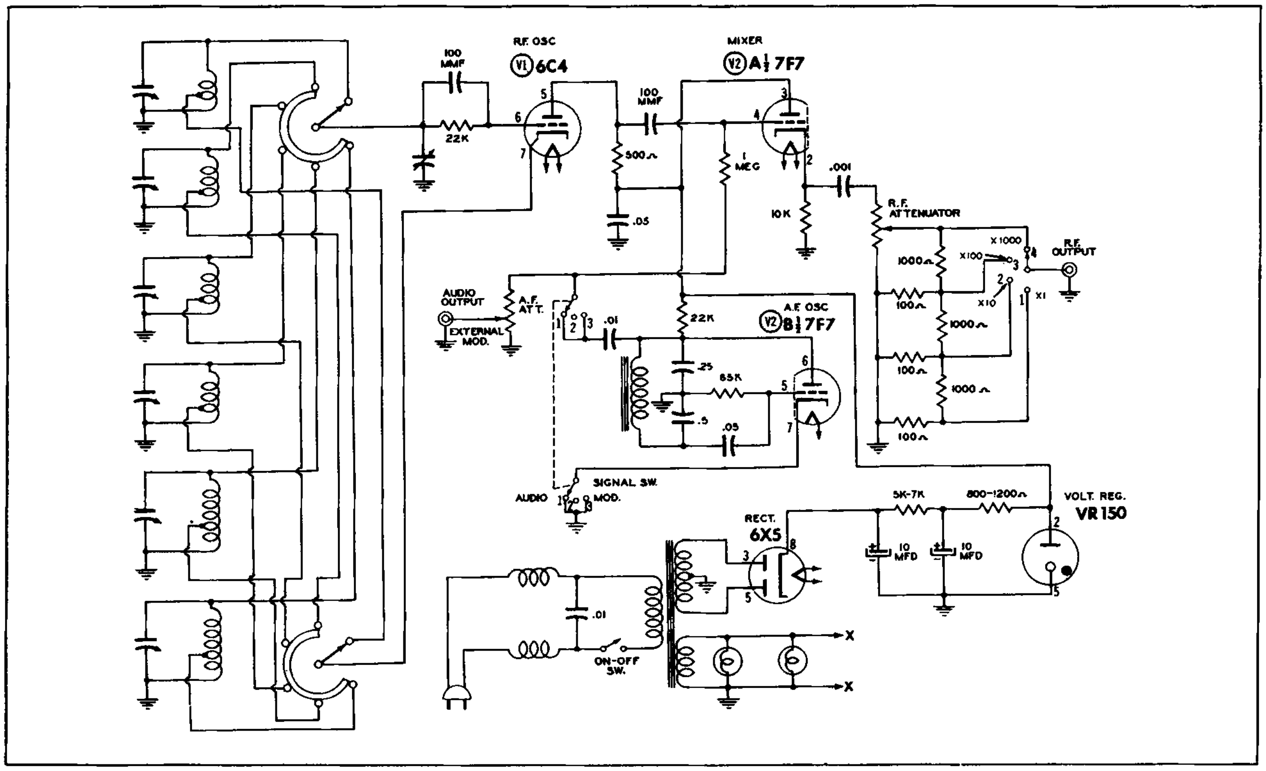



Figure 1. The Circuit Diagram of a Simple AM Generator.

And furthermore, "How do you know that the frequencies are in kilocycles?"

Both are very pertinent and very legitimate questions that might be asked by any serviceman - especially one whose experience with signal generators is limited. The answer to both questions will be found in the instruction booklet which is supplied with every test instrument. In some instruments, as we shall see later, sufficient information is given on the face of the dial to enable the user to determine the frequency coverage by inspection alone. In other instruments, such as the one pictured in Figure 2, recourse to the instruction booklet is necessary.

One point worth noting about most signal generators is this. When the different scales are identified or labeled by letters of the alphabet, such as A, B, C, D, etc., then almost without exception the lowest frequency scale is assigned the lowest letter.

Continuing with the scales shown on the AM generator of Figure 2, the second or "B" scale covers the frequency range from 200 kc to 600 kc. A comparison of this range with that of scale "A" reveals that the low end of scale "B" overlaps the high end of scale "A". In other words, a portion of the highest frequencies reappear at the low end of scale "B". This is another common practice and is done to insure that the rise in frequencies is continuous. If the beginning of scale "B" started just at the end of scale "A", it might happen under some circumstances* that the frequencies generated by the instrument for scale "A" did not quite extend up to the highest frequencies indicated on that scale. This would cause a gap to appear between A and B and impair, to some extent, the usefulness of this generator. It is to prevent this from happening that the frequency ranges of the various scales overlap.

The range of the third or "C" scale of the generator extends from 550 kc to 1700 kc. Writing 1700 kc in mc produces a result of 1.7 mc. Scale "D" starts below this, at 1.6 mc and rises to 5.0 mc. Scale "E" ranges from 5.0 to 16 mc. Next follows scale "F" with 10 to 50 mc and finally scale "G" with 45 as the first number and extending up to 150 mc. While 45 is the first number on scale "G", actually the dial contains markings below this point. However, the section below 45 (on scale "G") need not be used since it repeats a portion of scale "F".

The choice of a particular range is governed entirely by the switch marked "Band" located just below and slightly to the right of the dial knob. There is a separate position for band A, B, C, D, and E. Note, however, that bands F and G both occupy the same selector switch position. Also, if you look closely at scales F and G you will discover that every number on scale G is exactly 3 times the number appearing directly above it on scale F. This means that one tuned circuit is being used to generate all

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* A change in value of circuit capacitance, resistance, inductance, a variation in the operating voltages, or aging of the oscillator tube itself might readily alter the frequencies generated by an oscillator. Especially critical in this respect are the end frequencies of any resonant circuit.

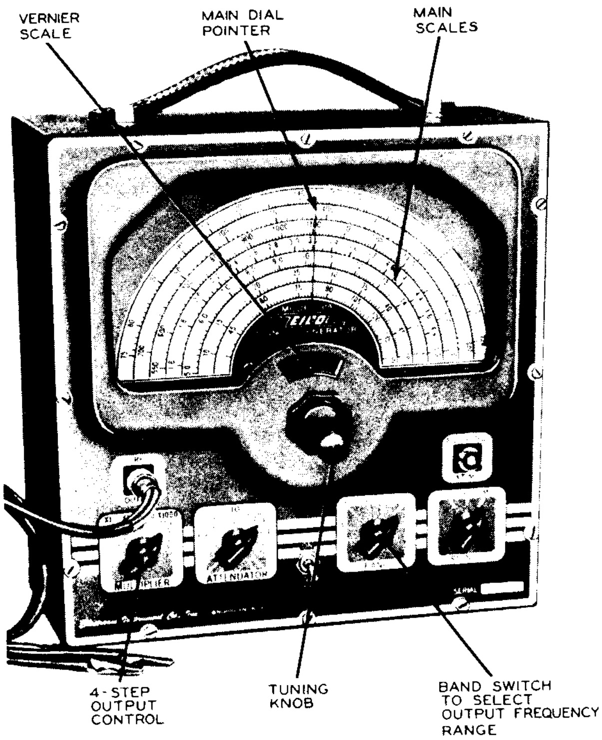


Figure 2. An AM Generator Available in Kit Form. Courtesy of Eico.

frequencies from 10 mc on up. The basic or fundamental frequencies being developed by the generator (with the "Band" switch in the F, G, position) are those indicated on scale F, namely, 10 to 50 mc. However, as is true of nearly all oscillators, harmonics are generated together with the fundamentals. In this instrument we are interested in the third order harmonics. Note, however, that there are present also the second harmonics and possibly some fourth, fifth, and even higher harmonics, although the harmonic amplitude falls off quite sharply as the harmonic order rises.

The range, then, of the generator shown in Figure 2 extends from 75 kc to 50 mc on fundamentals, and from 50 mc to 150 mc on harmonics. The practice of using harmonics for the higher frequencies is a common one since it is obviously more economical to use one set of tuned circuits for two ranges than one. The disadvantage of this arrangement is the decrease in signal output for all harmonics. Thus, the strength of the "G" scale signals will be less than those of scale "F" and might prove difficult to work with. Also, by using harmonics it is possible that spurious signals, caused by the beating of one frequency against another, will develop which will give false indications in the circuit you are working with. With careful design, however, these disadvantages can be minimized (and are) to the point where the majority of present day AM generators develop their highest frequencies harmonically and little difficulty is encountered in normal operation.

## VERNIER SCALES

The graduations on the various scales of the generator dial are simply designed and if you apply the rules established in Section 1 for reading VTVM scales, no difficulty will be encountered. Generator dials are seldom as complicated as VTVM scales.

There is, however, one feature concerning these dials that differs considerably from anything that has been previously encountered in vacuum-tube voltmeters. This feature is the use of an auxiliary vernier scale in conjunction with the generator dial. Now, by definition* a vernier is an auxiliary scale containing slightly smaller divisions than the main scale, and by means of which readings may be made with greater precision than allowed by the main scale.

On the generator shown in Figure 2, the vernier scale is located just above the dial knob. When the knob is rotated, it moves the main dial pointer across the scales; at the same time the vernier scale contains a greater number of divisions per inch and hence, for a given rotation of the knob, more divisions are covered on the vernier scale than on the main dial. And because of this, it is possible, as we shall see, to determine readings on any of the main scales to a greater degree of accuracy than if there was no vernier.

In Figure 3 two scales are shown. Scale A, the main scale, has 7 divisions while scale B, the vernier scale, has 21. As the pointer moves from 0 to 7 on scale A, it will travel from 0 to 21 on scale B. Furthermore, since both scales are linear, the 21 vernier divisions will be divided evenly between the 7 divisions of scale A. This means that as the pointer moves from 0 to 1 on the main scale, it will move from 0 to 3 on the vernier scale. (Another way of stating the same facts is to say that each vernier division is equal to 1/3 division on the main scale.)

Now, as long as we desire to deal only with the whole numbers on scale A (such as 1, 2, 3, 4, etc.) and we can set the pointer precisely on each major mark, then the vernier scale will be of little use. But when, as is frequently the case, we wish to set the pointer to some position between whole numbers, then the vernier scale comes in very handy.

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* As given in "A Dictionary of Electronic Terms," published by the Allied Radio Corporation of Chicago.

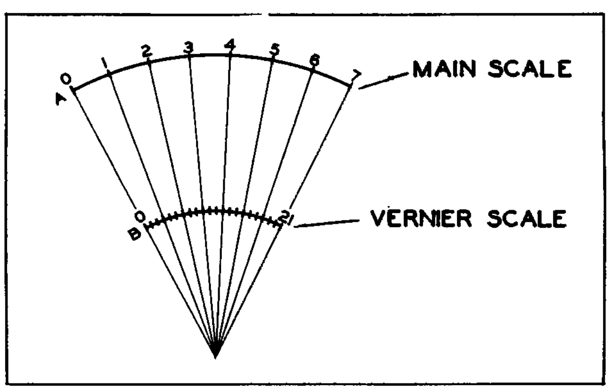


Figure 3.

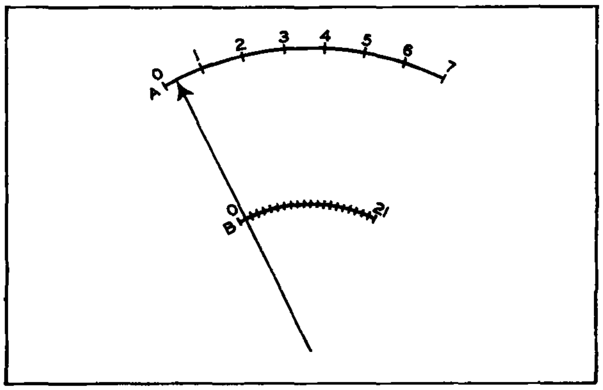


Figure 4. The Vernier Scale "B" Helps to Set the Pointer to a Desired Point on Scale "A".

To illustrate, suppose we desire to set the main scale pointer to .33. This point, we know, is one-third of the distance between 0 and 1 and, more frequently than not, we would be wrong. We may not be very far wrong, but the chances are good that we would be off to a certain extent. However, with the help of the vernier scale, we can actually hit .33 right on the head. For when we move the pointer from 0 to 1 on the main scale A, we go from 0 to 3 on the vernier scale B. This means that when we move the pointer on the vernier scale to 1, the pointer on the main scale is at .33. See Figure 4. Since we can hit 1 on the vernier scale quite accurately, we can reach .33 on the main scale just as precisely.

Continuing, when the pointer is directly at line 2 on the vernier scale, it is at .66 on the main scale. And, finally, when the pointer is at 3 on the vernier scale, it is at 1 on the main scale.

Thus, we see that with the help of the vernier scale, we can obtain many more accurate readings on the main scale than we could have without this additional scale. Other points than those discussed may also be determined more accurately with the aid of the vernier scale. For example, suppose we wish to set the pointer to .5. This point is approximately midway between .33 and .66 and by setting the pointer midway between lines 1 and 2 on the vernier scale we can come quite close to the .5 position. Certainly we can more closely approximate .5 on the main scale by using the vernier than we could be relying on scale A alone.

One fact made evident by the foregoing discussion is that the more divisions the vernier scale possesses (over a given section of its scale), the more accurate will be the settings made on the main scale.

We are now in a position to consider vernier scale usage in more specific terms. Thus, in Figure 2, suppose we wish to obtain a signal having a frequency of 145.6 kc. This would lie on scale A between 140 and 150 kc. To determine where 145.6 exists as closely as possible, set the pointer first on 140 kc and note the reading on the vernier scale. In this case let us say it is 73. Next, rotate the knob until the needle is at 150 kc on scale A. Again note the reading of the vernier scale. At this point it is 99.

We see, then, that for a variation of 10 kc (150 kc - 140 kc), the vernier moved 26 divisions (99-73) past its reference hairline. If we divide the 26 into the 10, we obtain an answer of .384. This means that every division of the vernier equals .384 kc on scale A. Thus, if we move the vernier from 73 to 74, we change the generator output frequency from 140 kc (at 73) to 140.384 kc (at 74).

To reach 145.6, we have to increase the generator frequency 5.6 kc above 140 kc. Since each vernier mark is equal to .384 kc, what we have to determine is how many times does .384 go into 5.6. This will tell us how many divisions to move the vernier scale past 73. Performing the division (i. e., $\frac{5.6}{.384}$) gives us an answer of 14.6. And so, if we add 14.6 to 73 (our starting point or 140 kc), we set the vernier dial to read 73 + 14.6 or 87.6, the signal generator will be developing an output frequency of 145.6 kc.

It should not be supposed that the value of .384 kc per vernier division holds true at all points on scale A. It would hold true if scale A were perfectly linear and if the vernier scale were likewise perfectly linear. Since this is seldom true, it is best to go through the same procedure for each different section of every scale. In this way you will be certain of approaching as close to the desired frequency as possible.

## OTHER GENERATOR CONTROLS

In addition to the "On-Off" switch and the "Band" switch which we have previously considered, there are three other controls and two signal outlets on the generator of Figure 2. One control, the "Multiplier," is a four-way selector switch serving to regulate, in four steps, the intensity or amplitude of the signal delivered by the generator. In the X1000 position, the maximum amount of signal is available at the "RF Output" terminal located just above this control. In the X100 position, approximately 1/10th as much signal is permitted to reach the output terminal, the remainder of the signal being dissipated in resistive attenuation pad. See Figure 1. In the X10 position, the signal level is still further decreased, and in the X1 position it is at its lowest point.

In each of the four positions, the level of the signal may be continuously varied by means of the "Attenuator" control. This type of arrangement provides full control of the signal from maximum to minimum.

On the other side of the panel there is a "Signal" control possessing three positions: Audio, wherein the audio signal (400-cycles) is made available at the "Audio Output" terminal; RF, when only an unmodulated RF signal appears at the "RF Output" terminal; and "Mod," when the RF signal at the "RF Output" terminal is modulated by the audio note.

Control of the amplitude of the audio signal at the "Audio Output" terminal is also achieved by rotating the "Attenuator" control. This knob attaches to a dual potentiometer, one section of which serves for the RF signal, and one for the audio signal.

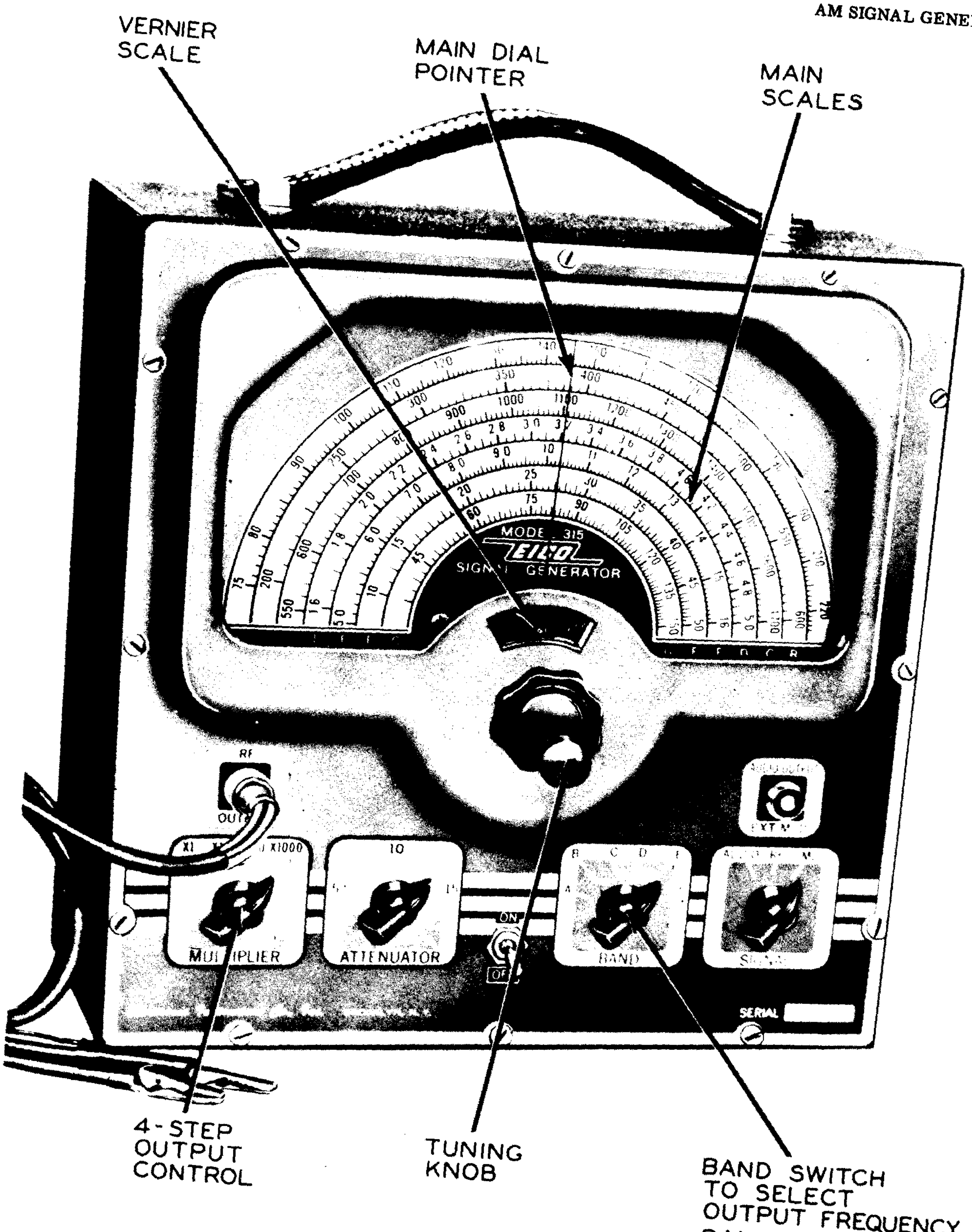


Figure 2. An AM Generator Available in Kit Form. (Model 315, Courtesy of Eico.)

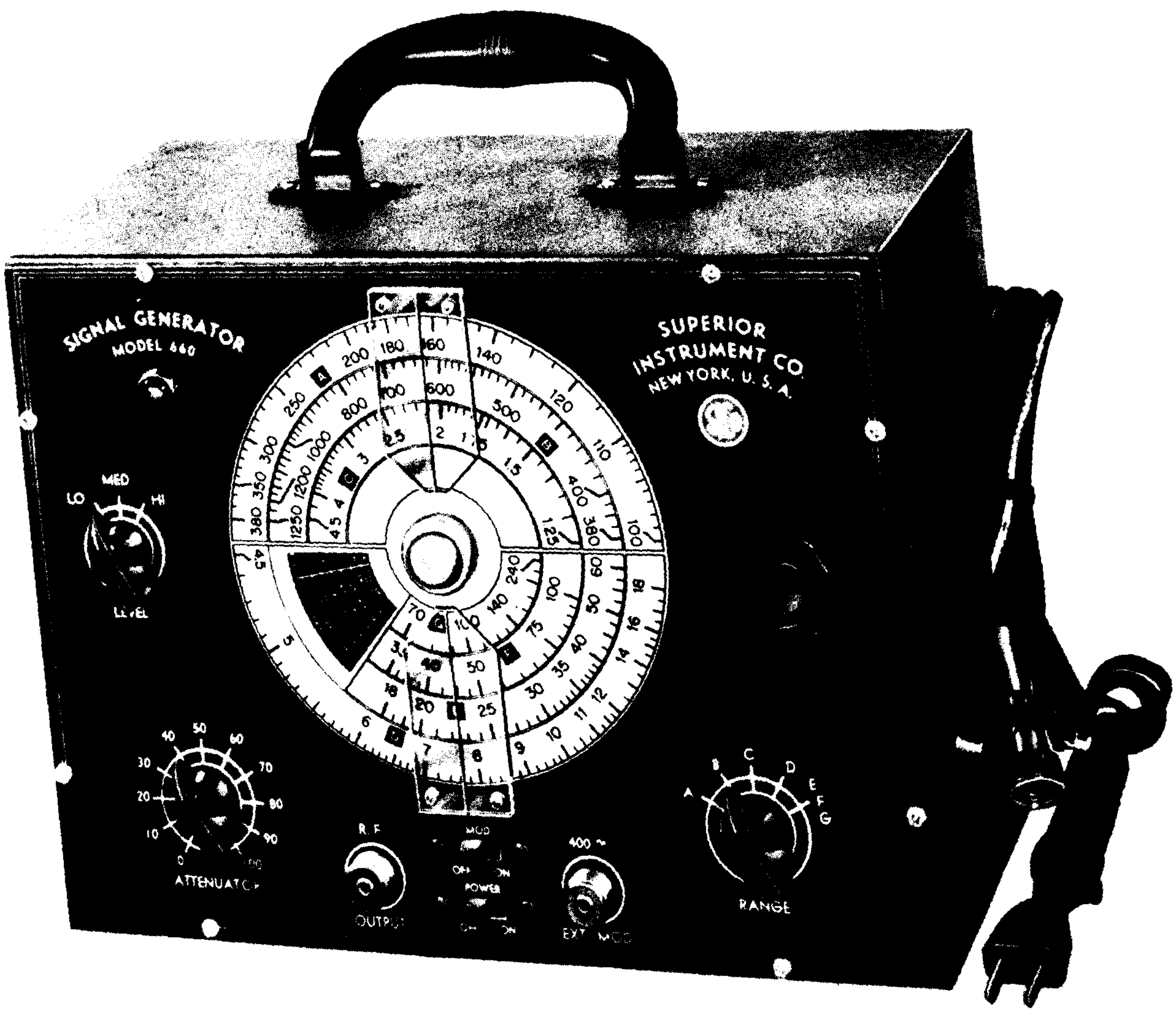


Figure 5. A Signal Generator with a Range from 100 kc to 240 mc. (Model 660, Courtesy of Superior Instrument Co.)

To obtain the signal voltages present at either the "RF Output" terminal or the "Audio Output" terminal, a coaxial cable is provided with the instrument. One end of the cable screws on to the output terminals while the other end contains two alligator clips. One clip attaches to the other conductor of the cable and represents the ground output connection of the generator. The other clip connects to the inner conductor of the cable and is the one which is usually referred to as the "hot" lead since it carries the signal.

While most generators - in common with this one - contain an internal audio oscillator whose output can be used to amplitude-modulate the RF signal, provision is also made to permit modulation by an external signal, if this is desired. In the instrument shown in Figure 2, the external modulating voltage is fed into the instrument at the "Audio Output - Ext. Mod." terminal. The "Signal" control is placed in the RF position to disable the internal audio oscillator and prevent it from feeding its signal to the buffer tube at the same time.

USE OF THE AM GENERATOR

To place the AM generator of Figure 2 into operation, it would be connected to the nearest AC outlet and the "On-Off" switch flipped to the "On" position. The instrument should be permitted a period of 10 to 15 minutes to warm up and in the meantime its various controls can be set to position. Initially the "Multiplier" control is switched to the X1000 position; and the "Attenuator" knob set anywhere from mid to maximum clockwise position. The "Band" switch would be set to the range which contained the desired frequency and the "Signal" control would be positioned either at "RF" or "Mod" depending upon whether an unmodulated or a modulated signal was desired. Finally, the dial would be set to the frequency required and possibly, as a last step, the coaxial cable connected to the "RF Output" terminal. When the 10 or 15 minutes have elapsed, the instrument is ready for use.

Those men who have had extensive experience with generators of this type will recognize that the foregoing sequence may be varied by the individual as he sees fit. Actually, the sequence given is merely to indicate a method of preparing this instrument for use and is not to be construed as the only method.

Once the generator is connected to the receiver and the signal modulation is either being heard or observed on an indicator (such as an oscilloscope or VTVM), then the "Multiplier" and "Attenuator" controls are adjusted for the desired signal output. If the generator is being used for signal tracing purposes, then it is customary to use a moderate to strong signal output. On the other hand, if the generator is being used for alignment, the controls are set as low as it is possible to place them and still obtain an indication from the receiver. Never overdrive a receiver being aligned because any adjustments made under these conditions will not provide maximum sensitivity when the set is used to receive weak or moderate signals. We will return to this point again (and again) in a subsequent section covering the application of generators in FM and TV receiver alignment.

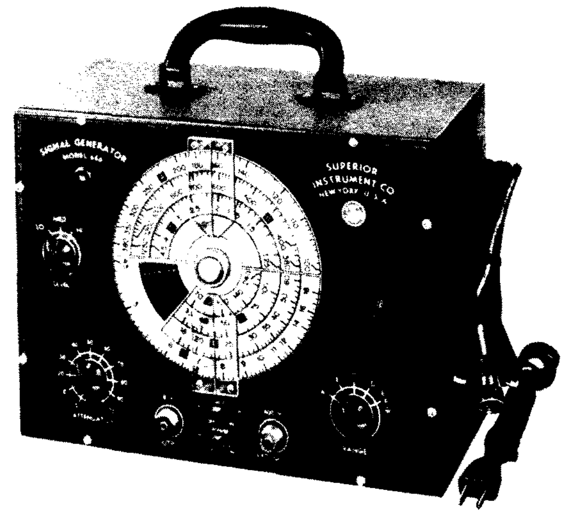


Figure 5. A Signal Generator With a Range From 100 kc to 240 mc. Courtesy of Superior Instrument Co.

If it is desired to employ the generator for audio alone, the "Signal" switch is set to "Audio." The coaxial cable connected to "Audio Output-Ext. Mod." adjust "Attenuator" for desired output (revealed by audio note heard, or the level developed on your oscilloscope or VTVM). None of the other controls have any effect on the audio output signal.

The front panel of another AM signal generator is shown in Figure 5. The frequencies covered by this instrument extend from 100 kc to 240 mc in seven (A, B, C, D, E, F, G) ranges. Not only is each of the scales identified by a letter, but also the frequencies for that range. To select the desired band of frequencies, there is a "Range" switch in the lower right-hand corner of the front panel. Note, however, that bands E, F, and G are all obtained at the same switch setting indicating that all frequencies beyond the fundamental range (18-60 mc) of band E are harmonics. For band F the second harmonics are utilized and for band G, the fourth harmonics. The instrument output will thus be expected normally to decrease as you go from scale E, to F, to G.

Two hairline indicators are used because the dial plate only rotates for $180^{\circ}$ and whatever is on the bottom half of the plate (bands D, E, F, and G) cannot pass underneath the top hairline indicator. The top indicator is thus used with bands A, B, and C while the bottom reference line deals with the remaining four ranges. Also, because of this arrangement, frequency on the top three scales increases from right to left while on the lower scales the frequency rises from left to right.

The other controls on this generator are self-explanatory and should cause no difficulty. The "Level" control, instead of being calibrated in terms of X1000, X100, X10, and X1, as in the previous generator, now contains the markings of Lo, Med, and Hi. A continuously variable potentiometer labeled

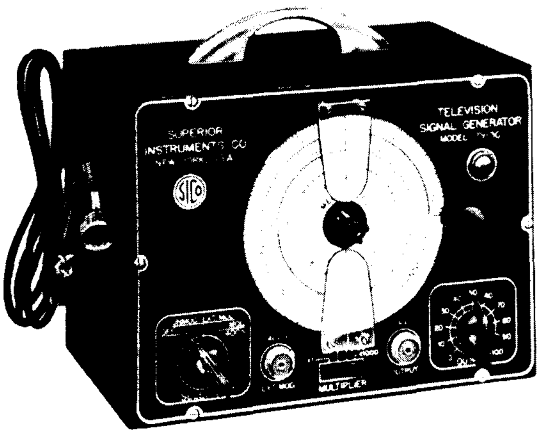


Figure 6. A Signal Generator Especially Designed for Television Service Operation. Its Range of Frequencies Extends From 18 to 250 mc. Courtesy of Superior Instrument Co.

"Attenuator" permits control of the signal level output for each position of the "Level" control.

Available, too, are "Mod" On-Off switch, a power switch, and two signal output connectors. The knob to turn the large dial plate is located at the right.

The instrument in Figure 5 can be employed for AM, FM, and TV receivers. For those shops which devote most of their time to television sets, a special signal generator developing only frequencies from 18 to 250 mc is made available by the same company. This unit is shown in Figure 6. The control marked "Output" in the lower right-hand corner of the panel regulated the level of the output RF signal. It serves the same purpose as the knob labeled "Attenuator" in Figure 5. A four position switch marked "Multiplier" performs the same function as the "Level" control on the signal generator of Figure 5.

It is interesting to compare these two instruments and note the differences in the labeling of controls which perform the same functions in their respective units. This in spite of the fact that both units were designed by the same manufacturer. There is no standard nomenclature for instruments doing similar jobs although it is true that most differences in control labeling can be resolved with a little study.

A simplification in dial markings is achieved in the signal generator shown in Figure 7. The dial is mounted behind the front panel and only a small section of it is visible at any time. Two scales take care of five bands,

(A) 65-205 kc
(B) 205-2050 kc
(C) 650-2050 kc
(D) 2050-6500 kc
(E) 6.5-20.5 mc

and the reason this can be done can be seen from an

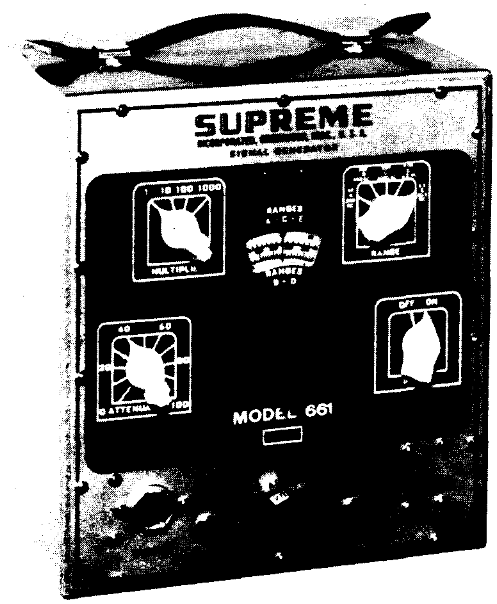


Figure 7. A Supreme Model 661 AM Signal Generator.

inspection of the above frequency arrangement. Three of the bands (i. e., A, C, and E) are multiples of each other permitting the use of one scale (with the appropriate mental multiplication) for all three. The other two bands, B and D, can both be accommodated on another separate scale by the same arrangement.

Two additional signal generators are shown in Figures 8A and 8B. Both units contain controls which are similar in name and functions to the controls on the AM generators just discussed. In Figure 8A the

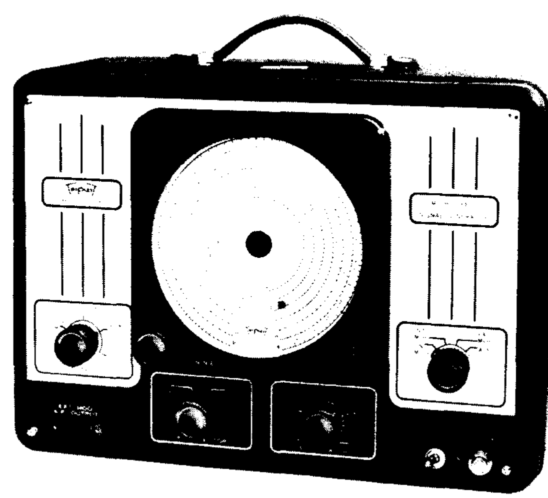

Figure 8A. A Signal Generator Which Will Generate Frequencies up to 120 mc. The Range Selector Markings Extend Only to 40 mc, but by Means of Harmonics, 120 mc can be Obtained. Courtesy of Triplett Electrical Instrument Co.

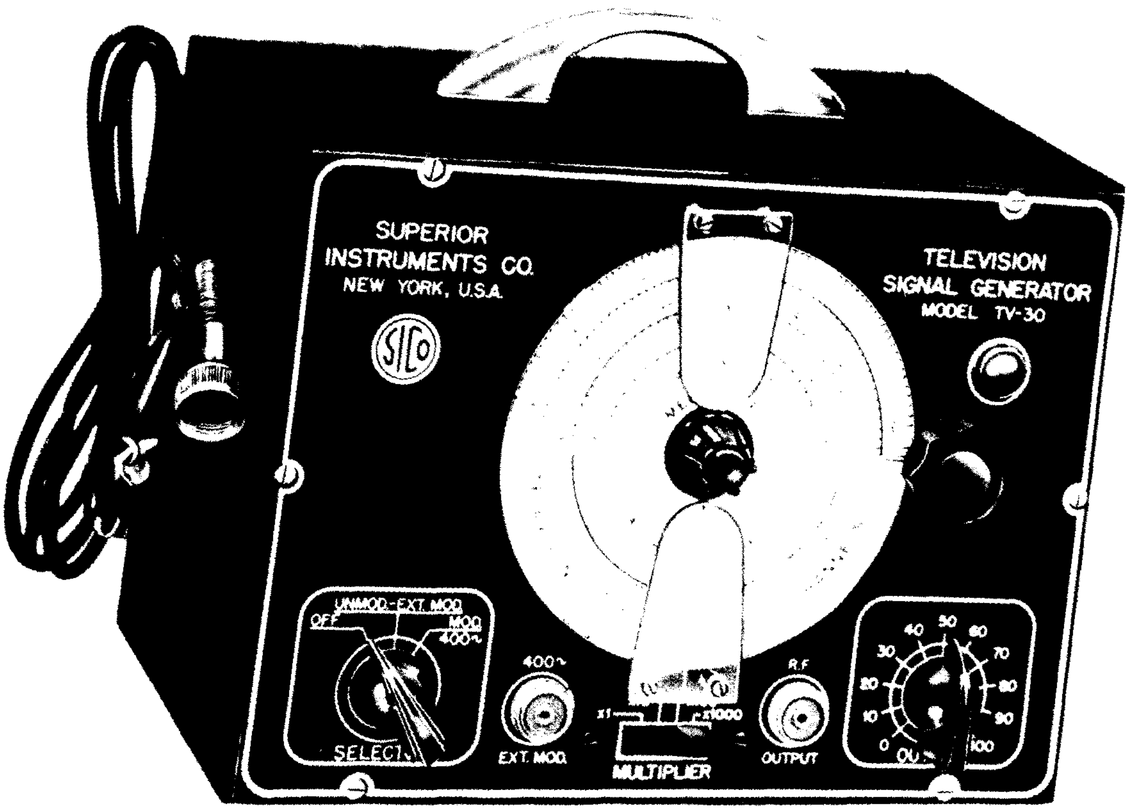


Figure 6. A Signal Generator Especially Designed for TV Service Operation. Its Range of Frequencies Extends from 18 to 250 mc. (Model TV-30, Courtesy of Superior Instrument Co.)

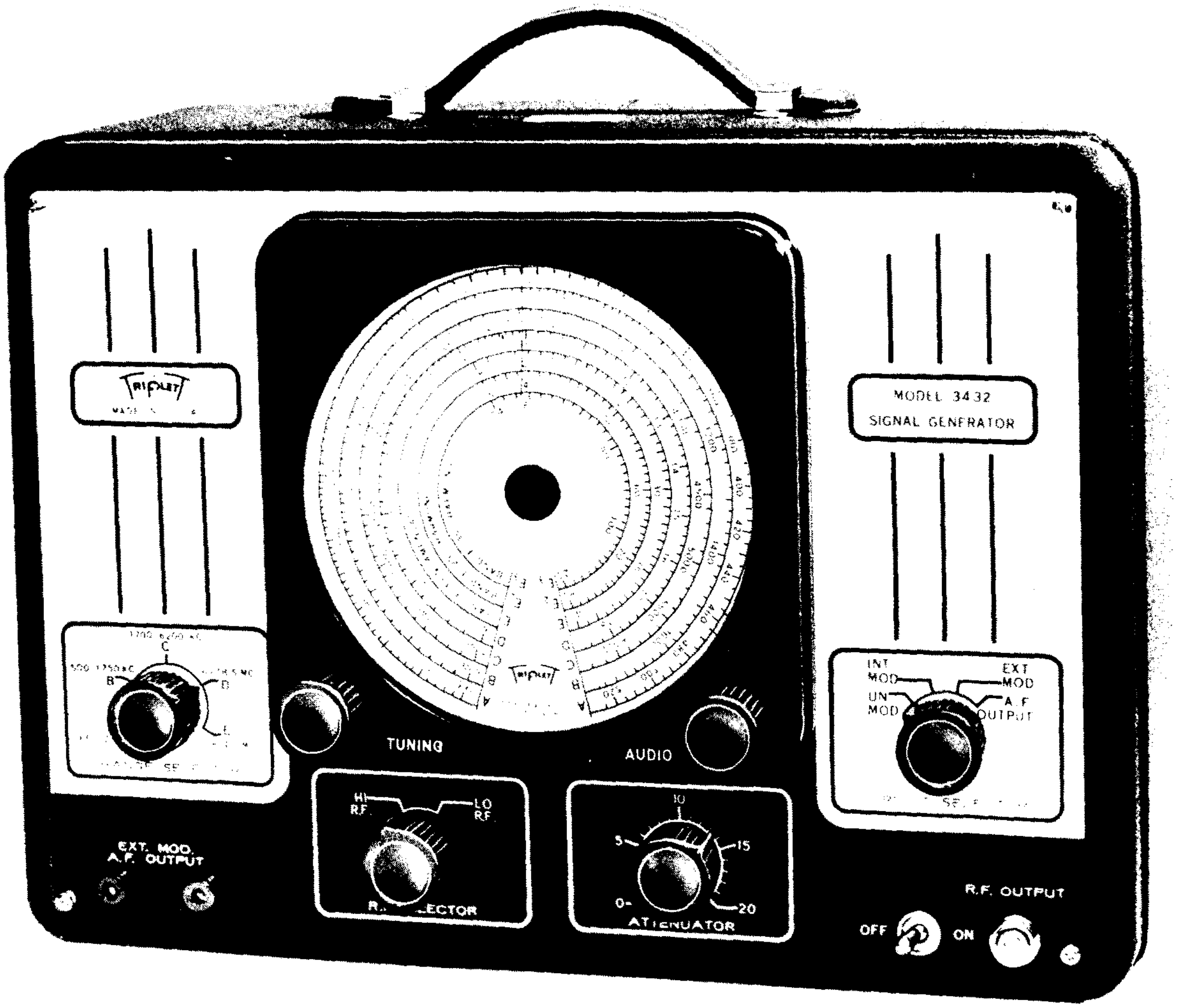


Figure 8A. A Signal Generator Which Will Generate Frequencies up to 120 mc. The Range Selector Markings Extend only to 40 mc. But by Means of Harmonics 120 mc Can Be Obtained. (Model 3432, Courtesy of Triplett Electrical Instrument Co.)


Figure 8B. A Simpson Model 340 Signal Generator. (Courtesy of Simpson Electrical Instrument Co.)

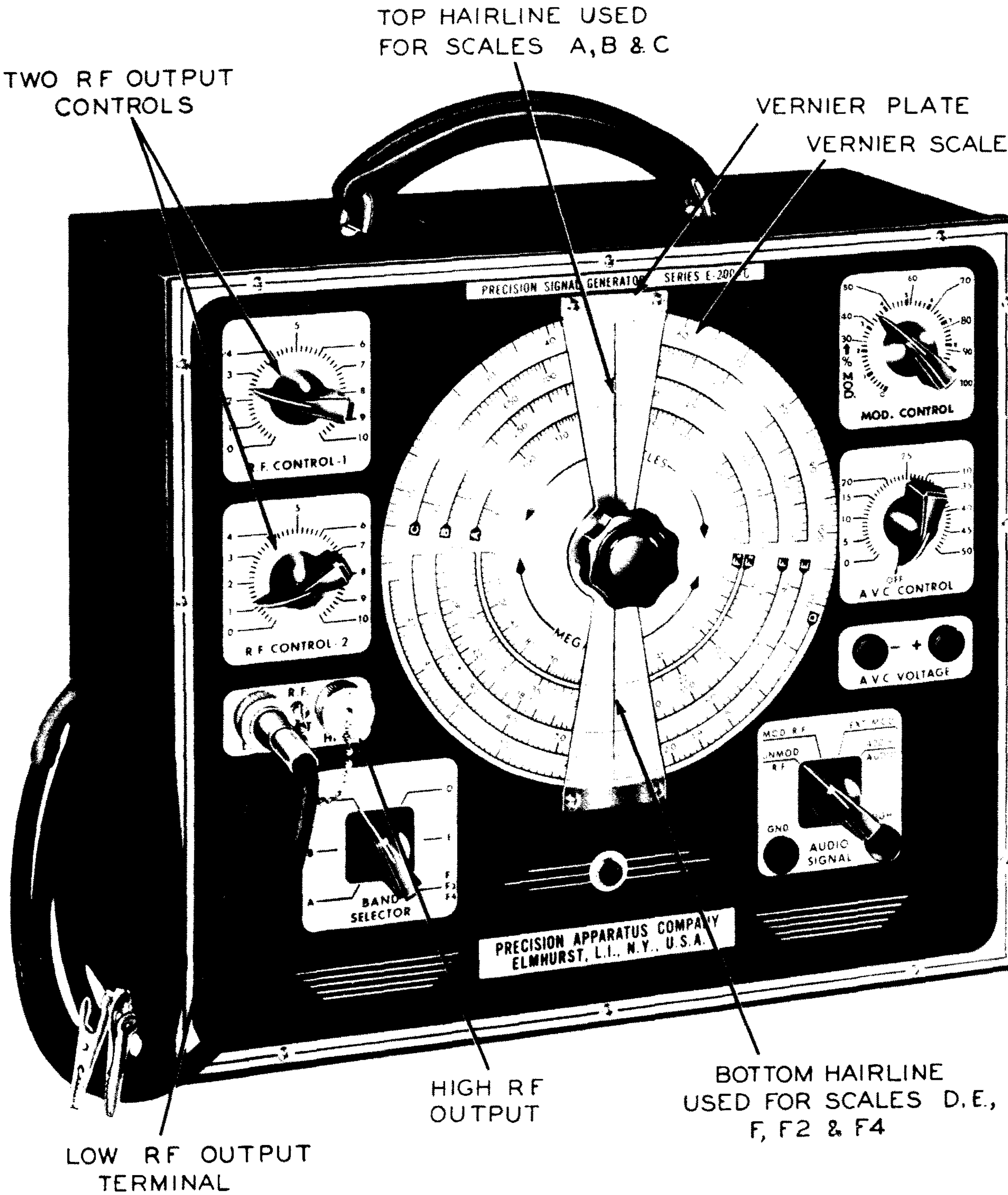


Figure 9. The Precision Model E-200C Signal Generator. The RF Attenuator Controls Are Both Continuously Variable. This Is a Departure from the Previous Instrument. (Courtesy of Precision Apparatus Company, Inc.)

Figure 8B. A Simpson Model 340 Signal Generator. Courtesy of Simpson Electrical Instrument Co.

"Int. Mod" position of the "Circuit Selector" switch refers to the modulation which is applied to the RF signal by the instrument's own audio oscillator. This position is usually referred to as "Mod RF" rather than as "Int. Mod."

## MORE ELABORATE AM GENERATORS

The foregoing analysis has dealt with those controls which are basic to all signal generators without regard to their cost. On more elaborate units additional controls and connector terminals will be found, enabling the instrument to perform a wider variety of jobs.

As an illustration, consider the AM signal generator shown in Figure 9. Some of its controls, such as the "Band Selector," the four position selector switch at the right, and the center dial are immediately recognizable. The RF output connector terminal uses a coaxial cable, while the audio signal is obtained from a pair of pin jacks at the right. In place of the four position "Multiplier" control used in Figure 2, this instrument has a continuously variable potentiometer labeled "RF Control - 1." Then, for any setting of this control, "RF Control - 2" permits the operator to take all of the RF signal offered or any portion of it. In other words, "RF Control - 2" is identical in its function to the "Attenuator" control of the previous signal generators. The RF output signal may be obtained at one of two terminals. One terminal, at the left, is marked "Low;" the other, slightly to the right of it, is marked "High." The RF signal is available at both connectors, except that the amplitude is somewhat lower at the "Low" terminal than at the "High" terminal, due to the presence of a 4,000-ohm resistor in the line leading to the "Low" connector. The manufacturer recommends the use of the "Low" terminal at all times except where the circuits are misaligned and the maximum signal from the generator is required. A screw-cap allows shielding of the unused terminal to minimize signal leakage from this source.

At the opposite (right-hand) side of the instrument panel there is a "Mod Control" with which the intensity of the audio signal can be varied from zero to maximum. It is called a modulation control because by regulating the amplitude of the audio voltage, it will regulate the extent to which the RF carrier is modulated. The greater the degree of modulation, the louder will be the audio output from the circuit under test.

Another feature of this instrument which has not been encountered in previous signal generators is the "AVC Control" and the two pin jacks marked "AVC Voltage" - and +. The purpose of this arrangement is to make available a DC voltage which can be applied to a receiver being aligned. The voltage itself is obtained from the two pin jacks while its amplitude can be varied by means of the "AVC Control" potentiometer located just above it.

Normally, when a set to be aligned possesses AVC, it is necessary to keep the injected signal voltage low in order that the set does not develop sufficient AVC voltage to counteract the variations in output produced when the various circuits are tuned through resonance. It is, after all, the purpose of the AVC network to maintain the output of a receiver steady as the input signal varies. However, when we inject a signal for alignment purposes, we wish to observe just how the output varies as each tuned circuit is adjusted. To the AVC system, the variations produced by alignment have the same effect as varying the strength of the input signal and it reacts accordingly. The result, with the AVC network in operation, is to broaden the response curve of the various tuned circuits, making it difficult (if not impossible) to achieve peak alignment.

The solution to this problem is either (1) to feed in so low a signal that the AVC action will be

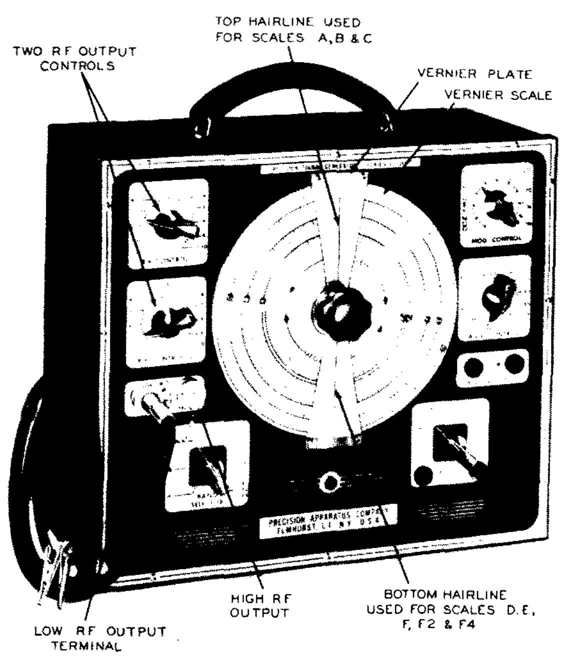


Figure 9. The Precision Model E-200C Signal Generator. The RF Attenuator Controls are Both Continuously Variable. This Is a Departure From the Previous Instrument. Courtesy of Precision Apparatus Co.

small or (2) to disable the AVC system and apply in its place a fixed DC voltage equal in value to the AVC biasing voltage developed with normal signals.

The first method is the simplest to perform and is widely used. Unfortunately, however, the alignment obtained by this method does not correspond exactly with the alignment of the receiver under normal operating conditions and, consequently, the set is not actually adjusted for optimum operation under its normal operating conditions. The difficulty arises from the fact that when the grid bias of a tube changes, so does its input capacity. This capacity, in turn, parallels whatever tuned circuit is connected across the input of the amplifier stage, and as it changes in value, so does the resonant frequency of a tuned circuit. It is thus evident that for peak performance the tuned circuit should be aligned with a grid bias as close to the normal value as possible.

In recognition of these facts, a controllable DC voltage is made available at the front panel of the AM generator shown in Figure 9. The AVC line in the receiver is opened up and the DC voltage from the generator substituted in its place. The voltage is set at the value normally developed by the receiver AVC circuits and the set is aligned. The scale on the AVC control is calibrated to indicate the exact voltage appearing at the two AVC jacks.

SCALE CALIBRATION -

This same generator (Figure 9) has a vernier scale arrangement that differs from the vernier scale previously discussed in connection with the generator of Figure 2. Along the upper circumference of the dial there is a scale marked from 0 to 110. Directly above this scale, in the center of the instrument, is a small vernier plate* with markings from 0 to 10. Through the use of this auxiliary plate, readings on to 0-110 vernier scale can be made accurately to tenths of one division. In other words, between 0 to 110 we can obtain 1100 readable points. And from our previous discussion we know that a vernier scale possessing 1100 readable points is considerably more accurate than a scale possessing only 110 divisions.

The manner in which the vernier scale and the vernier plate above it are utilized can be seen from the following discussion. Let us suppose that the vernier scale is so set up that the number 40 is directly underneath the 0 of the vernier plate. Then it can be seen from Figure 10 that none of the other vernier plate markings are directly over a division on the vernier scale except number 10 on the vernier plate. And if you look closely you will see that this 10 on the vernier plate coincides with 49 on the vernier scale. In other words, 10 vernier plate divisions are exactly equal to 9 vernier scale divisions. It is this particular relationship which enables the vernier plate to divide up each vernier scale division into ten equal parts.

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* Note carefully this distinction between the small vernier plate and the larger vernier scale.

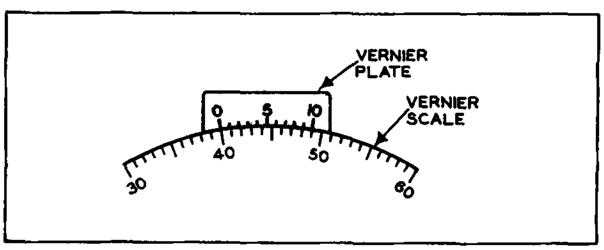



Figure 10. The Reading on the Vernier Scale in its Present Position is 40. This Is True Because the Zero on the Vernier Plate Is Directly Over the 40 on the Vernier Scale.

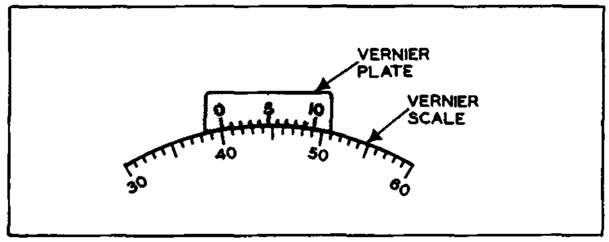



Figure 11. The Vernier Scale Reading Is 40.1.

Now, if you move the large vernier scale slightly to the left until the number 1 division on the vernier plate is directly over one of the vernier scale divisions - as shown in Figure 11 - then you will notice that the 0 of the vernier plate is just slightly beyond the number 40 on the vernier scale below it. To be exact, the vernier scale is now set at 40.1.

Next, move the vernier scale again slightly to the left until the number 2 division of the vernier plate is directly over a division on the vernier scale. If you now examine the point where the 0 of the vernier plate is with relationship to the vernier scale beneath it, you will see that it appears as shown in Figure 12. The 0 of the vernier plate is now at 40.2 on the vernier scale.

It is interesting and important to note from Figures 11, 12, and 13 that one and only one vernier plate division can fully coincide, at one time, with a vernier scale division except for the extremes of zero and 10. In Figure 11 only the number 1 vernier plate division coincides with a scale division beneath it and consequently the decimal to be added to 40 (in this case) is .1. The full reading then becomes 40.1. In Figure 12, only the number 2 vernier plate division coincides with a scale division beneath it and now the decimal to be added to 40 is .2. The full reading then becomes 40.2.

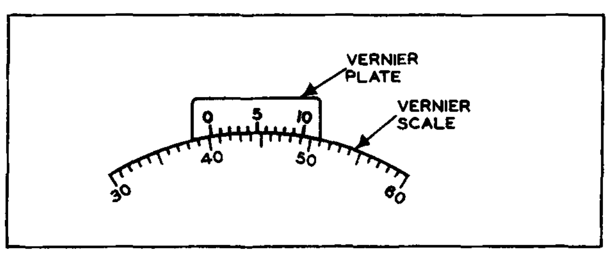



Figure 12. The Vernier Scale Reading Is 40.2 Because Only the Two (2) Mark on the Vernier Plate Is Directly Over a Vernier Scale Division.

We can continue moving the large vernier scale slowly to the left (or counterclockwise) and if you watch the vernier plate you will see the number 3 division coincide with a vernier scale division, then the number 4 vernier plate division, etc., until the zero itself passes directly over the 41 marking of the vernier scale. The dial reading at this point would be 41.

This same procedure can be employed at any point along the 0-110 vernier scale with the result, as stated previously, that we can obtain 1100 readable points. It is necessary only to remember to look along the vernier plate and locate that division which most completely coincides with (runs into) one of the dial divisions directly below it. If this number happens to be the sixth line of the vernier plate, then we add 6/10 to that division on the vernier scale which is to the left of the zero line of the vernier plate. In the above illustrations, the number 40 was the one to which the .6 would be added. However, the vernier plate could be used in conjunction with any division of the vernier scale.

Once you become familiar with the use of the vernier scale on this instrument, you can use it with any frequency scale, A, B, C, D, E, F, F2, and F4. An example will serve to illustrate the method.

Suppose it is desired to obtain an output frequency of 716 kc. Reference to the dial plate reveals that this frequency is on band C. Setting the "Band Selector" switch to band C, we rotate the dial until the 710 kc line is directly underneath the top hairline. The vernier scale would then be read and it might be 38.2. (Note that the vernier scale is not read with reference to the hairline used by scale C but, instead, read with reference to the zero line on the vernier plate. This is important and must be observed, otherwise the vernier plate is useless.)

Scale C would now be turned until the 720 kc line was directly underneath the top hairline. The vernier scale would again be read and its value might be 40.1. This means that for a change of 10 kc on scale C, the vernier scale (with the help of the vernier plate) changed 40.1 - 38.2 or 1.9 divisions.

Dividing the 10 kc into the 1.9 divisions tells us that for each kc at this point on scale C, the vernier moves .19 divisions. Hence for 6 kc, the vernier scale would have to move .19 times 6 or 1.14 divisions. Since the vernier scale was 38.2 at 710 kc, if we add 1.14 to it (for a total of 39.34), the dial would be at 716 kc, which is what we want. Hence the vernier scale would be set to 39.3 and the job is completed. (The 39.34 is converted to 39.3 since we cannot set the vernier scale to any value closer than this. Had the number been 39.35, the setting would have been 39.4.)

The same vernier scale would be used for bands D, E, F, F2, and F4 on the bottom half of the dial plate except that for reading the frequencies on these scales, the bottom hairline is used. Otherwise the procedure is exactly as outlined above. Thus, to obtain an output of 33.7 mc, we would first set scale F2 so that the 33 mc line was underneath the bottom hairline marker. Then the vernier scale reading would be noted. Next, the F2 scale would be moved until the 34 mc mark was directly underneath the hairline and the vernier scale reading again noted. Seven-tenths of the difference between these two vernier readings would lead us, as before, to the correct vernier setting in order to obtain an output frequency of 33.7 mc.

It is also possible to reverse the foregoing procedure to set the dial according to a given frequency. Thus, suppose you know from past experience that when the vernier scale is set at 34.7 and the "Band Selector" switch is set for the "A" band, that the output frequency is 109.95 kc and you wish to set the generator so that this frequency is developed. To reach 34.7 on the vernier scale, move the dial until the 34 falls directly under the zero line of the vernier plate. Then watch the 7th division on the vernier plate as you slowly rotate the dial toward 35. When the 7th line on the vernier plate is directly over one of the dial divisions below it, stop, because at this point the vernier scale reading is 34.7.

## CRYSTAL CONTROLLED AM GENERATOR

The AM generators discussed thus far are typical of the majority of such units which are available to the radio or television serviceman. However, for certain applications, where signals possessing crystal accuracy are desired, or where it is necessary to know the level of the output voltage, a generator such as shown in Figure 13 can be obtained. This particular instrument provides RF signals from 125 kc to 120 mc and from 150 mc to 220 mc, all on fundamentals. In addition, a crystal oscillator is included into which crystals between the ranges of 250 kc and 20 mc may be connected. For use in the mobile band, extending from 152 to 162 mc, special crystals ground to produce a specific frequency are available. All output voltages may be calibrated within the limits of one-half microvolt to 100,000 microvolts by means of a step and a continuously variable microvolt control.

In the center of the front panel there is a large frequency dial calibrated with the frequencies of the 8 bands covered by this instrument. The large dial plate may be rotated rapidly by using the center knob, or much more slowly by using a vernier drive (giving a reduction ratio of approximately 50 to 1) located at the lower edge of the main dial. The vernier drive may be disengaged completely from the main drive by pulling forward and rotating the knob.

Directly above the tuning dial is a meter with which the RF output may be calibrated. In addition, the meter also contains three db calibrated scales permitting it to be used as a 3-range decibel meter. For this purpose the "Meter Circuit Selector" switch is turned to the desired db range and the signal is fed in at the pin jack on the panel labeled "Meter."

Choice of the desired operating frequency is determined by the "Band Selector" switch. The last position of the switch, in the extreme clockwise position, is labeled "Int. Xtal." When the selector switch is in this position, output is obtained from the crystal oscillator. Either an external crystal (between 250 kc and 20 mc) is plugged into the "Ext. Xtal" socket

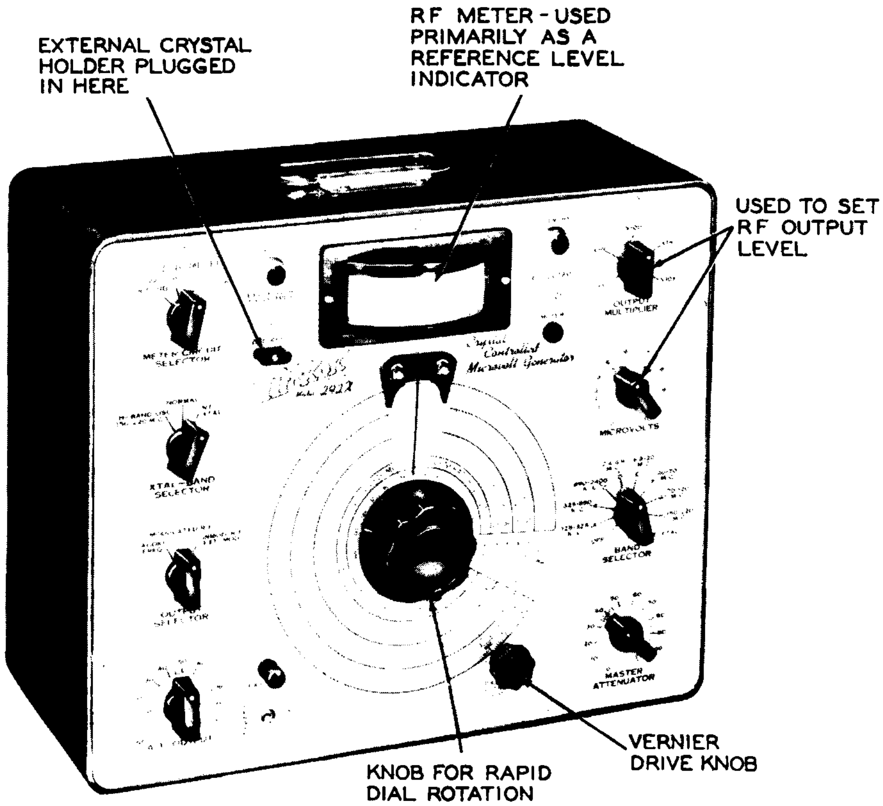



Figure 13. A Crystal-Controlled AM Generator. (Model 292X, Courtesy of Hickok Electrical Instrument Co.)

on the panel of the instrument, or a special crystal unit (for the 152-162 mc band) would be connected internally in the generator.

All RF signal output (including that derived from the crystal oscillator) is taken from the "RF Output" jack. Control of the amplitude of this signal is achieved by three controls: "Master Attenuator," "Microvolts," and "Output Multiplier." The "Master Attenuator" is adjusted until the meter is positioned at the proper reference point on its scale. (This information is contained in the instruction booklet that comes with the instrument.) Having done this, the settings of the "Output Multiplier" and "Microvolts" controls will then give the amplitude of the signal directly. For example, if the "Output Multiplier" control is set in the x 1 position, and the 0-10 dial on the "Microvolts" control is at 6, the generator output will be putting out 6 x 1 or 6 microvolts.

On the left-hand side of the panel, there is an audio output control which regulates the amplitude of the audio voltage obtainable from this instrument. This control also has ganged to it an On-Off switch. An "Output Selector" determines the type of signal made available by the unit, whether it be audio, pure RF, or modulated RF.

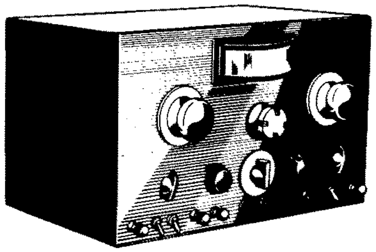
The "Xtal-Band Selector" switch is in the normal position when the generator is required to develop signals having frequencies from 125 kc to 120 mc (bands A through G). For the H-band, 150-220 mc, the switch is turned to the left. And when the crystal oscillator is to be used, the switch is turned to the "Int. Xtal" position.

A standby-operate switch enables the operator to keep the tube filaments lit, but with no B+ voltages applied to the circuits. The instrument is now in the standby position. In the operate position, the B+ voltages are activated and the instrument is ready for use.

The foregoing brief discussion of the instrument shown in Figure 13 will give you some idea of how such a unit would be employed. Actually, to obtain full benefit of all its facilities, the operating instruction manual would be required.

The instruments which have been discussed and illustrated in this section do not represent all such units commercially available. They are merely representative of the type of generators the serviceman is most likely to encounter. However, if the purpose of each of the various controls discussed is understood, then little difficulty should be encountered in dealing with other AM Generators.

Thus far we have not discussed application of the various instruments either in television or television alignment. This will be reserved for later sections, after additional test instruments have been described.



# section three

## Sweep Signal Generators

WHY SWEEP GENERATORS?

For many years, the favorite test instruments of the radio serviceman were the multimeter (VTVM or VOM) and the AM signal generator. With these he could perform any service task required - from the tracking down of a defective component to the complete alignment of a receiver. Other instruments were available but for many service shops these were considered as nice to have but not absolutely essential.

With the advent of FM and television, the serviceman found that his basic instruments now had to be expanded to include a sweep frequency generator and an oscilloscope. Where previously these two additional instruments were useful but not essential, now they assumed an importance equal to that of the multimeter and the AM generator.

To understand the reason for this change we must turn to the newer FM and television circuits and compare them with AM receiver circuitry. Actually, to get at the real reason for the change we should go back to the broadcast station itself. A receiver is nothing more than a device which converts the transmitted signal back to its original form, be it speech, music, or a picture. Hence, the basic design of the receiver is established by the transmitter.

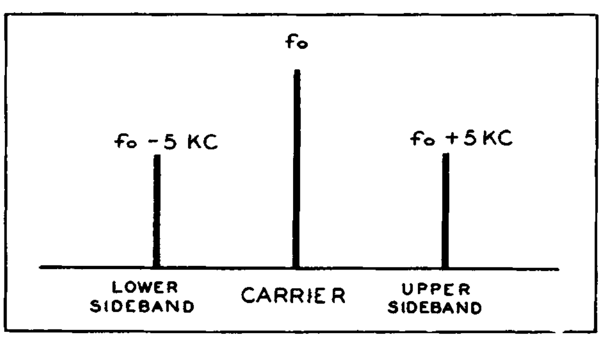



Figure 1. A Signal Which Is Broadcast by an AM Radio Station can Occupy a Maximum Band Width of 10 kc.

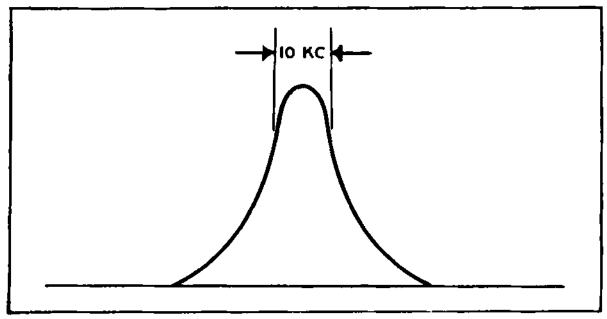



Figure 2. A Typical Response Curve of AM Radio Receiver.

The signal which is broadcast by an AM radio station usually is restricted to a bandwidth of 10 kc.* Half or 5 of this 10 kc are above the station's carrier frequency and half below. See Figure 1. (The same information is contained in both halves (or sidebands) of the signal, and one sideband could be dispensed with. However, to do this would complicate the circuitry of the receiver and the transmitter and is not economically desirable.) The response curve of the receiver's tuned circuits, in order to receive this signal, possesses the shape shown in Figure 2. The received signal is centered about the peak of the curve where it receives the maximum amount of amplification. While the amplification at this point is not absolutely uniform, as it should be, its variation in the immediate vicinity of the peak is sufficiently small to be unimportant in most instances.

The AM broadcast band extends from 550 kc to 1700 kc (approximately) and when we compare 10 kc to these values (550 kc, 1700 kc, or any intermediate frequency), we see that it represents but a small

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* FCC regulations permit use of audio modulation frequencies up to 7.5 kc which results in a maximum bandpass of 15 kc. However, if frequencies this high cause interference to other stations, the range must be reduced, generally down to 5 kc.

portion of the carrier frequency. Because of this and because the response curve is symmetrical, simple tuning circuits can be employed in the receiver. Satisfactory alignment can be carried out by feeding in a single frequency signal and peaking each tuned circuit for maximum response on a VTVM.

In FM receivers, the situation is altered somewhat for several reasons. First, an FM signal occupies a bandwidth of approximately 200 kc which is 20 times wider than that required by an AM signal. Secondly, FM IF amplifiers make use, from time to time, of double-peaked transformers and for optimum results the alignment of these circuits should be carried out visually. Finally, the response of an FM detector possesses a special shape (i.e., an S-curve) and this, too, should be "seen" to determine whether it possesses the proper linearity.

It is possible to align FM receivers using only an AM generator and a VTVM, in spite of the wider bandpass of the circuits, but visual alignment is recommended.

We come now to television receivers and to fully appreciate their requirements, let us examine the signal which is transmitted by the broadcast station. This is shown in Figure 3 for channel No. 2, 54-60 mc. The television signal, complete, consists of a video portion and an audio portion. The video portion extends roughly for 5.25 mc while the audio occupies a bandwidth of slightly less than 50 kc. However, the combination of the two plus the spacing between the video and the audio signals results in a bandpass of 6 mc. Thus, where the RF stages of a radio receiver are required to handle only 10 kc and the RF stages of an FM receiver must deal with 200 kc, the input section of a television receiver finds itself faced with a signal 6 mc wide.

This is still not the full story on television receivers. In the video IF section of the TV receiver, it is important that the proper bandwidth (3.5 mc to 4.0 mc depending upon set design) be maintained and that the video carrier receive approximately half of the maximum amplification.

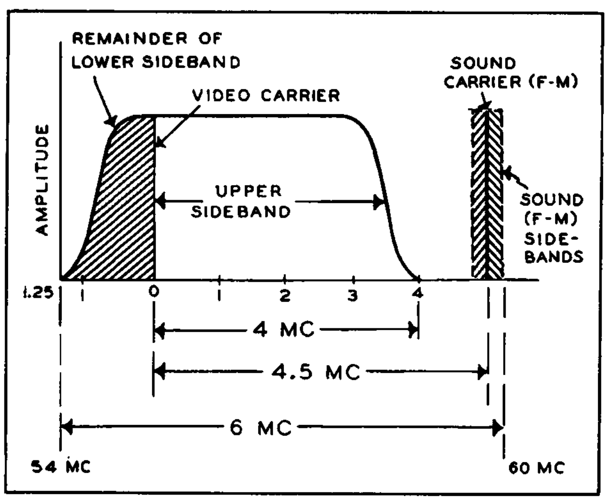


Figure 3. The Video and Sound Signals Broadcast by a Television Station. The 54-60 mc Range Is That Allotted to Channel 2.

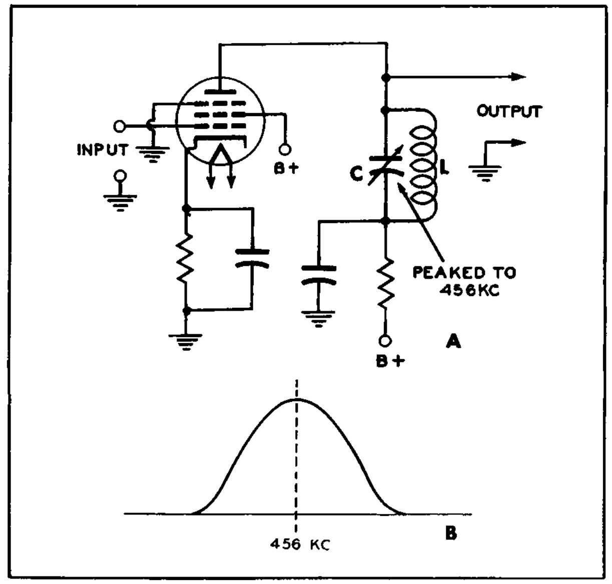


Figure 4. (A) A Simple Tuned Circuit LC, and (B) Its Response Curve.

Furthermore, the sound signal, if it is permitted to pass through the video IF system (as in intercarrier sets), must be restricted to a certain level on the response curve. The criticalness of TV receiver alignment thus becomes evident, and this, coupled with the fact that the response curve is not symmetrical, leads to the necessity for aligning video circuits visually. With visual alignment you obtain a graphic picture of the circuit response as it is now, and by comparing the curve you see with the curve shown in the manufacturer's service manual, you can tell immediately whether or not the system is aligned properly. If additional adjustments are required, these can be made on the spot and their effects will be at once apparent on the scope screen. Once mastered, this method of alignment can be performed in not much more time than it takes to align a radio receiver. This in spite of the fact that the bandpass of TV circuits is fully 400 times broader than radio circuits.

## THE RESPONSE CURVE - WHAT IT MEANS

A simple tuned circuit, consisting of a coil and a capacitor, will respond to different frequencies in the manner shown in Figure 4. Let us assume that this resonant circuit is peaked to 456 kc. This means that if you apply a 456 kc signal to the grid of the tube, the resultant plate current that flows through the tube and the resonant circuit will develop more voltage across the tuned circuit than any other signal of equal input amplitude operating at some other frequency.

Another way of saying the same thing is to state that the impedance of L and C in Figure 4 is maximum at 456 kc. We can actually determine this by taking an AM signal generator and connecting it to the grid of the tube. To check the voltage which is developed across L and C, let us use a vacuum tube voltmeter having a high-frequency probe. We need this probe to measure voltages having frequencies of the order of 456,000-cycles.

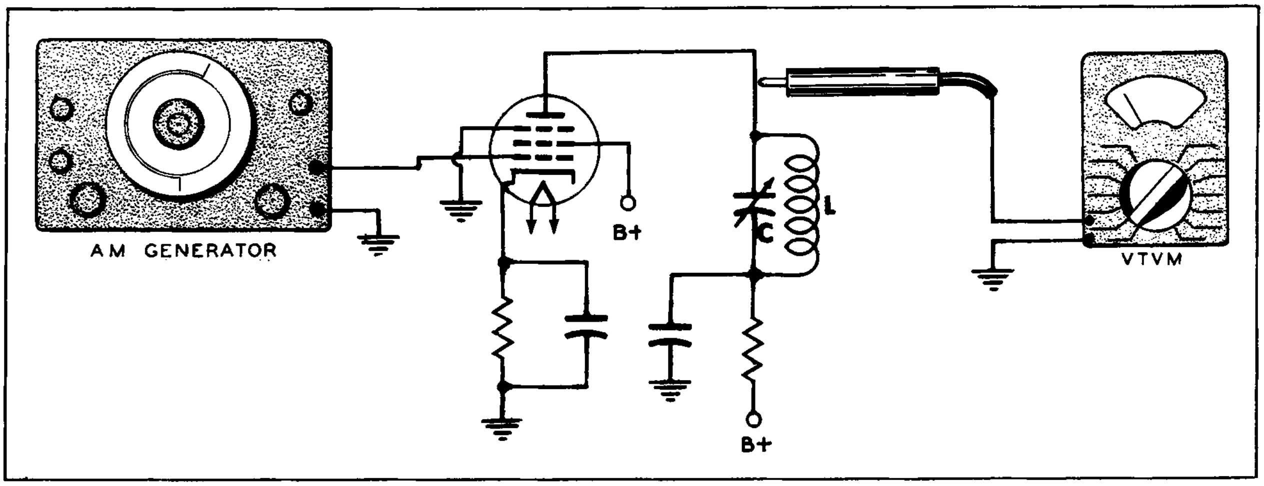


Figure 5. The Equipment Set Up to Obtain the Response Curve of LC.

The set-up of our apparatus is shown in Figure 5. The AM generator feeds its signal into the tube and the resulting plate current flows through the resonant circuit, L and C. We will assume that 1 volt of signal is applied to the tube for each different frequency to which we set the generator. This will cause the same amount of plate current to flow for each different signal. However, we will not develop the same amount of voltage across L and C because its impedance will vary with different frequencies and voltage is equal to impedance x current. Even though the plate current is the same for each applied frequency, the impedance of L and C is not and hence the voltage developed across L and C will vary.

We have now laid the groundwork for the plotting of the response curve of L and C point-to-point or rather, frequency-by-frequency. To start, let us apply a frequency of 456 kc to the grid of the tube and let us say that the VTVM indicates a reading of 1 volt across the LC combination.

Next, alter the frequency of the signal generator to 458 kc. If you look at the VTVM now, you will find that its reading is no longer 1 volt, but something slightly less, say .94 volts. What this means is that the impedance of L and C is not as high at 458 kc as it is at 456 kc.

If we continue to raise the frequency of the signal generator and watch the needle on the VTVM scale, we will find that it will move lower as the frequency rises. Points I through P in the graph of Figure 6 show this. If we return to 456 kc and then decrease the signal frequency gradually down to 446 kc, we will find that again the meter readings will decrease. This decrease is represented by points G through A in the graph of Figure 6.

Thus we find that the maximum voltage is developed across L and C at 456 kc. At all other frequencies above and below this value, the voltage goes down.

Without disturbing the equipment set-up, let us attach a motor drive to the dial of the AM signal generator which will cause the dial to rotate from one end of the scale to the other. This, in turn, will vary the output frequency of the generator.

If the motor turns the dial very slowly, we will actually be able to watch the needle of the VTVM move back and forth in response to the changing voltages. However, just watching the motion of the needle will not help us develop a clear picture in our mind of how the circuit response varies.

A far better method of observing the complete circuit response can be achieved by replacing the VTVM with an oscilloscope. If the voltage that is developed across L and C is applied to the vertical

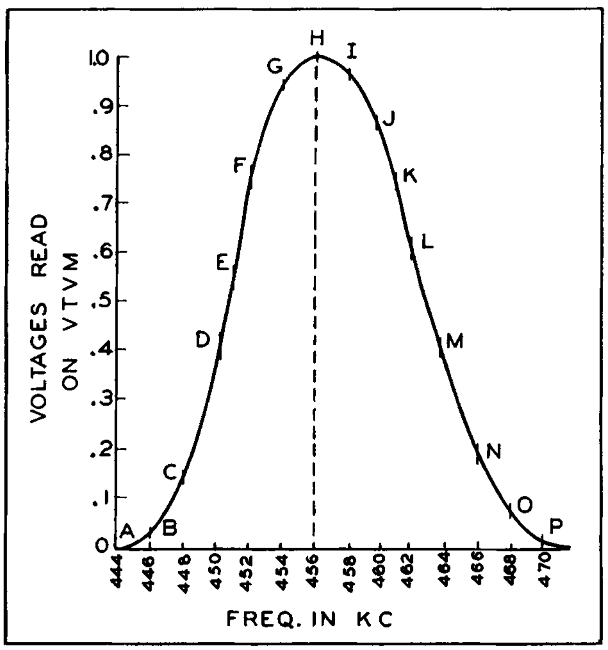


Figure 6. The Response Curve of LC in Figure 5 Obtained Point by Point. (For the Sake of Simplicity, it Is Being Assumed That the Amplification of the Pentode Stage in Figure 5 Is 1.)

input terminals of the oscilloscope, you will see the entire response curve of L and C over the range of frequencies provided by the curve which we plotted so tediously point-by-point in Figure 6.

We could, if we wish, apply the same technique to a whole IF system rather than to a single tuned circuit. Again we would feed the signal in at one end and observe the voltage variation that appeared at the other end. The beauty of such an arrangement is that it permits us to see instantly what effect any one adjustment has on the overall response. Visual alignment is widely employed in television because the wide bandpass of video circuits rules out a point-to-point alignment and because the placement of certain frequencies (such as the sound carrier or the video carrier) must occur at specific points on the response curve. It is only by means of the visual method that these points can be quickly and accurately checked.

## SWEEP GENERATORS

In order to produce a response curve on the screen of the oscilloscope, it was necessary to attach a small motor to the generator dial. This may seem like a rather crude method for continuously varying the generator output frequency, yet the first sweep generators that were manufactured contained just such a motor. However, instead of having the motor turn the outside dial, it was employed to whirl the rotor plates of a variable capacitor at a rate of 60 times a second or more. The rotating capacitor plates caused the generator frequency to vary and in this way frequency variation was achieved. In time more efficient methods were developed, the two now finding widest application being the reactance tube and an electro-mechanical arrangement using a speaker-like assembly.

The reactance tube method of obtaining frequency sweeping, or what is the same thing, frequency modulation is based on the fact that a tube and an appropriate electrical circuit can be made to appear as a capacitance or inductance to an electrical circuit. And, if we apply a 60-cycle voltage to the grid of such a tube, the current through it will vary causing its capacitive (or inductive) effect to change at the same 60-cycle rate. By placing the reactance tube network across the tank circuit of an oscillator, we will produce a frequency variation. In the past, extensive use of this method was made in sweep generators. Within recent years, however, it has been largely superceded in popular-priced instruments by an electro-mechanical method which is less expensive and which can produce wider sweeping ranges, when carefully designed. (Some difficulty is experienced on small frequency sweeps. Also, its moving parts are subject to wear and warping.)

In the electro-mechanical system of varying the frequency of an oscillator, a metal plate is positioned close to an oscillator coil and then the metal plate is alternately moved closer to and away from the coil. This mechanical movement changes the inductance of the oscillator coil and with it the oscillator frequency.

In the EICO sweep generator the oscillator coil consists of a specially designed flat open wound spiral coil embossed on a bakelite base plate. A flat metal membrane, which is mounted on the diaphragm of a speaker, is placed parallel to and very close to this coil. See Figure 7. When the speaker diaphragm is vibrated, the metal membrane moves with it, varying the inductance of the oscillator coil.

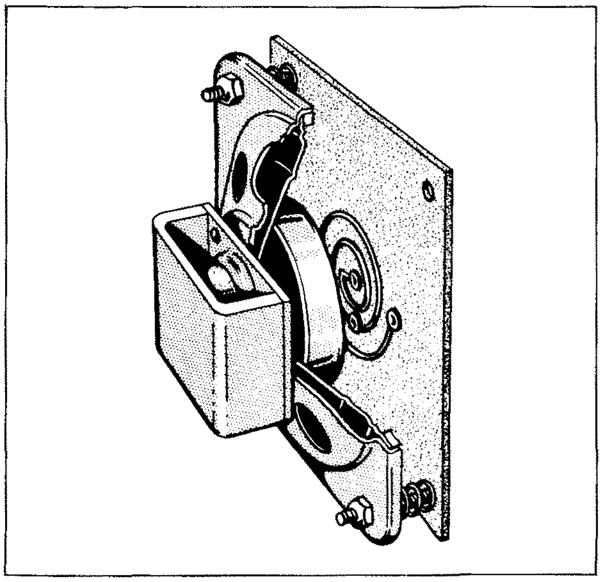

Figure 7. The Speaker-mounted Movable Membrane and Flat Oscillator Coil by Means of Which Frequency Sweeping Is Achieved.

The extent of the frequency sweep is determined by the amplitude of the diaphragm vibration. This, in turn, depends upon the voltage applied to the speaker coil. The sweep rate is determined by the frequency of the voltage applied to the speaker voice coil and this is usually the same as the power line frequency (i.e., 60 cycles). Also, because use is made of the power line, the 60-cycle rate of variation is a sinusoidal one.

Now, so far as the operation of the sweep generator is concerned, it makes little difference whether the frequency varies back and forth sinusoidally or in some other fashion. However, sweep generators are invariably employed with oscilloscopes and to an oscilloscope the manner in which the frequency sweeps back and forth in the generator is most important. Because of this, it may be desirable to review briefly the frequency variation in a sweep generator to see how this will affect the oscilloscope.

## SINE WAVES

Almost everyone who has had any contact at all with radio is more or less familiar with a sine wave. See Figure 8. For half of its cycle (ABCDE) the wave is positive and the current in the circuit to which this voltage is applied will flow in one direction. During the second half of its cycle (EFGHI), the voltage polarity reverses and with it, the current direction.

In examining this wave more closely, we find that it starts from zero (at point A) and increases in amplitude until a peak is reached at point C. Then it

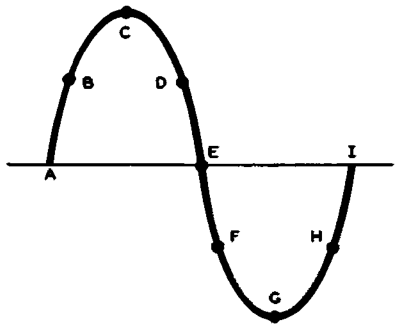


Figure 8. A Sine Wave.

decreases in a similar manner until, at point E, it is back to zero again. From point E to point G the voltage rises again, this time in the negative direction until point G is reached. This is the negative peak. Beyond G the wave drops back to zero, reaching this value at I.

If we apply this sine wave of voltage to a sweep generator, the output frequency will vary in a similar manner. See Figure 9. For the sake of this discussion, let us assume that at point A, when the sine wave voltage is zero, the generator is putting out a frequency of 25 mc. Then, as the sine voltage rises to its peak (point C), the sweep generator output frequency rises to a value of 27 mc. From C to E, as the sine voltage decreases, the frequency of the sweep generator follows suit, dropping down from 27 mc to 25 mc.

From E to G, the sine wave dips into the negative half cycle and the output frequency of the sweep generator drops, in step, from 25 mc to 23 mc. Point G is the lowest point of the sine wave and from here to point I, the voltage returns to zero. In step with this, the frequency output of the generator rises from 23 mc to 25 mc. This sequence is repeated cycle after cycle for as long as the equipment is in use.

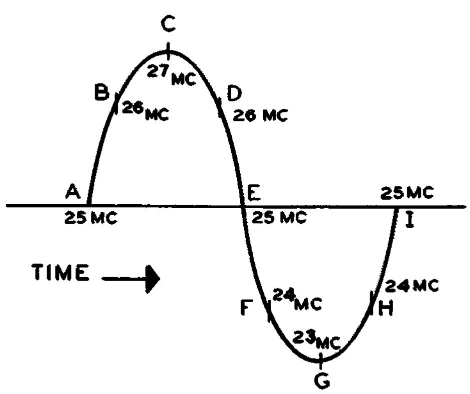


Figure 9. The Sinusoidal Change in Output Frequency of a Sweep Generator in Which the Modulator Is Driven by a 60-cycle Voltage. (Whether the Output Frequencies Increase on the Positive 1/2 Cycle, as Shown, Depends on the AC Connections to the Voice Coil of the Speaker-driving Unit.)

Looking at Figure 9, we see that the center frequency of the sweep generator is 25 mc. During one half cycle it rises to 27 mc and during the following half cycle it decreases to 23 mc. The sweeping range of the generator is thus from 23 mc to 27 mc, or, stated somewhat differently, it is 25 mc ±2mc.

By changing the frequency of the sweep generator, we can raise or lower the center output frequency from 25 mc to any other frequency which the unit is capable of developing. In fact, we will soon see sweep generators whose ranges extend from 500 kc to 220 mc and more. Also, at many points, a sweeping range of as much as 15 mc is available. However, for simplicity of discussion, we will use the 25 mc ±2 mc mentioned above.

There is still another property of the sine wave variation which has not been discussed and this concerns the rate at which the frequency varies as it goes through one complete cycle. Let us return to Figures 8 and 9 and consider the positive half cycle ABCDE. The wave rises from A to B fairly rapidly. We know this because the slope of the wave here is steep. From B to C and from C to D the wave amplitude changes much more slowly because to go from B to D takes four times as long as it does to go from A to B. See Figure 10.

From D to E the rate of change again becomes quite rapid because of the steep slope of the wave within this region. The rapid change is maintained until point F is reached.

From F to G to H the rate of change again slows down; in fact it takes just as long to cover this distance as it did to go from B to D and this should be so because FGH occupies the same position on the negative half of the sine wave as BCD on the positive half.

The final secion of the curve, H to I, requires as much time to complete as it did going from A to B.

This uneven rate of change throughout the sine wave cycle reflects itself in an uneven variation in frequency from the output of the sweep generator. Thus, in Figure 9, the output signal starts from 25 mc and rises fairly rapidly to 26 mc. From 26 to 27 mc,

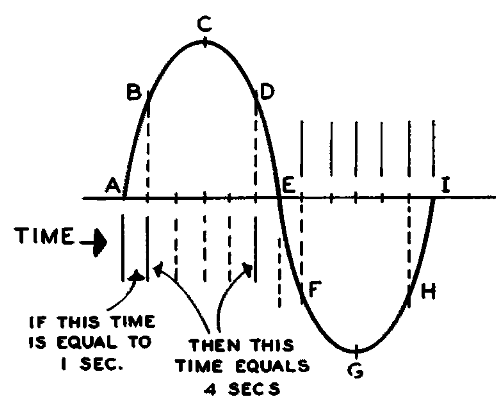


Figure 10. The Rate of Change Varies at Different Points on a Sine Wave.

the rate of change slows down and so the generator needs more time to cover the 1 mc from 26 to 27 mc than it did to go from 25 to 26 mc.

The return from 27 to 26 mc requires as much time as it did in going from 26 to 27 mc. However, once past point D (26 mc), the generator output rate increases and the swing through 26 to 24 mc is accomplished in short order. From points F to G to H (24 to 23 to 24 mc) a slowing down occurs again, just as it did at the positive peak. Finally, from H to I, or from 24 to 25 mc, the rate of change increases again.*

SWEEP GENERATOR AND OSCILLOSCOPE

With this understanding of how the frequency of the signal output of a sweep generator acts when it is varied in a sinusoidal manner, let us take this signal and apply it to an IF amplifier. The signal is fed in at the input end of the amplifier or system and the output is obtained at the other end and applied to the vertical input terminals of the oscilloscope. A detector is required between the output of the amplifier and the oscilloscope because the frequencies involved (24-26 mc) are much too high to pass through the vertical amplifiers of the oscilloscope and also because we are not really interested in the frequencies themselves but rather what happens to their amplitude as they pass through the circuit under test.

A response curve of a circuit, such as the curve shown in Figure 11, tells us which frequencies the circuit allows to pass and which frequencies it attenuates. Thus, 25 mc is permitted to pass through freely while 23 mc and 27 mc are greatly attenuated. Note, too, that there are other frequencies, such as 24 and 26 mc here, which although they pass through the system, do not receive as much amplification as the 25 mc signal.

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* While the frequencies as shown in Figure 9 may not occur at precisely the points shown, the rate of change as indicated in the discussion does take place and this is actually what the discussion is trying to emphasize.

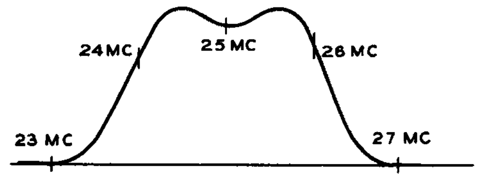


Figure 11. A Response Curve. See Text.

Now, assuming that the signals applied to the system to be tested are all equal in amplitude, we can see from Figure 11 that when they come out at the other end of the system, the 25 mc signal will be stronger than either the 23 or 27 mc signals. It is this change in amplitude that we are interested in showing on the scope screen.

When we pass a set of signals through a system and the amplitude of the signals change, then we can rightfully say that the signals have been amplitude modulated. And to obtain this modulation, or variation in signal amplitude, we pass the output signal through an AM detector.

This is the reason for inserting a detector between the amplifier and the oscilloscope as shown in Figure 12. The detector "skims off" the amplitude variation introduced by the system through which the signal has passed and then feeds this to the oscilloscope producing the response curve seen on the screen.

We have now progressed to the point where we can consider a statement made earlier in the discussion to the effect that the manner in which frequency is swept back and forth in the generator is important to the oscilloscope which must develop the response pattern.

In an oscilloscope, the electron beam starts at the left-hand side of the screen and moves toward the right at a constant rate. When it reaches the extreme right-hand side, it is rapidly returned to the extreme left-hand side from which point the same cycle of events recur. As the beam moves across the fluore-

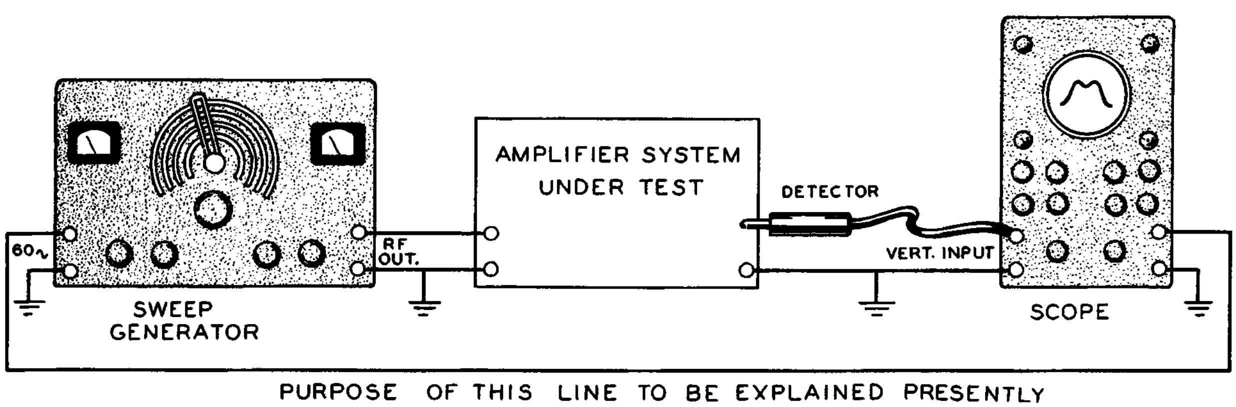


Figure 12. How to Connect Sweep Generators and Oscilloscopes to an Amplifier System to Obtain Its Response Curve. See Text.

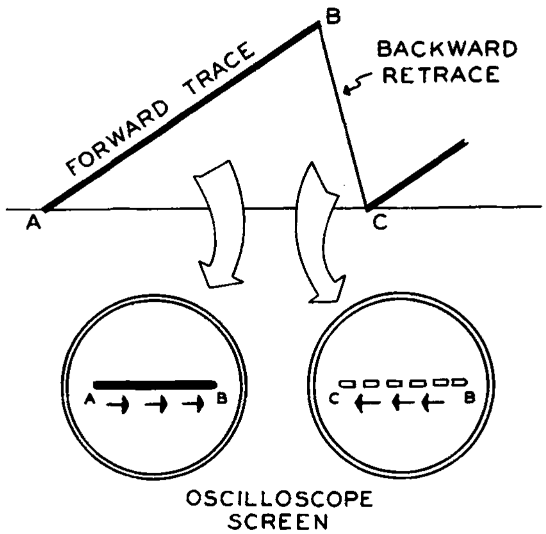


Figure 13. The Manner in Which the Beam on an Oscilloscope Screen Traces and Retraces.

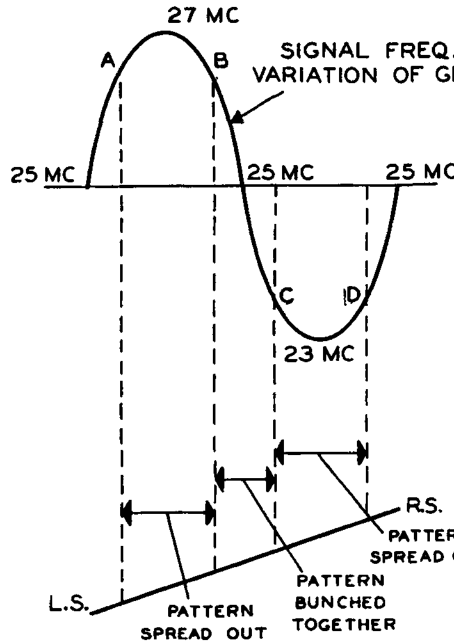


Figure 14. A Sinusoidal Frequency Variation, Coupled With a Linear Saw-tooth Beam Motion, Will Produce a Pattern Bunched in the Middle and Stretched Out at the Ends.

scent screen of the oscilloscope tube, it leaves a bright green trace. If the forward motion of the beam recurs often enough - say 40 times or more a second- the brightness of the line will remain steady, without flickering.

This is the normal operation of an oscilloscope and to obtain the type of motion described, a saw-tooth deflection voltage is applied to the horizontal deflection plates. See Figure 13. From A to B the voltage rises slowly but steadily, forcing the beam to move across the screen from left to right. From B to C, the voltage drops sharply, producing the rapid retrace of the beam from right to left on the screen.

The saw-tooth wave of Figure 13 is the type of voltage ordinarily employed in the scope to move the beam back and forth across the screen. In view of this, it would only seem natural to retain this type of voltage when using the oscilloscope to depict the response curve such as we have in Figure 11. But if this procedure is followed, certain complications arise, as we shall soon see.

To start, let us develop a response pattern on the oscilloscope using a sweep generator having a sinusoidal frequency and an oscilloscope in which the beam is swung across the screen by a saw-tooth voltage. In the oscilloscope, the use of a saw-tooth driving voltage means that the beam moves evenly and steadily from left to right across the screen. On the other hand, the frequency variation of the signal from the sweep generator is an uneven process, as we have noted. At times the frequency is changing slowly; at other times it is shifting rapidly. Thus, when we combine a sinusoidally changing frequency with a linearly (or steadily) moving electron beam we will derive a pattern in which the frequencies are not evenly spaced along the screen. When the signal frequency changes slowly, the curve will be stretched out; when the frequency is changing rapidly, the curve will be bunched together. Remember that the beam is moving along at a steady pace. If, during any given time, say 1 second, the frequency of the generator is changing rapidly, then that portion of the traced-out response curve will occupy just as much space on the oscilloscope screen as a smaller frequency change occuring slowly. †

In Figure 14, the sinusoidal frequency variation (from the signal generator) is compared to the steady movement of the electron beam. From point B to point C of the sine curve there is a much faster change than from A to B or from C to D. The visual result is a pattern that is bunched together in the middle and spread out at the ends.

The only solution to this problem is to employ the same sinusoidal driving voltage for the oscilloscope that is used in the sweep generator. And in order to accomplish this, there is available on the front panel of all sinusoidal sweep generators a terminal post from which we can obtain sufficient 60 -cycle voltage for the oscilloscope. The internal saw-tooth generator of the oscilloscope is disabled* and the 60 cycle sine wave voltage from the sweep generator is applied in its place to the horizontal input terminals of the oscilloscope. With this substitution, the motion of the scope scanning beam changes, as the following discussion will reveal.

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† See Chapter 3 of "Television & FM Reciver Servicing" by the same author. Published by D. Van Nostrand Co., Inc., 250 4th Avenue, New York 3, New York.

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* Or otherwise prevented from reaching the horizontal deflection plates of the cathode-ray tube.

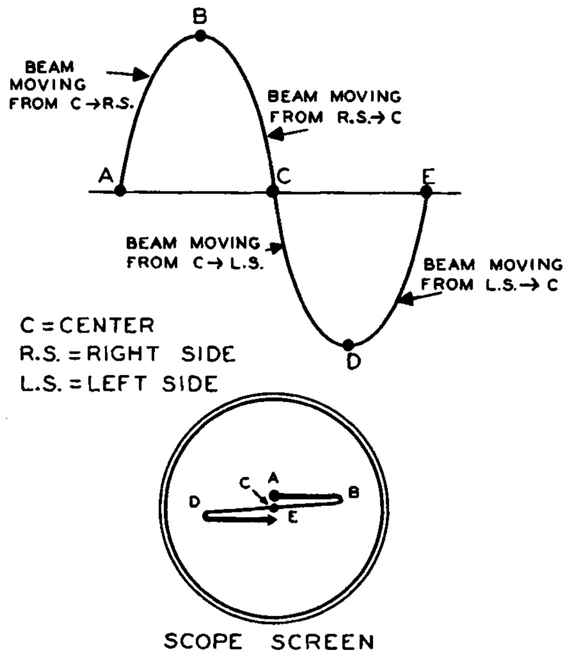


Figure 15. The Motion of the Electron Beam in the Oscilloscope When it Is Being Driven by a Sine Voltage.

Consider the sine wave shown in Figure 15. At point A, when the applied voltage is zero, the electron beam is at the center of the screen. From A to B, the beam is deflected to the right, traveling from the center of the screen to the far right-hand edge which it reaches when the applied voltage reaches point B. At B it pauses momentarily, then slowly starts to retrace to the left. The closer it gets to the center of the screen, the faster it travels until, at point C, it is at the center (where it was at point A) and now traveling as fast as it ever will throughout the entire sine wave cycle.

Once past the center, the beam begins to slow down (although still moving to the left). This slowdown continues until point D, when the beam is as far to the left as it will go. There is a momentary pause and then the beam starts moving back toward the center again until, at point E, it is at the center and traveling fast toward the right.

This is one complete sine wave deflection cycle. Comparing this motion with that produced by a saw-tooth wave, we see that with sine wave deflection the beam does not have a special retrace time. We could, if we wished, call the left-to-right motion the tracing motion, and the right-to-left travel the retrace motion. But in both directions the beam is sometimes traveling fast, sometimes slow. Under the influence of a saw-tooth wave, the slower motion is toward the right and the faster motion (retrace) is toward the left.

By combining a sinusoidal sweep generator with a sinusoidally deflected scanning beam we will obtain a response pattern in which the frequency is evenly spaced. This is true because when the rate of frequency change in the generator increases, the beam will be traveling faster across the oscilloscope screen. And when the frequency variation slows down, so will the rate of beam travel. The two will therefore be in step with each other and the pattern produced will neither be compressed or spread out, if the circuits are correctly aligned.

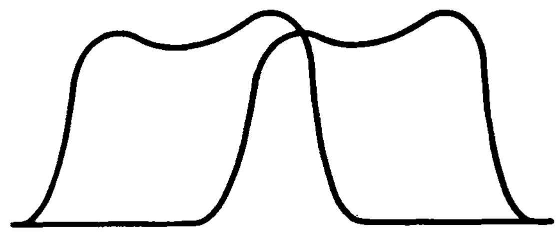

Figure 16. A Double Pattern On Figure 10 Due to Improper Phase Control Setting.

## DOUBLE PATTERNS

The pattern in Figure 11 is the one that should be obtained on the screen when its circuit (Figure 12) is being checked. It may frequently happen, however, that more than one pattern is obtained. See Figure 16. Let us see why this occurs and what can be done to correct it.

The pattern in Figure 11 was obtained when the 60-cycle sine wave voltage modulating the generator was exactly in phase with the 60-cycle voltage driving the beam in the oscilloscope. Now, although the voltages for the beam deflection and the sweep generator oscillators are taken from the same source, it does not necessarily follow that these voltages are still in phase with each other by the time they actually reach the beam or the modulating circuit. The voltages are transferred from point to point by means of capacitors and resistors and such networks will alter the phase of a voltage. Consequently, it becomes evident that some form of phase control is needed at the signal generator. With this control, the phase of one of the sine-wave voltages is shifted until, at their point of application, both are in phase. Visually, the serviceman adjusts the phase control until both patterns on the screen blend into one.

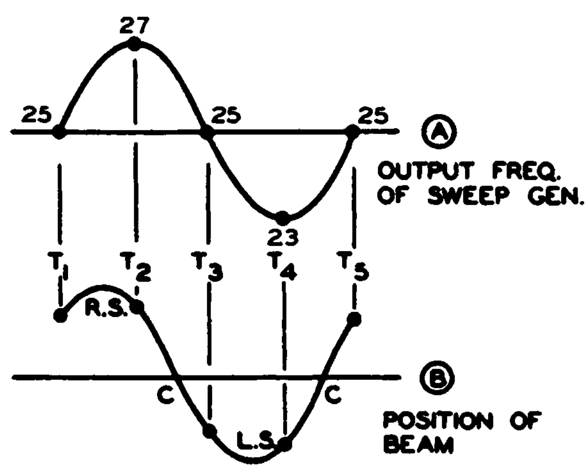


Figure 17. To Illustrate Why Double Patterns are Obtained on the Screen.

It may be instructive to determine why a phase difference between the two driving 60-cycle voltage causes the appearance of more than one pattern: We will assume that the sine wave voltage shown in Figure 17A represents the frequency variation of the signal generator. The voltage driving the electron beam in the oscilloscope is shown in Figure 17B. The voltages, it can be seen, are out of phase by approximately 45$^{\circ}$. Both voltages are keyed to each other to make it simpler to refer to specific points in the discussion and to the double pattern of Figure 18.

At the start, time T1, the output voltage of the signal generator is at 25 mc. At this moment the beam is halfway between the center of the screen and the extreme right side. This is due to the positive voltage which is being applied to the scope deflection system at this time. If the deflection voltage were in phase with the modulating voltage, the beam would be in the center of the screen. Since curve B leads curve A by 45$^{\circ}$, the beam is displaced to the right.

At T1 the response of the circuit to 25 mc is such (see Figure 11) as to place the beam at the point noted in Figure 18.

From time T1 to time T2, the deflection voltage will drive the electron beam from its starting position to the extreme right side of the screen and then about halfway back toward the center. During this same interval the signal generator frequency will change from 25 to 27 mc. Note this portion of the response curve in Figures 11 and 18. In Figure 18, a portion of the response curve is bent back on itself because the beam moves to the right-hand side of the screen and then halfway back to the center again in the time interval from T1 to T2.

From T2 to T3, the electron beam travels from its last position (T2) to a point halfway between the center of the screen and the left-hand side of the screen. During this time the signal generator frequency will go from 27 to 25 mc. The beam is traveling fairly fast between T2 and T3 whereas the generator is changing more slowly. As a result the visible curve on the scope screen is "stretched out" or elongated more than it is in Figure 10.

We may pause for a moment and note again that on the steep slopes between the positive and negative peaks of a sine curve the voltage is changing quite rapidly whereas at or near the peaks it is changing slowly. In fact at the peak it stops momentarily. This explains the stretching out of the curve.

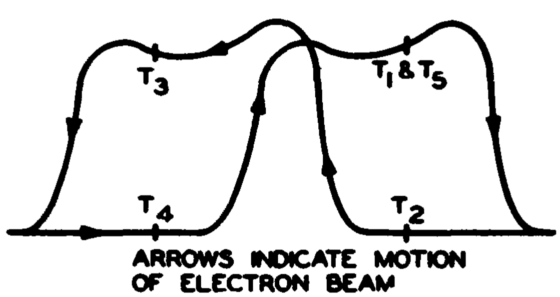


Figure 18. The Arrows Indicate the Path of the Electron Beam. T1 Through T5 are Keyed to Figure 17.

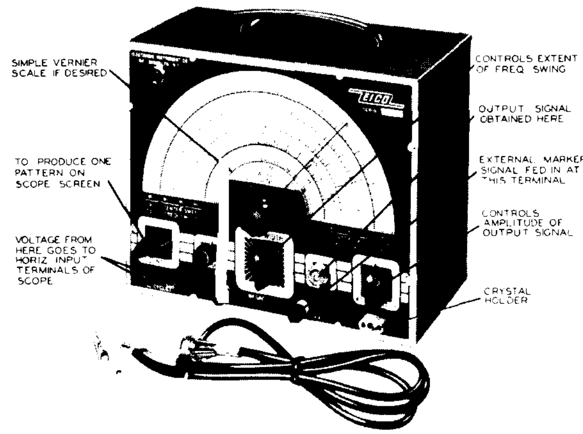


Figure 19. A Commercial Sweep Generator Which is Available in Kit Form. Courtesy of Eico.

Between T3 and T4 the beam moves fairly slowly from its last position (T3) to the left-hand side of the screen and then back to a point halfway to the center of the screen. During the same interval the generator frequency is changing from 25 mc to 24 mc.

Finally, in the time interval T4 to T5 the pattern is completed.

The overall result is two similarly shaped response curves slightly displaced. By adjusting the phase control the curves can be brought together until only one is visible.

## COMMERCIAL SWEEP GENERATORS *

There are a variety of sweep generators available to the serviceman ranging in price from $34.95 for a kit to well up in the hundreds of dollars for elaborately designed instruments capable of performing a variety of jobs.

An example of what is available in the kit classification is the instrument shown in Figure 19. It is designed to cover, roughly, a range of frequencies from 500 kc (.5 mc) to 227 mc. On the main tuning dial, the bottom scale is a reference scale marked from 0 to 100 linearily. (This might to some extent be employed as a vernier scale although it would obviously be a very rough vernier scale. As we shall see in a later section, precise calibration of the scale of a sweep generator is not as important as the precise calibration of the dial of an AM generator.)

The next three scales marked "Center Sweep Frequencies" and calibrated from 0-60, 0-120, and 168-227 are the center frequencies about which the sweeping takes place. For example, if the main dial pointer is set at 100 megacycles and the "Sweep-width" control is set at a maximum sweep width of

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* As the reader has undoubtedly guessed by now, the words sweep generator and frequency modulated or FM generator have the same meaning.

30 megacycles, the output frequency will sweep back and forth from 85 to 115 megacycles.

The uppermost scale is for an internal oscillator operating from 54 to 114 mc. In this particular instrument this scale is used in calibrating the instrument and also is useful as a source of standard RF signals in the above range.

The reader will notice that all output ranges are available without bandswitching. How this can be accomplished will become evident when the description of the circuit is given later.

The various controls found on this instrument are as follows:

"SWEEPWIDTH" CONTROL: This control varies the amount of sweepwidth about the center frequency indicated by the main tuning dial pointer. It is calibrated linearly from 0 to 30 megacycles and intermediate points give an approximate indication of the actual amount of sweep.

"RF ATTENUATOR:" This control determines the strength of the RF signals delivered to the RF output connector.

"RF OUTPUT" CONNECTOR: The coaxial cable supplied with the instrument is attached to this connector and the output fed to the FM or TV receiver being aligned.

"60 CYCLE" OUTPUT TIP JACKS: These tip jacks are used to supply 60-cycle voltages to the horizontal deflection amplifiers of the oscilloscope used. Connect two test leads from these tip jacks to the horizontal binding posts on the oscilloscope or use a shielded cable.

"PHASING CONTROL:" This control varies the phase of the 60-cycle AC supplied through the tip jacks. Always adjust this control to obtain a single trace on the oscilloscope screen.

When turned to the extreme counter-clockwise position, the sweep generator is turned off.

"CRYSTAL" SOCKET: External crystals are inserted in this socket to obtain marker points on the trace being observed for calibration purposes and for use as a crystal controlled RF signal for external applications. When a crystal is inserted, it is connected in a oscillator circuit which oscillates at the crystal frequency, also producing harmonics such as the 2nd, 3rd, 4th, 5th, 6th, etc. For example, a 5 mc crystal will produce harmonics at 10 mc, 15 mc, 20 mc, 25 mc, 30 mc, etc.

"CRYSTAL AMPLITUDE" CONTROL: This control varies the output of the crystal marker oscillator. It should be adjusted for minimum observable output so that it has the least effect on the pattern observed. The output of the crystal marker oscillator is connected so that its output together with that of the sweep generator is varied simultaneously with the "RF Attenuator" control.

"EXT. MARKER" BINDING POSTS: These binding posts allow injection of an external marker, such as a standard AM signal generator. The ground lead of the external AM signal generator is connected to the binding post marked "GND" while the high side is connected to that marked "Ext. Marker". The output of the external marker can be varied simultaneously with the sweep generator output using the "RF Attenuator".

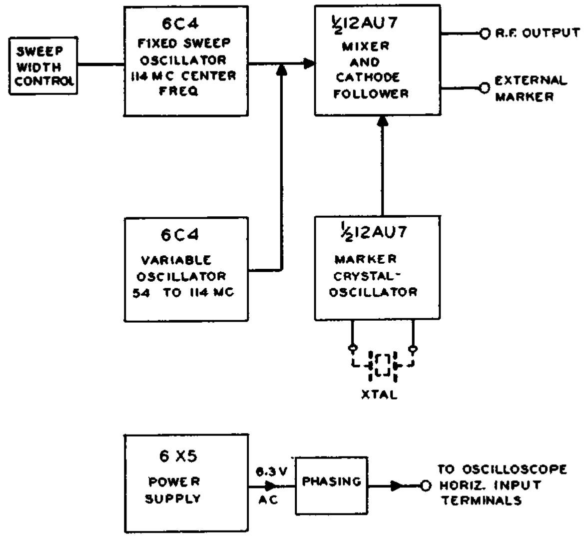


Figure 20. A Block Diagram of the Sweep Generator Shown in Figure 19.

## CIRCUIT DESCRIPTION

A block diagram of the system used in the EICO Model 360 sweep signal generator is shown in Figure 20. An oscillator with a fixed center frequency of 114 megacycles is frequency modulated to a maximum sweepwidth of 30 megacycles, sweeping this fixed oscillator back and forth from 99 to 129 megacycles. The amount of frequency modulation is controlled by the "Sweepwidth" control setting.

From the block diagram it is seen that the output of the fixed sweep oscillator is heterodyned or mixed with that of a variable oscillator. The latter variable oscillator is a standard Hartley oscillator having a frequency range of 54 to 114 mc which is controlled by the main tuning dial setting. The resultant beats or heterodynes between these two oscillators (one fixed and frequency modulated and the other variable) provide the frequency ranges of the instrument. For example, the difference frequencies between the 114 mc fixed swept oscillator and the 54-114 mc variable oscillator provide the frequency range of 60 to 0 mc. The sum frequencies of the two oscillators provide the range of 168 to 228 mc. The second harmonic of the difference frequencies gives the range 120 to 0 mc.

The output of these two oscillators is "mixed" in the mixer tube which also serves as a cathode follower output tube. This tube is 1/2 of a 12AU7 dual triode, the other half being used in a Pierce crystal oscillator circuit. A schematic diagram of the instrument is shown in Figure 21.

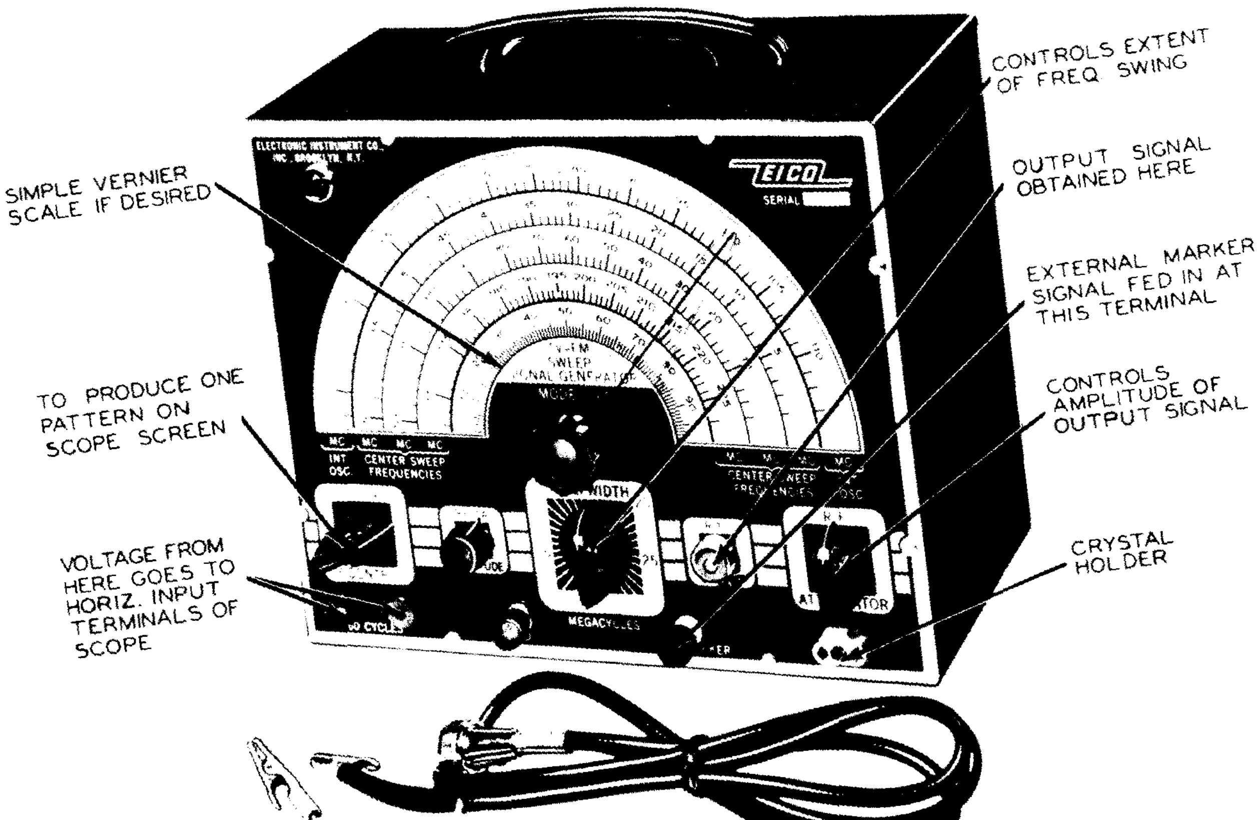


Figure 19. A Commercial Sweep Generator Which Is Available in Kit Form. (Model 360, Courtesy of Eico.)


Figure 22. A Precision Model E400 Sweep Generator. (Courtesy of Precision Apparatus Company, Inc.)

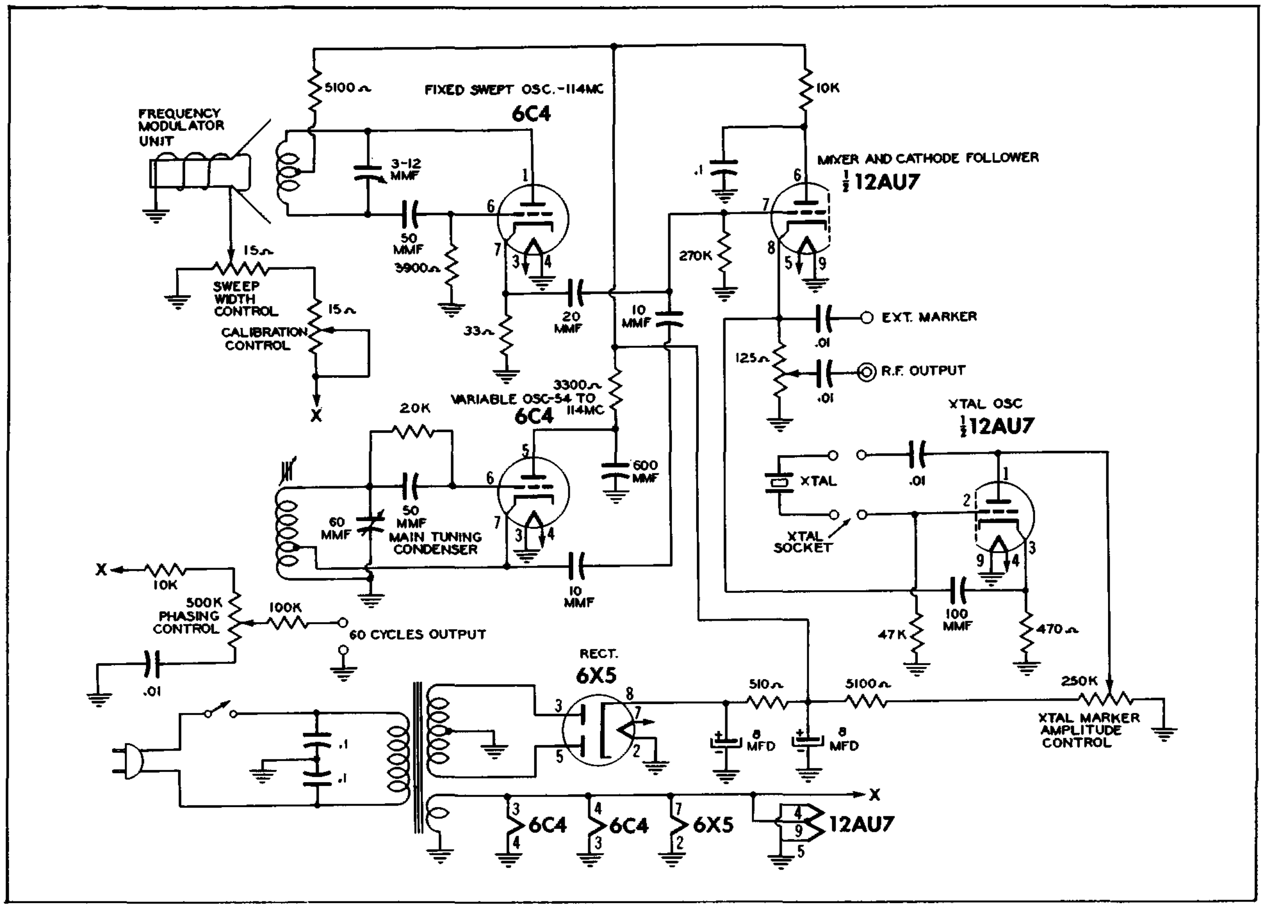


Figure 21. A Schematic Diagram of the Eico Sweep Generator.

PRODUCING FREQUENCY MODULATION OF THE FIXED SWEPT OSCILLATOR. The fixed swept oscillator at a center frequency of 114 mc is frequency modulated by mechanical means. The oscillator coil consists of a specially designed, flat open wound spiral coil embossed on a bakelite base plate. A flat metal membrane is placed parallel and very close to this coil, and is mounted on the diaphragm of a speaker. When the diaphragm is vibrated, the metal membrane vibrates varying the inductances of the oscillator coil which is very close to it. The oscillator frequency is thus varied. To obtain different sweep widths, a rheostat varies the amount of voltage applied to the speaker voice coil. The greater the voltage, the greater the diaphragm vibration, and the greater the frequency variation.

A WIRED SWEEP GENERATOR -

A sweep generator which is more elaborate than the previous instrument is the unit shown in Figure 22. Continuous frequency coverage from 2 megacycles to 240 megacycles is achieved in five bands without any skip. Furthermore, the harmonics are strong enough so that it is possible to go as high as 480 megacycles and appropriate scales are provided for these higher frequencies.

This unit is manufactured by the same firm that produced the AM generator shown in Figure 9, Section 2. It, too, contains a vernier scale and vernier plate. Of the 160 divisions contained on the vernier scale, only 150 of them are useful so far as the frequency scales are concerned. This 150, however, should be multiplied by 10 because of the vernier plate. Hence, a direct reading to one part in 1500 is possible and this provides greater accuracy than would be needed in a sweep generator for any application.

Before we examine the various front panel controls, it may be instructive to examine briefly the circuit of this generator. See Figure 23. With sweep generators, even more than AM signal generators, it is to the advantage of the serviceman to know as much as possible about the operation of the instrument. The sweep generator is a fairly complex piece of equipment, subject to misuse or misapplication. The serviceman who comes in daily contact with sweep generators may not appreciate it, but actually, to know how to apply such an instrument properly and to its fullest extent requires a greater amount of technical know-how than it does to operate an AM generator.

OSCILLATOR "A". This is a variable oscillator covering a fundamental range of 71 to 120 mc. At every point within this frequency range, the

Figure 22. A Precision Model E400 Sweep Generator. Courtesy of Precision Apparatus Co., Inc.

oscillator is frequency modulated by the same electro-mechanical method as the previous generator. The oscillator frequency is thereby varied above and below the oscillator mean frequency at a 60-cycle repetition rate.

(In the previous instrument, the variable oscillator was not modulated at all. Here, it is.)

OSCILLATORS "B" and "C" are fixed frequency oscillators calibrated at 75.0 mc and 37.5 mc respectively. In operation only one of these oscillators is in use at any one time. The output of oscillator "A" and either oscillator "B" or "C" are simultaneously injected into a high frequency RF mixer stage labeled "D". This stage mixes the signals of oscillator "A" with those of "B" or "C" and delivers the carriers, sum and difference frequencies to the "RF Amplifier-Marker Injection" stage (labeled "E").

A crystal oscillator (labeled "F") provides for the simultaneous insertion of any one of four crystals for applications requiring use of crystal-accuracy marker and calibrating pips. The use of a 4-crystal holder eliminates the inconvenience of frequent insertion and removal of crystals. Each of the 4-crystal positions is quickly selected by a rotary switch and the crystal marker amplitude may be controlled separately.

In addition, variable frequency marker input terminals provide a direct means for use of any standard, suitable AM signal generator as a marker pip-generator.

## FUNCTION AND DESCRIPTION OF FRONT PANEL CONTROLS AND SWITCHES

Main Tuning Dial and Band Selector Switch -

(a) The markings "A(X)," "B," "C(Y)," "D," and "E" on the "Band Selector" switch refer to the corresponding bands on the main tuning dial.

(b) The marking "A(X)," "C(Y)," indicate that bands "A" and "X" are in operation when the "Band Selector" is set to "A(X)" and that bands "C" and "Y" are in operation when the "Band Selector" is set to "C(Y)".

(c) When the "Band Selector" switch is rotated to the position marked "Xtal only" all oscillators with the exception of the internal Crystal Marker oscillator are disabled, permitting application of just the pure Crystal Marker oscillator output as a simple crystal oscillator for external use with no interference from the remainder of the generator's oscillators.

"SWEEP WIDTH" CONTROL: Rotation of the "Sweep Width" control varies the degree to which the variable oscillator (Osc. "A") is deviated from its mean frequency. For example: if the "Sweep Width" control is set to 200 kc and if the main tuning dial is set to 10.7 megacycles, the RF output from the sweep generator will be varying from approximately 10,800 kc (10.8 mc) to approximately 10,600 kc (10.6 mc) at a 60-cycle rate. Therefore, the calibration on the "Sweep Width" dial indicates total sweep width, not deviation to each side of the mean frequency. The deviation is only 1/2 of the total sweep.

The calibrations of the "Sweep Width" control are NOT intended for use as accurate indications of sweep width at every setting of the main dial. They are intended for use as a convenient guide to the approximate setting required to bring the full response pattern into view on the scope screen. This is true of all sweep generators.

"SWEEP RANGE" SWITCH: This switch sets the range for which the "Sweep Width" control is calibrated, (0-1000 kc or 0-15 mc). The third position (marked "Ext. Dev.") frees the modulator from its internal 60 cycles excitation and allows the operator to excite the modulator from an external AC source through use of the panel pin jacks marked "Ext. Dev." The fourth position (marked "Dev. Off") disables the modulator from both internal and external deviation sources. Under this fourth condition, all frequencies indicated on the main tuning dial are unmodulated RF signals. Should a source of audio frequency voltage then be applied to the "Audio Mod."

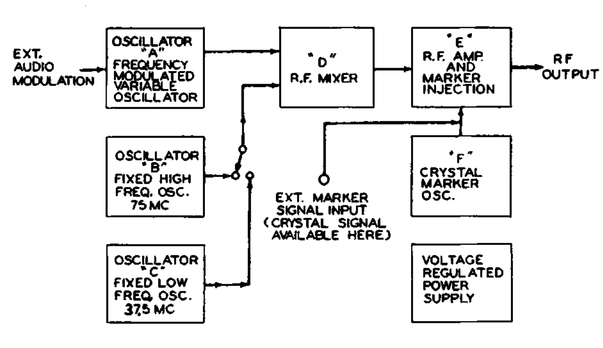


Figure 23. A Simplified Block Diagram of the Sweep Generator Shown in Figure 22.

pin jacks on the front panel, the output of the generator becomes an amplitude modulated (or AM) signal generator. This is a useful feature of this generator and is not always available on other instruments.

"PHASE CONTROL:" Due to the fact that full sinusoidal voltages are simultaneously applied to the electro-mechanical modulator and the "Hor. Sweep" terminals of the oscillograph, two traces of the tuned circuit response curve will normally appear on the oscillograph. Without corrective network, one of the traces will usually be found out of phase with the other trace, resulting in both traces appearing on the oscilloscope, adjacent to each other. The "Phase Control" operates a capacity phase-shift network which permits both traces to be superimposed on the oscillograph.

The inherent characteristics of the modulator unit are such as may sometimes prevent exact superimposition of the two traces (by manipulation of the "Phasing Control"). As a result, it may be found (when wide sweep width is employed) that similar portions of the two traces may lie closely adjacent to each other instead of being exactly superimposed. This has absolutely no effect upon the overall operation and can be disregarded by the operator.

"RF LEVEL" and "OUTPUT CONTROL:" The control labeled "RF Level" adjusts or controls the magnitude of RF which is fed or transmitted to the "Output Control." With the "Output Control" set to maximum, the "RF Level" control should be set at a point which will result in the maximum output required for the particular application. From that point on, the "Output Control" is used to attenuate the signal from the sweep generator.

"CRYSTAL MARKER:" (Selector, Attenuator, Panel Connector and Switch).

(a) "Crystal Selector" Switch. When one to four appropriate crystals are inserted into the multiple crystal socket this switch will select any one of the 4 crystals and electrically insert it into the internal oscillator circuit.

(b) Crystal Marker "On-Off" Toggle Switch. This switch permits the internal crystal marker oscillator to be turned On or Off. When the internal crystal marker is not required, this toggle switch should always be thrown to the "Off" position.

(c) "Crystal Marker Amplitude" Control. The "Crystal Marker Amplitude" control is an attenuator for the internal crystal marker oscillator. In use, the amplitude or height of the marker "pip" will increase as the control is turned clockwise. This control should be advanced only as far as required to just make the "pip" visible. If the control is advanced to obtain an excessively strong "pip", the overall response curve may be distorted by the strong marker signal.

(d) "Ext. Mark. Input - Crystal Mark. Output" Connector. This connector in the lower left-hand corner of the panel, permits the operator to obtain externally the output of the crystal marker oscillator only, for a variety of purposes. For this function, the "Band Selector" Switch is rotated to the "Xtal Only" position.

At the same terminal another generator can inject an external marker signal into this instrument. This marker signal will combine with the swept signal, traveling with this latter signal to the circuit under test.

"HOR. SWEEP" CONNECTOR. This connector supplies a horizontal sweep actuating voltage to the horizontal input terminals of the oscilloscope being used.

"EXT. DEV." PIN JACKS (External Deviation). With the "Sweep Range" selector switch rotated to the "Ext. Dev." position, an external source of AC voltage at a frequency between 25 to approximately 200 cps. may be applied to the "Ext. Dev." pin jacks, thereby externally exciting the modulator. Care must be taken when applying AC voltage to the "Ext. Dev." pin jacks. Should excessive voltage be applied, the modulator driving coil may be overloaded and damaged. Apply only enough voltage as will yield sufficient sweep width to bring the entire response curve of the tuned circuit under test into view on the oscillograph screen. (Approx. 1.5 volts maximum).

When an external source of sweep potential is employed, the approximate deviation calibrations of the "Sweep Width" control are no longer applicable. Also, the "Hor. Sweep" connector still puts out a 60-cycle sine wave driving voltage which would not be suitable with any external modulating voltage except one whose frequency was also 60 cycles.

"OUTPUT" CONNECTOR. A coaxial cable connects to the "Output" connector on the instrument panel.

BINDING POSTS ON PANEL. These binding posts are provided for additional grounding connections to be made by the operator. One grounding strap should be connected from one binding post on the panel to the receiver under test. If found necessary, another ground connection may be made by the operator from the other binding post to another point on the receiver or to the oscilloscope being used.

INITIAL SET-UP OF INSTRUMENT. Before we leave this instrument, it may be advantageous to note how it would be set up initially--in preparation for an alignment. When a generator is being used in the shop, perhaps by several people, it may come to the serviceman who is now going to use it with the controls set in almost any fashion, depending how the previous man employed it. To the inexperienced serviceman, the resetting of the controls is perhaps as big a job as the actual performance of the alignment procedure itself. Toward that end, the following preliminary set-up procedure will be of interest.

(a) "PHASE CONTROL" is set at approximately mid position.

(b) "BAND SELECTOR" switch is set to the proper frequency band.

(c) The main tuning dial is rotated to the mid frequency of the range to be covered.

(d) "SWEEP RANGE" switch is set to the proper range (0-1000 kc for FM; and 0-15 mc to TV).

(e) The position of the "SWEEP WIDTH" knob will depend on the passband of the circuit to be swept over. Generally the generator sweep should have a value about 50 percent greater than the maximum band pass of the circuit under test. For a 4.0 mc TV system this would mean setting the "Sweep Width" control to 6 mc.

(f) The "RF LEVEL" and "OUTPUT CONTROL" knobs should be advanced to full rotation. This will insure maximum output at the start.

(g) Initially there would probably be no need for a crystal marker and so the "Crystal Marker" switch would be thrown to the "Off" position. With the crystal oscillator thus made inoperative, the position of the "Crystal Selector" switch would be of no consequence.

The instrument, with the power on, would now be ready for connection to the receiver with which it is to be used. Just what this next phase of the operation is, will be covered in detail in a later section. At the moment we are primarily concerned with becoming familiar with the instrument and its capabilities and controls.

## SWEEP GENERATORS WITH INTERNAL VARIABLE MARKERS

The sweep generators which have been described to this point have been designed for use with an external variable marker generator for the identification of different frequency points along the response curve. In the generator shown in Figure 24, such a marker oscillator is actually made part of the sweep instrument itself. The ranges covered by the marker unit are 19 to 31 mc and 30 to 48 mc. A separate dial is employed for the marker generator so that any of its frequencies may be chosen independently of the sweep frequency generator.

The output of the marker generator is combined with the sweeping signal and then both may be obtained from the terminal marked "Output." The amplitude of the marker pip can be controlled by the "Marker Injection" knob.

A crystal may be plugged into the external holder to permit accurate adjustment of the receiver oscillator. Extremely accurate pips may also be generated for fixed markers on the response curve when proper crystals are used. Crystals are available from the factory for any frequency between 10 mc and 215 mc.

Finally, an external signal generator may be connected between the "External Marker" pin jack and "GND" to provide an additional marker frequency if it is desired. Since this binding post is internally connected to the marker oscillator and crystal oscillator circuits, it is possible to obtain from this pin jack signals directly from either of these oscillators.

Of particular interest is the use of the marker generator signal to align the various trap circuits and peaking coils in the video IF system of a television receiver. 400-cycle modulation of this marker generator output can be achieved by flipping the "Int. Marker" switch (located in the lower right-hand corner of the panel) to the "Mod." position. If an unmodulated signal is desired, the switch is moved to the "CW" position. When the instrument is being used to sweep out a response curve, the switch is normally in the "CW" position.

Next to the "CW"-"Mod." switch is another switch containing the words "ABS" and "Osc." In the "Osc." position, the marker generator signal produces a pip on the response curve, as shown in Figure 25A. However, in the "ABS" position, the pip is changed to a dip in the curve. See Figure 25B.

The use of marker signals in receiver circuit alignment is actually a consequence or by-produce, as it were, of using sweep frequency generators to perform circuit adjustment. When you obtain the

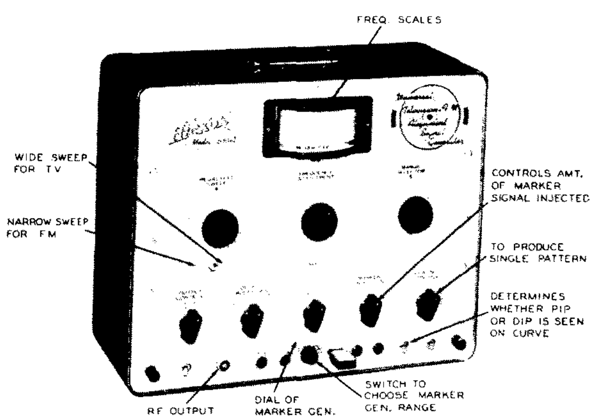


Figure 24. A Sweep Generator Possessing its Own Marker Generator. Courtesy of Hickok Electrical Instrument Co.

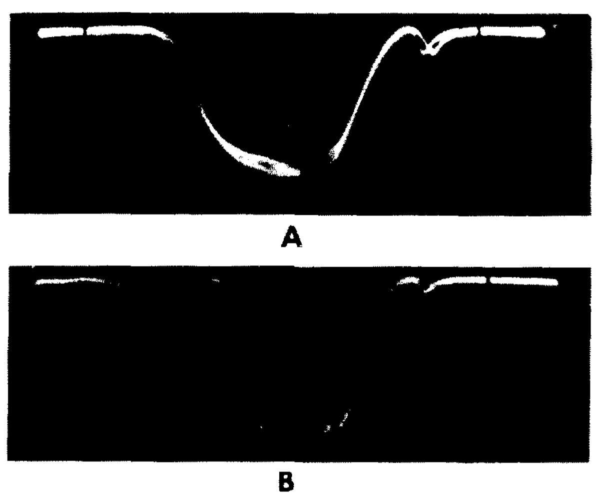


Figure 25. A Comparison Between the Appearance of a Conventional Pip Produced by the Beat Method (A), and a Pip (or Dip, Actually) Produced by the Absorption Method (B).

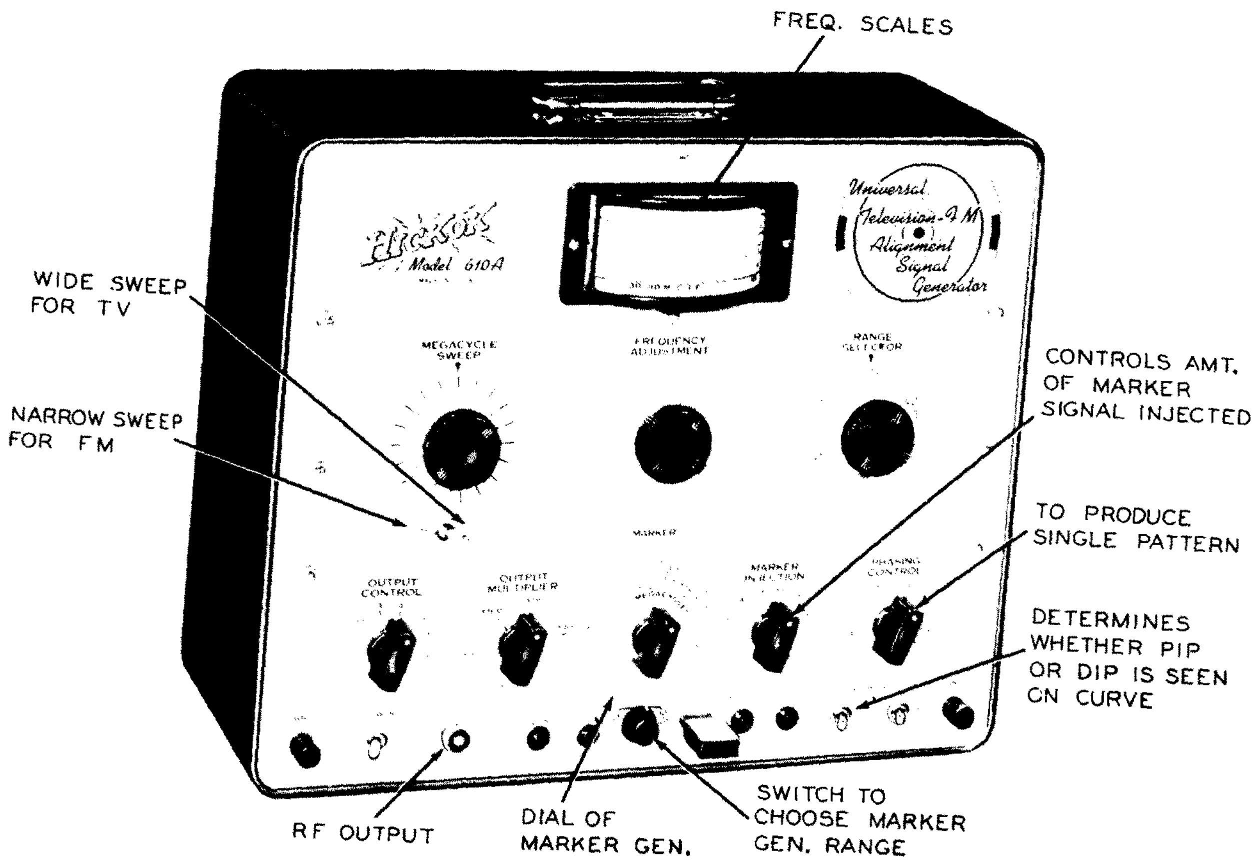


Figure 24. A Sweep Generator Possessing its Own Marker Generator. (Model 610-A, Courtesy Hickok Electrical Instrument Co.)

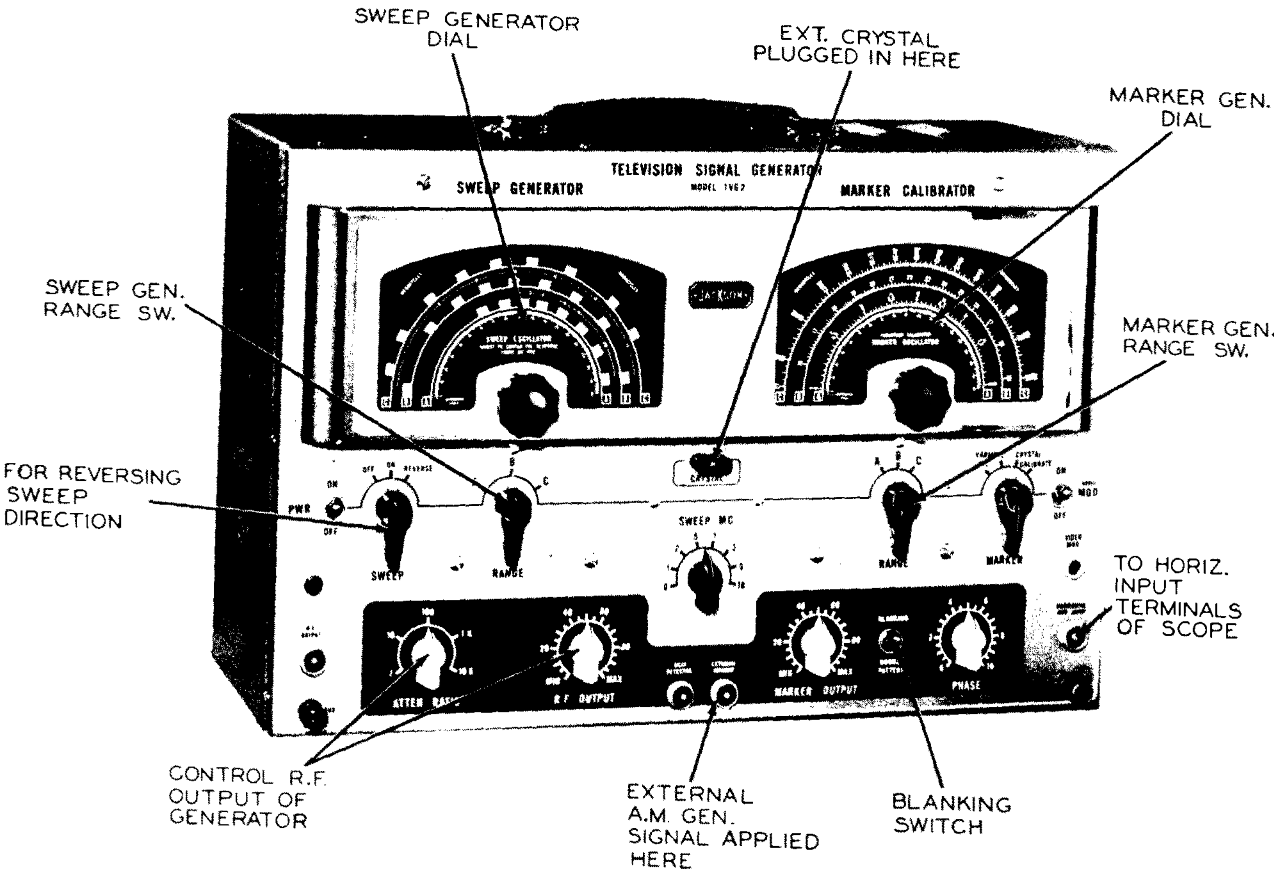


Figure 26. A Sweep and Marker Generator with Blanking and Reverse Sweep Features. (Model TVG2, Courtesy of Jackson Electrical Instrument Co.)

response curve of any system on an oscilloscope screen, you must have some way of determining the various frequency points on that curve in order to determine, first, if the curve extends over the proper range and second, if specific frequencies are located where they should be. It is the function of the marker generator to provide this information and it does so in the following manner. The signal from the marker generator is combined with the signal from the sweep generator and both are then passed through the system to be aligned.* At the output of this circuit both voltages are applied to a detector (usually the video second detector of the receiver) where the marker frequency beats with the sweep frequency signal to produce a series of sum and difference frequencies. As a concrete illustration, suppose the sweep generator is sweeping from 22 to 28 mc and the marker generator is at 25 mc. Then when these signals reach the video second detector after having passed through the video IF system, they will beat together. The 25 mc marker will beat with the sweep generator's 25 mc to produce a difference frequency of zero cycles (DC). As the sweep generator moves away from 25 mc, say to 25.001 mc, then the best difference frequency produced will be .001 mc or 1,000 cycles. At 25.002 mc, the best difference frequency will be 2,000 cycles, etc. In other words, the marker signal will beat with the sweep signal at every frequency within the 22 to 28 mc sweep range. The sum frequencies produced will extend from 47 mc to 52 mc and since frequencies this high will never pass through the vertical deflection circuits of the oscilloscope, they can be disregarded. The difference frequencies produced by this beating action will extend from 0 (when both signals are at 25 mc) to 3 mc when the sweep generator is either at 22 mc (25 mc-22 mc) or at 28 mc (28 mc-25 mc).

Now, since the vertical deflection amplifiers of most oscilloscopes seldom have a flat response beyond 500,000 cycles, all the difference frequencies produced above this value (i.e., 1/2 mc) will either be attenuated or eliminated altogether. In addition, if we place a small by-pass capacitor (500 mmf. or so) across the input terminals of the oscilloscope, all but the very low beat frequencies will be shunted away from the oscilloscope circuits and will not appear on the screen. The result, as shown in Figure 25A, is a fairly well defined pip on the screen.

Note, then, that this pip is produced by the very low beat frequencies which occur when the sweep frequency is close to the marker frequency. In this discussion this would be at 25 mc. Beat frequencies are produced at all other sweep frequencies but because of the factors mentioned above, do not appear on the screen.

The scanning beam in the oscilloscope is moving across the screen in step with the changing frequencies coming out of the sweep generator to trace out the response curve. When we introduce the marker signal into the circuit, the pip it produces will appear at that point on the curve where the sweep signal frequency is the same as the marker signal frequency. If we change the marker frequency, the beat between it and the sweep signal occurs at some other point in the sweeping range and, on the response curve, the pip moves to a different position. In this way we can move the pip to whatever section of the curve we wish and note from the marker dial just what the frequency of the curve is at that point.

Most marker pips are produced by the beating method. Another method, available in the generator of Figure 24, is an absorption type of marker where the voltage in the sweep signal having the same frequency as the absorption circuit is "sucked out" or absorbed by the marker circuit. The indiction that this type of marker provides is shown in Figure 25B and is seen to be actually a dip or notch in the response curve.

## BLANKING CONTROLS

The sweep generator shown in Figure 26 contains an internal marker oscillator, a sweep generator, and the usual controls that go with these two generators. Of interest are the additional features contained in this instrument since they may, in one form or another, appear in other sweep generators that the serviceman is likely to encounter. These features include a "Blanking" or "Double Pattern" switch, a method of injecting video modulation, a beat detector jack, and a method of reversing the sweep.

The "Blanking" or "Double Pattern" switch, located in the lower right-hand corner of the instrument panel determines, by its position, whether the normal double pattern will be seen on the oscilloscope screen or instead a single pattern with a base line.

The blanking circuit when turned on, injects a negative pulse into the FM oscillator circuit in such a manner that oscillation is stopped during the return trace of the oscilloscope, thereby producing a base line and a single trace response curve on the oscilloscope screen. Thus, as the electron beam sweeps forward from left to right, the response curve of the circuit under test is traced out. On the return trip, the beam would ordinarily trace back over the same curve. This second tracing is not actually necessary since it provides the same information as the forward

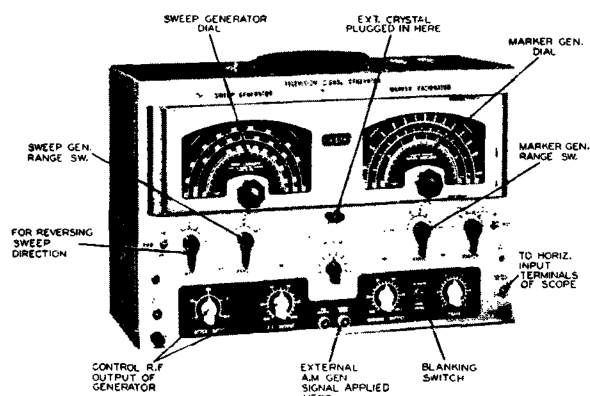


Figure 26. A Sweep and Marker Generator With Blanking and Reverse Sweep Features. Courtesy of Jackson Electrical Instrument Company.

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* Additional information on producing marker pips is also found in a later section on Special Test Instruments.

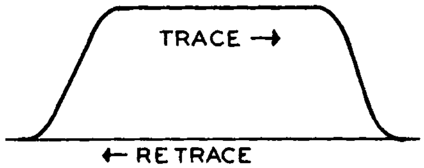



Figure 27. The Appearance of a Response Curve and its Zero Reference Retrace Line When Blanking Is Employed in Sweep Generator.

trace. Furthermore, there is generally sufficient unbalance existing in the circuit so that the second trace does not coincide at all points with the first trace, resulting in two curves. This second trace can be removed by stopping the oscillations of the sweep generator during this period and that is what happens when the "Blanking" switch is flipped on the generator of Figure 26. Within the scope, however, the beam is not similarly blanked out and so it produces a zero voltage or reference line because during this period it is receiving nothing from the circuit under test. See Figure 27. (The circuit, by the same token, is not putting out any voltage because it is receiving nothing from the sweep generator.) The presence of the base line aids the technician to better orient the various values of the response curve and thereby tends to simplify and hasten the servicing and alignment process. The zero base line proves to be especially valuable for FM discriminator alignment since in this instance the linear portion of the S-response curve should extend for equal distances above and below this level. See Figure 28.

VIDEO MODULATION -

A connector is provided as a means of inserting a video signal from a normally operating television receiver into the generator. This signal modulates the marker oscillator to "rebroadcast" this video signal on any desired channel or frequency. It may also be used to insert an audio signal, either sine or square wave, for linearity adjustment. (The marker generator, in three ranges, covers the frequencies of 4 mc to 216 mc.)

The manner in which the video modulation feature can be employed will be seen from the following:

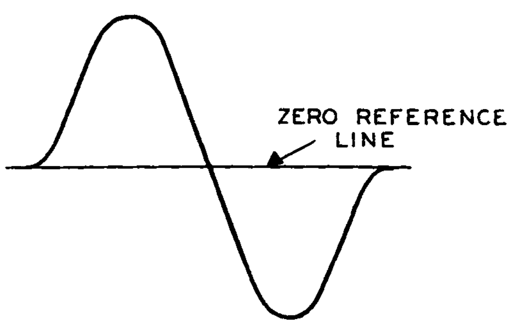



Figure 28. The "S" Response Curve of an FM Detector With Zero Reference Line Produced by Blanking Circuit in the Sweep Generator.

1. Video modulating the Marker Generator.

(a) Turn the instrument on and set the "Marker" selector to "Variable" position.

(b) Set the "Range" switch (underneath the marker generator) to Band "C" and the dial to the picture carrier frequency of the channel to be checked.

(c) Connect the "RF Output" cable of the generator to the antenna terminals of the television receiver to be checked.

(d) Tune in a picture from a television station on a normally operating television set. (This is another set, not the one to be tested.)

(e) Using a shielded lead, feed the video signal from the good TV set picture grid into this generator through the "Video Mod." connector. A 0.1 mfd. capacitor should be placed in series to isolate the DC voltage from the set.

(f) If the picture appears reversed (negative picture) on the screen of the sét under test, adjust the contrast control on the set feeding the video signal. If this does not correct the condition, then the video signal should be taken from some other point in the TV set where its polarity is opposite to what it is at the picture tube. This point is generally at the grid of the last video amplifier. Note, then, that the detected signal from the good set is used, in conjunction with the signal generator, to provide a test signal, for the set to be checked. Such a procedure might be feasible when only one station is on the air yet you wish to check receivers on other channels. The video signal you derive from one set could be used to modulate the signal generator on any frequency. An arrangement of this type is also useful when no stations are on the air but you have a source of video signal available in the shop. (A video signal generator suitable for this purpose is described in a later section.) With this equipment you can generate your own video RF signals.

2. Modulating to produce Bar Patterns. Vertical and horizontal bars on the picture tube raster offer a method of checking horizontal and vertical linearity adjustments of a television receiver. By using an audio oscillator capable of generating multiples of the vertical (60 cycles) or horizontal sweep frequency (15.75 kc), it is possible to produce vertical or horizontal bars with this instrument.

(a) Obtain a signal from the variable marker oscillator by the procedure described above. (Steps la, b, and c.)

(b) Select a picture carrier frequency and feed the RF output into the antenna terminals, or select the picture intermediate frequency and feed the RF output to the grid of the first video IF stage.

(c) Feed the output of the audio oscillator into the "Video Mod." connector.

(d) To produce horizontal bars to check vertical linearity, set the audio frequency oscillator to a multiple of the 60-cycle receiver vertical sweep frequency. As an example, if the audio frequency is 600 cycles, 10 horizontal bars should appear. The top or the bottom bar may be decreased in width, due to the retrace time of the receiver vertical sweep oscillator.

(e) To produce vertical bars to check the horizontal linearity, set the audio oscillator (or AM generator) to some multiple of the 15.75 kc horizontal sweep oscillator frequency. If the applied frequency is 157.5 kc, 10 vertical bars will appear. If the frequency is 78.75 kc, 5 vertical bars should appear. Equal spacing between bars indicate good linearity.

Note: For satisfactory modulation, either video or bar pattern, between 5 and 10 volts will be necessary at the "Video Mod." connector.

BEAT DETECTOR -

A terminal is provided as a means of connecting headphones to hear, or connecting an oscilloscope to observe, the zero beat between the crystal oscillator and the variable marker oscillator for calibration. The manner in which this calibration is accomplished is as follows:

(a) Plug in the desired calibrating crystal in the panel holder provided for it. As an example: A 12.5 mc crystal to check the 25 mc point on Band "B" of the variable or marker oscillator. (Crystal oscillators produce strong harmonics and it is feasible to use lower frequency crystals when the desired frequency is quite high. Lower frequency crystals are also sturdier and less expensive.)

(b) Turn the "Marker" selector switch to the "Calibrate" position and allow the instrument to warm up for at least 10 minutes.

(c) Set the marker frequency dial to the 25 mc reading.

(d) Connect headphones to the "Beat Detector" jack. Swing the marker frequency dial back and forth until a beat note is heard.

(e) At the zero beat point, note the dial reading. If the scale is off, you can do one of two things. First, either bring the frequency of the generator back into line by making such adjustments as are recommended by the manufacturer or second, drawing up a calibration chart in which you list on one side the frequency markings as they are on the dial and on the opposite side, the correct value of each of these markings. In following this latter procedure, only the major scale markings need be checked.

USING AN EXTERNAL MARKER SIGNAL -

This instrument (Figure 26) is capable of developing its own marker signal. However, if it is desirable (as it frequently is) to use 2 marker pips on a given response curve, this may be accomplished by connecting an accurate RF signal generator to the "External Marker" connector and setting it to produce the desired marker frequency. The output control of the auxiliary oscillator should be adjusted to give approximately the same size "pip" as the one produced by the generator of Figure 26.

Incidentally, it will undoubtedly occur to many readers that the calibration of other AM generators may be checked against the crystal oscillator in this instrument. Simply connect the external generator to the "External Marker" connector. Then plug in the appropriate crystal in the crystal holder. and turn the "Marker" selector switch to the "Crystal" position. Connect headphones to the "Beat Detector" jack. Then swing the dial of the external generator back and forth slightly until a beat note is heard.

SWEEP PHASE REVERSAL -

The "Sweep" control has "Off-On-Reverse" positions. In the "Off" position, the 60-cycle driving voltage is removed from the FM oscillator and the output from the sweep section is unmodulated RF. In the "On" position the driving or sweeping voltage is applied to the FM oscillator and the sweep section is delivering an FM signal. This, when fed to a television receiver, would produce a response pattern. Now, it can happen, because of the manner in which the test equipment is designed, that in the response pattern obtained, the high frequency end of the curve is at the left and the low frequency end is at the right. See Figure 29A. All this means is that the oscilloscope tracing beam is at the left-hand side of the screen when the sweep generator is sweeping out the high frequency end of the response curve. It does not affect the response curve or its circuit in any way.

However, the reversed pattern can sometimes confuse the technician since many textbooks and instruction manuals show response curves with the low frequency section at the left and the high frequency section at the right, as in Figure 29B. To reverse the curve so that it can be compared with the standard patterns, this generator contains a reverse position

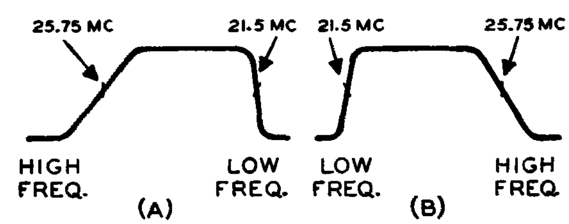



Figure 29. (A) A Video IF Response Curve That May be Obtained on the Scope Screen. Note That the High IF Frequencies Are at the Left and Low IF Values at the Right. (B) By Flipping the Phase Reversal on the Jackson Generator, the Curve in (A) Is Reversed to the Form Shown in (B).

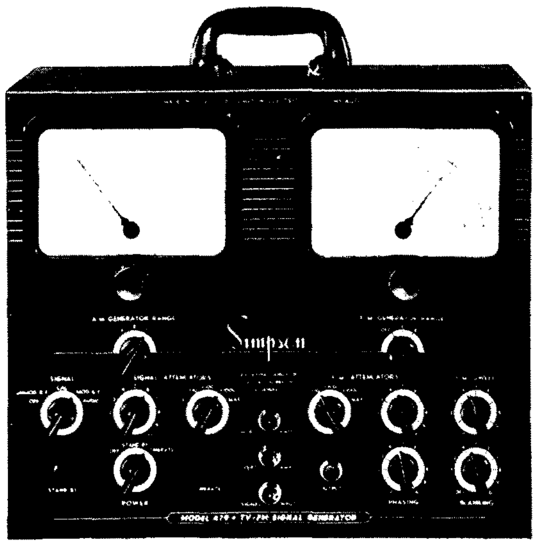


Figure 30. A Crystal-controlled AM, FM, and TV Sweep Generator. Courtesy of Simpson Electric Co.

on its "Sweep" selector switch and by turning to this position, the direction of sweep is reversed.

## A SECOND TYPE AM - FM - TV GENERATOR

Combination AM, FM and TV generators are gradually becoming more common as the scope of the servicing field expands. The generator in Figure 24 could be considered as representing an initial step toward achieving this combination by including a marker generator (of limited range) with its sweep generator. The next instrument (Figure 26) took a longer step forward in this direction not only by extending the range of its marker generator, but by adding such extras as a beat detector jack, a phase reversal switch, and making provision for audio and video modulation. Still another generator along somewhat the same lines is the unit shown in Figure 30.

Physically this instrument is divided into two sections: A right-hand section and a left-hand section. Grouped on the left is a three-range RF generator, a crystal calibrator, and a 400-cycle audio oscillator.

The type of signal desired is selected by a "Signal" selector switch (left). When this switch is in the "Off" position, the section is inoperative. In the "Unmod. RF" position, an unmodulated RF signal is available at the "Output" cable and controlled through the two "Signal Attenuator" controls. In the "Cal." position, a 5 mc crystal oscillator or one of its harmonics is mixed with the RF signal or one of its harmonics to produce a "beat" pattern which can be observed on an oscilloscope screen and thus provide an accurate means of adjusting the RF signal to an exact frequency.

To see this beat pattern, the "Output" cable would be connected to the vertical input terminals of an oscillscope. As the AM signal generator dial is turned slowly through zero beat, the sequence of patterns shown in Figure 31 will be observed. The one which is obtained at zero beat is indicated. To determine the precise point where zero beat occurs, it is necessary to turn the generator dial as slowly as possible. Even so, at higher frequencies, it may be quite difficult to determine exactly when zero beat is reached because even a hair's turn of the dial will change the generator's frequency enough to cause it to pass through zero beat and be several

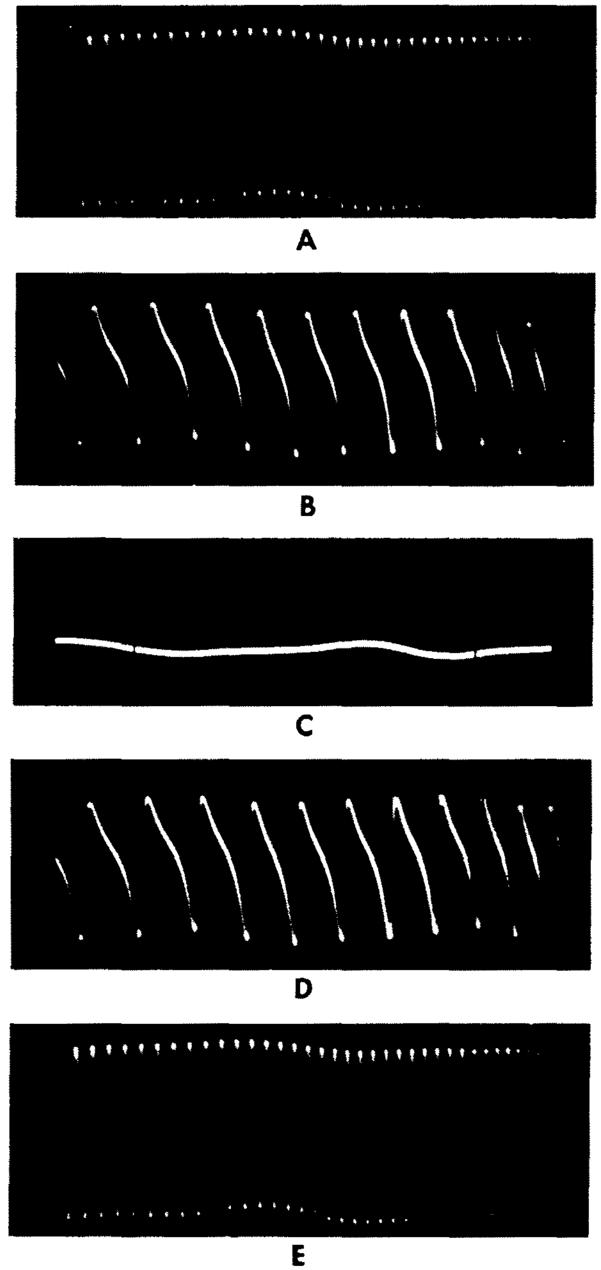



Figure 31. A Sequence of Patterns Passing Through Zero Beat. Zero Beat is Obtained at "C". "A", "B", "D" and "E" Are Above or Below Zero Beat.


Figure 30. A Crystal Controlled AM, FM and TV Sweep Generator. (Model 479, Courtesy of Simpson Electrical Co.)


Figure 32. An FM-TV Generator in Which the Sweep Frequencies Are Obtained at Certain Fixed Positions of a Selector Switch. (Model 675, Courtesy of Supreme Instrument Co.)

hundreds of cycles away from it. In such situations it is best to go back and forth over the zero beat point until you have narrowed it down as closely as you can.

When the "Signal" control is in the "Mod. RF" position, a 400-cycle modulated RF signal is available at the output cable and controlled by the two "Signal Attenuator" controls.

In the "Audio" position, a 400-cycle audio signal is available at the output cable and controlled through the "Signal Attenuators."

The "AM Generator Range" switch (upper left) together with the tuning dial selects the desired RF signal.

Band "A" Fundamental 3.2-8 mc second harmonic 6.4-16 mc.

Band "B" Fundamental 15-38 mc second harmonic 30-76 mc.

Band "C" Fundamental 75-125 mc second harmonic 150-250 mc.

The "Power" switch (lower left) controls the power input to the unit. In the "Off" position the entire instrument is turned off. In the "Stand By" position all tube heaters are on but no plate voltage is applied. In the "Operate" position the plate supply is turned on. The green light (left) is on in the "Stand By" position and the red light (right) indicates the "Operate" position.

The right-hand section of this instrument contains a frequency modulated signal generator, a 140 mc fixed frequency oscillator, mixer, phasing and blanking circuits.

The fundamental range ot the FM generator is 140 to 260 mc and is available at the "Output" terminal when the "FM Generator Range" switch (upper right) is in position "B". In position "A" the 140 mc fixed oscillator is in operation and is mixed with the FM generator to produce difference frequencies from 2-120 mc. In the "Off" position, both oscillators are inoperative.

The "FM Sweep" control (right) regulates the amount of frequency sweep from zero to over 15 megacycles. (The numbers on this dial are for reference only.)

The "FM Attenuator" controls the output from the FM section.

The "Phasing" control adjusts the horizontal sweep of the oscilloscope to coincide with the frequency sweep of the oscillator in order to superimpose the return trace on the forward trace.

The "Blanking" control injects a negative pulse into the FM oscillator circuit in such a manner that oscillation is stopped during the return trace of the oscilloscope thus producing a base line and a single trace response curve on the cathode-ray tube.

The output attenuator is a step attenuator through which all signals must pass into the "Output" jack directly below it.

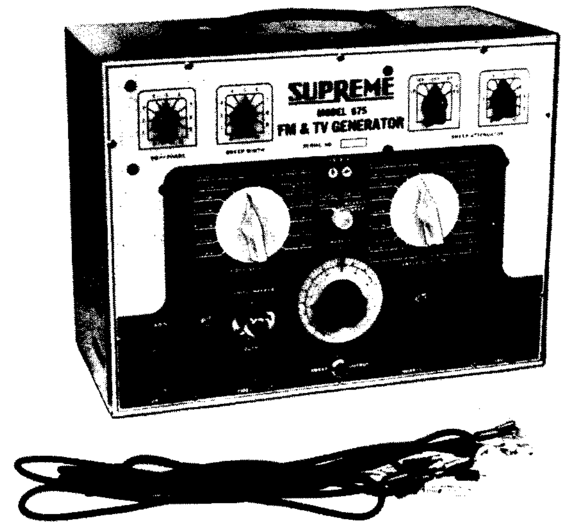



Figure 32. An FM-TV Generator in Which the Sweep Frequencies are Obtained at Certain Fixed Positions of a Selector Switch. Courtesy of Supreme Instrument Co.

Four cables are supplied for making connections between the generator, the receiver and the oscilloscope.

After the sweep signal has passed through the receiver and it has been demodulated by the video second detector, it is returned to the generator by means of a coaxial cable to the "Signal Input" terminal where it passes through to the "Vert. Ampl." cable and from here to the vertical amplifier of an oscilloscope. This arrangement was designed to simplify the alignment operation by internal switching of the oscilloscope input. (Note: The receiver output can be fed directly to the oscilloscope, if desired, The arrangement suggested here is only for convenience.)

The "Horiz. Ampl." cable connects to the horizontal amplifier of the oscilloscope to provide a synchronized 60-cycle sine wave sweep with variable phasing.

## FIXED FREQUENCY GENERATOR

A somewhat different approach to FM & TV generator design is illustrated by the instrument shown in Figure 32. Here, the various sweep frequencies required for the alignment and adjustment of television receiver circuits are obtained from certain fixed positions of a selector switch rather than by the more conventional continuous frequency dial.

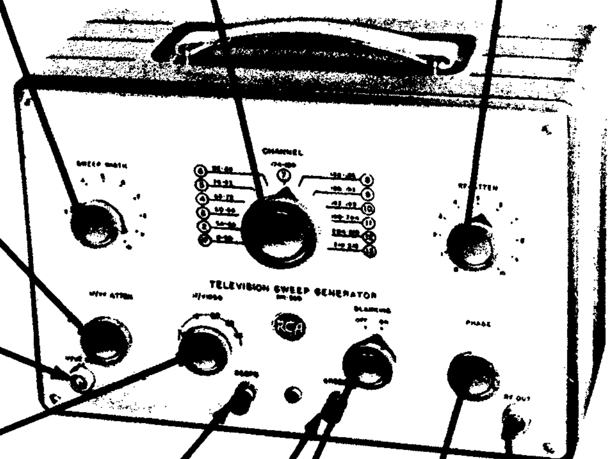
The front panel of this instrument contains two large selector switches, one labeled "Sweep Selector," and the other "Video Selector." The various positions of the "Sweep Selector" switch are as follows:

**CHANNEL selector**—Switch to the desired TV channel or to intermediate-frequency range. When this selector is at positions "2" through "13", the rf-output voltage appears at the RF OUT terminal. When the selector is at "IF" position, the output if and video frequencies are determined by the IF/VIDEO control and are obtained at the IF/VF OUT terminal.

**SWEEP WIDTH control**—Has two functions; turns the power on between positions "OFF" and "1", and adjusts the sweep width of the output voltage.

**RF ATTEN control**—Determines the amplitude of the rf output (at RF OUT terminal) when the CHANNEL selector is at positions "2" through "13".

**IF/VF ATTEN control**—Permits continuous adjustment of the amplitude of the if/vf output (at IF/VF OUT terminal) when the CHANNEL selector is at "IF" position.



**IF/VF OUT terminal**—The if/vf output voltage appears at this terminal when the CHANNEL selector is at "IF" position.

**IF/VIDEO control**—Tunes the variable-frequency oscillator to produce the desired if and video frequencies at the IF/VF OUT terminal with the CHANNEL selector at "IF" position.

**SCOPE terminal**—A sinusoidal voltage of line frequency, which can be applied to the horizontal-input terminals of an oscilloscope, appears across this terminal and the GROUND terminal. The phase relationship of this sweep voltage and the output of the WR-59B can be adjusted by means of the PHASE control to produce a single pattern on the oscilloscope.

**RF OUT terminal**—The rf output voltage appears at this terminal when the CHANNEL selector is at positions "2" through "13".

**GROUND terminal**—Is directly connected to the chassis of the instrument; serves as a common ground for the chassis of the equipment under test and associated test instruments.

**PHASE control**—Used only if the voltage across the SCOPE and GROUND terminals is applied to an oscilloscope. It adjusts the phase of this voltage with respect to the output voltage of the WR-59B, so that a single pattern will appear on the oscilloscope.

**BLANKING switch**—At "ON" position, provides a zero-reference line which is useful for checking the response curve of the circuit under test.

Figure 33. Another Sweep Generator in Which the Various Frequencies are Selected by Means of a Switch. Courtesy of RCA.

| Channel | Frequency | Band Width |
|---|---|---|
| A | 4.5 mc | 1 mc |
| B | 10.7 mc | 2 mc |
| C | 100. mc | 2 mc |
| D | 20-24 mc | 4 mc |
| E | 20-28 mc | 8 mc |
| F | 38-48 mc | 10 mc |
| 2 | 54-60 mc | 10 mc |
| 3 | 60-66 mc | 10 mc |
| 4 | 66-72 mc | 10 mc |
| 5 | 76-82 mc | 10 mc |
| 6 | 82-88 mc | 10 mc |
| 7 | 174-180 mc | 10 mc |
| 8 | 180-186 mc | 10 mc |
| 9 | 186-192 mc | 10 mc |
| 10 | 192-198 mc | 10 mc |
| 11 | 198-204 mc | 10 mc |
| 12 | 204-210 mc | 10 mc |
| 13 | 210-216 mc | 10 mc |

Sweep width is variable on each channel from zero to the maximum indicated above. Each channel is calibrated on the single frequency indicated or in the middle of the range indicated with the "Sweep Width" control turned to zero. Channels "A," "B," & "C" are provided with air trimmers for calibration.

On the other side of the panel, the "Video Selector" control selects the output frequency of the video carrier oscillator in any of the standard channel ranges. Thus, for Channel 2, 54-60 mc, the video carrier frequency is 55.25 mc; etc. Normally, the output of the video carrier oscillator is unmodulated. However, any external signal having a frequency from 5 cycles to 5 megacycles can be used to modulate the carrier. The modulating signal would be fed into the generator at the "Video Input" terminal and the modulated video carrier signal obtained at the outlet marked "Video-Marker Output." This latter signal can be fed to the antenna of a receiver and if it is properly modulated, can be substituted as a miniature TV station in place of regular broadcasts. This is a desirable servicing feature that is especially valuable in areas where signals are weak, unreliable, or are available only during limited periods of the day. (A suitable source of video signals will be described in the section on Special Test Instruments.)

At the end of the "Video Selector" switch there are two positions marked "X" and "Y." In the "X" position a marker generator is activated and its output appears at the "Video-Marker Output" terminal. The frequency range in the "X" position is 19 to 31 mc; in the "Y" position it is 31 to 50 mc.

The desired frequency in either of these ranges is selected on a 3-inch dial in the center of the panel.

The generator also contains a crystal oscillator whose frequency is determined by an external plug-in crystal. This oscillator is separate from the marker oscillator and thus makes it possible to obtain two markers at the same time by using a crystal of the desired frequency and setting the marker oscillator to the other desired frequency.

Another sweep generator wherein the various frequencies are obtained by means of a selector switch is the unit shown in Figure 33. Sweep frequencies for each of the twelve channels are available plus an IF position where a variable frequency oscillator produces signals from 0.3 to 50 mc. The operating frequency within this 0.3-50 mc range is selected by the "IF Video" knob. The markings on this control are only approximate since precise determination of any frequency in the response curve swept out is accomplished by a separate marker generator.

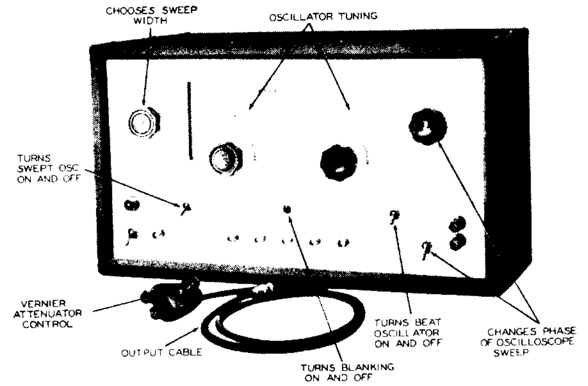



Figure 34. A Variable Permeability Sweep Generator. Courtesy of General Electric.

The maximum sweep width for the RF and IF positions is 10 mc.

## VARIABLE PERMEABILITY SWEEP GENERATOR

In the most sweep generators, the periodic variations in frequency are achieved either by electromechanical means or by a reactance tube. In the sweep generator shown in Figure 34, still another method is employed, one known as the variable permeability or the variable reluctance method.

The basic circuit employed is shown in Figure 35. An iron core choke is constructed with a wide gap and a small piece of powdered iron is placed across this gap. The tuning coil of the oscillator is then wound around this iron slug and whatever affects the permeability of the iron slug will automatically serve to alter the frequency generated by the oscillator.

When current is sent through the main choke winding, lines of flux are established in the iron core of the choke in the manner shown in Figure 35. Note that the lines of flux are more concentrated in the powdered iron slug than they are in the laminated iron core. Increasing the current through the choke winding will cause the lines of flux in both the laminated iron core and the powdered iron slug to increase in like measure. However, since the flux lines are more concentrated in the iron slug, their effect in altering the permeability of this iron section will be greatest. By applying a 60-cycle voltage to the main choke coil, we can force the slug permeability to vary in a similar manner and since the oscillator coil is wound around this slug, its frequency will vary, too. Since the flux changes 60 times a second, the frequency of the oscillator will shift back and forth at the same rate and we have achieved frequency modu-

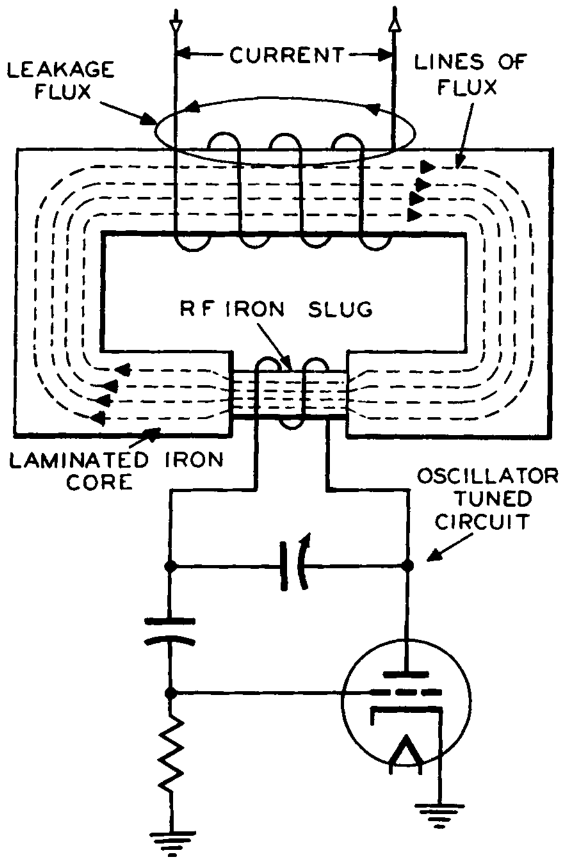



Figure 35. The Basic Modulator and Oscillator Circuit Used in the G.E. Variable Reluctance Generator.

lation. (For those readers who wish a more detailed description of this method of frequency modulation, reference should be made to the May, 1950 issue of Radio and Television News Magazine, P. 48.)

The sweep oscillator (or swept oscillator, as the manufacturer labels this stage) consists of a 6J6 dual triode with both sections paralleled as a modified Colpitts oscillator tuneable through a range of 165 to 220 mc. A series of voltage taps from the secondary of the power transformer allows the operator to select several widths of sweep output by means of the "Sweep Width" selector switch shown in Figure 34. Available sweep widths are as follows:

| "Sweep Width" Control | Approx. Width |
|---|---|
| Position 1* | 0 |
| 2 | 500 kc |
| 3 | 4.5 mc |
| 4 | 2 mc |
| 5 | 9 mc |
| 6 | 14 mc |
| 7 | 19 mc |

In position 1, the sweep oscillator functions as a simple AM generator producing frequencies over the range from 165 to 220 mc, depending on the setting of the oscillator variable capacitor. A front panel calibrated dial is provided for this purpose.

This generator will also cover the range from 4 mc to 110 mc and this is accomplished by beating another oscillator against the sweep oscillator. (See Figure 36.) The second or beat oscillator is tuneable from 220 mc through 275 mc. To cover the frequencies from 55 to 110 mc, the beat oscillator is left at 275 mc and the sweep oscillator is varied throughout its range from 165 to 220 mc. 275 mc minus 165 mc equals 110 mc and 275 minus 220 mc equals 55 mc. Hence the range from 55 to 110 mc is covered. The difference frequencies of the two oscillators are produced in a mixer and fed through an attenuator to the front panel.

The generator is also capable of developing voltages having frequencies from 4 mc to 55 mc. This is achieved by tuning the sweep oscillator to 220 mc and varying the beat oscillator over its range from 220 mc to 275 mc. The lowest output frequency which can be reached is 4 mc because when the beat oscillator approaches 220 mc, it has a tendency to lock in with the sweep oscillator and the frequency drops sharply to zero. Because of this, it is difficult (if not impossible) to obtain any frequencies below 4 mc.

The output attenuator in this instrument is in five steps, x 1, x .1, x .01, x .001, and x .0001. The strongest output would be obtained from the x 1 connector. Instead of using a selector switch to achieve the desired output level, there is a separate front panel connector for each level output. The RF output cable is plugged into whatever connector is desired.

Another feature of interest is the placement of the RF output potentiometer at the terminal end of the output cable. This attenuator control can be partially seen in Figure 34: it is shown by itself in Figure 37. The knob at the top of the unit is connected to the shaft of the potentiometer. Either balanced or unbalanced output arrangements are available.

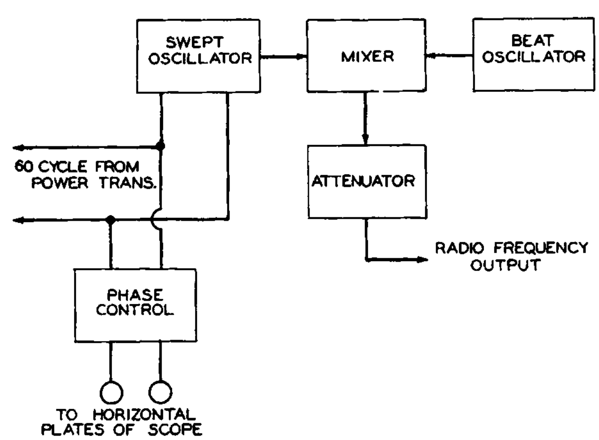



Figure 36. A Block Diagram (Simplified) of the G.E. Sweep Generator.

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* Maximum counter clockwise.

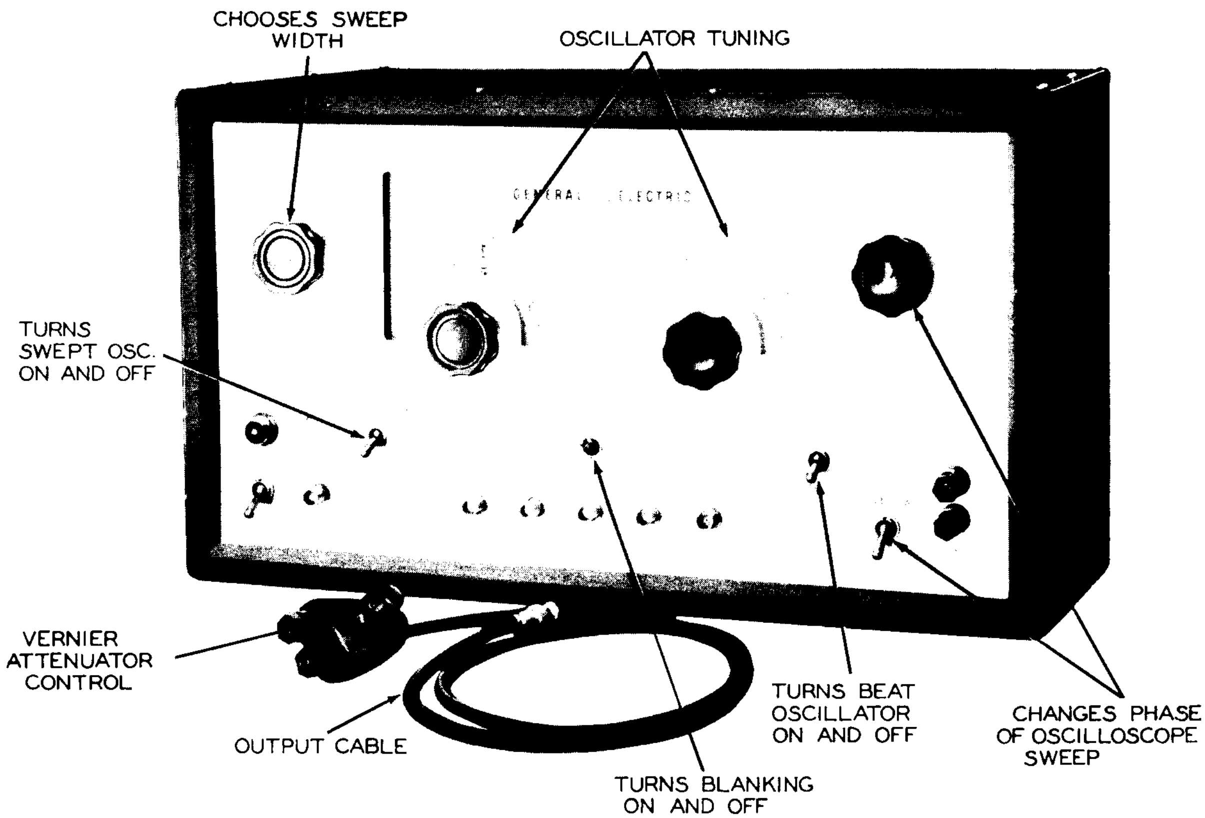



**Figure 34. A Variable Permeability Sweep Generator. (Model ST-4A, Courtesy of General Electric Co.)**

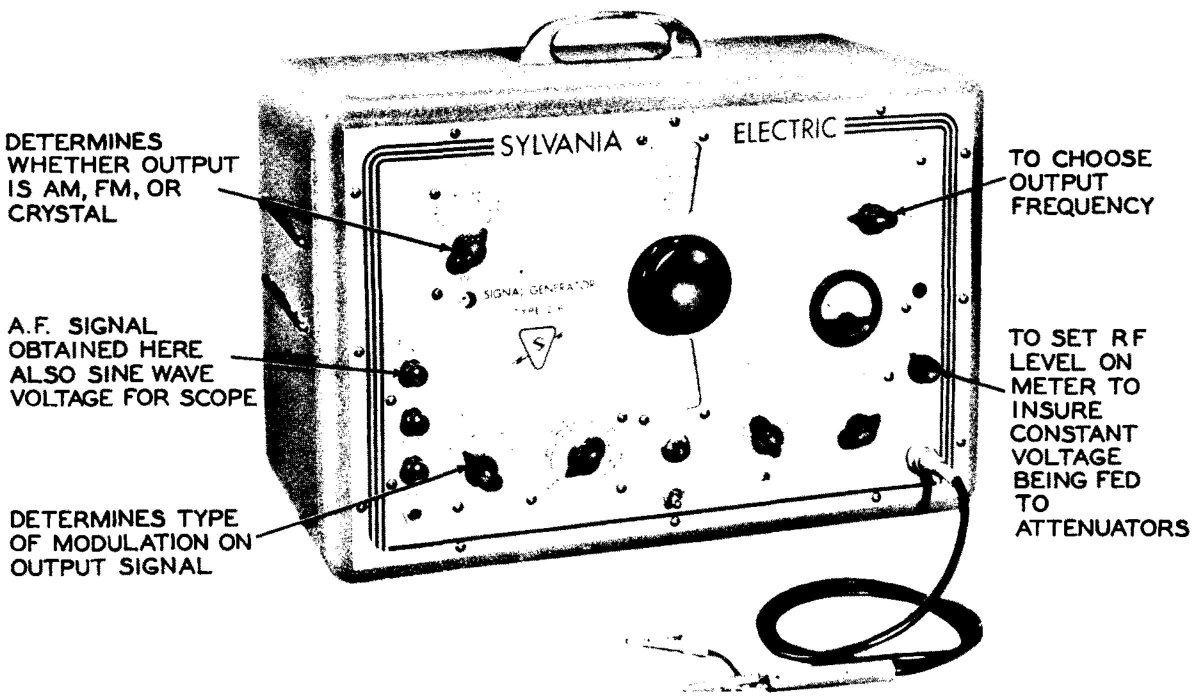



Figure 38. A Sweep Generator Designed Primarily for AM-FM Application, Although it Can Be Employed for Peaking of TV Circuits. (Model 216, Courtesy of Sylvania Electric Products Inc.)

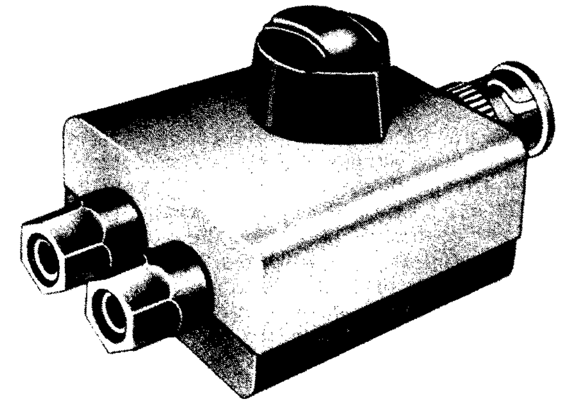


Figure 37A. The Output Adaptor Which Converts the Single-Ended Output of the G.E. Sweep Generator to a Balanced Output for Working Into a 300-Ohm Resistive Load.

Most of the remaining controls on the front of this sweep generator are similar to controls on other instruments which have already been discussed. Thus, there is a phase control, a phase reversal switch, and a blanking switch. Terminals are provided, too, for feeding a portion of the 60-cycle sweep voltage to the oscilloscope. Finally, an "Output To Marker" jack permits a portion of the RF output voltages to be fed to a separate marker generator also manufactured by the same company. Just what is accomplished by this will be seen presently when marker generators are discussed in the section on Special Test Instruments.

## AM - FM GENERATORS

Sweep generators, in general, are designed to be used with FM or TV receivers. This particular combination is a natural one since all television receivers contain an FM sound section and the allocated RF frequencies for the FM broadcast band, 88-108 mc, falls between the low and the high band television channels.

There are, however, a number of generators available that are meant to be used primarily with AM or FM receivers only. These instruments are useful for those shops that concentrate chiefly on AM or FM receiver servicing with little or no work in the TV line. Such instruments are also useful in those localities where there is no television.

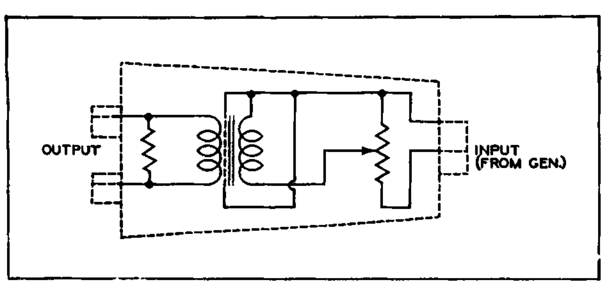



Figure 37B. Schematic Diagram of the Output Adaptor.

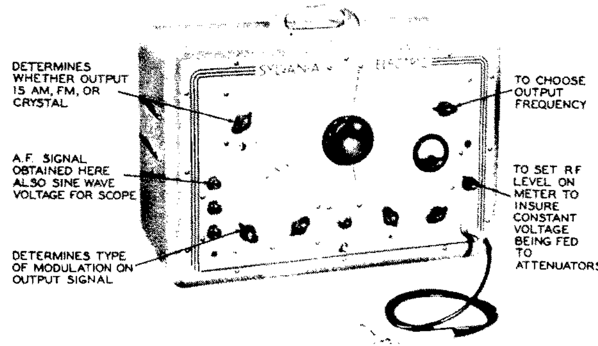



Figure 38. A Sweep Generator Designed Primarily for AM-FM Application, Although it can be Employed for Peaking of TV Circuits. Courtesy of Sylvania Electric Products, Inc.

An AM - FM generator that will illustrate the type of controls found on such instruments is shown in Figure 38. The functions of some of these controls will be recognizable immediately from previous discussions. Thus, the "RF Amplitude" control smoothly varies the RF output of the generator from zero to whatever level is established by the "RF Attenuator" switch. The lowest position of this latter control is at the "10K" point. The highest is at the "1" position.

The "Range" selector switch, in the upper right-hand corner, establishes the band of frequencies generated by the instrument. There are seven bands listed, extending from 80 kc at the low end to 60 mc at the high end. 60 mc, however, is not the highest frequency that can be obtained from the generator and the reason for this will be seen from the following description of the generator circuitry.

### CIRCUIT DESCRIPTION

Basically, there are two oscillators in this generator. One is continuously variable from 80 kc to 60 mc by means of a tuning dial and the "Range" selector switch, and its frequency is read directly from the dial, in black figures. The other oscillator may operate at either 1 mc or 60 mc depending on the setting of the "Output Selector" switch. It may be amplitude modulated or frequency modulated, depending on the setting of the "Circuit Selector" and the "Output Selector" switches. 400 cycle internal amplitude modulation, 0 to 100%, is available, using the AM CW setting of the "Output Selector" switch and the 400 AM position of the "Circuit Selector" control. 60 cycle frequency modulation is available on the 60 mc and 1 mc fixed oscillators, and 400 cycles on the 60 mc oscillator. The percentage modulation (for AM) or frequency deviation (for FM), is controlled by rotating the "Modulation" knob.

The outputs of the variable oscillator and the modulated fixed oscillator are combined in a mixer tube, when FM sweeps are used, and therefore the signal generator output under these conditions is a combination frequency of the two. Hence, to get the frequency of the output of the signal generator, it is necessary to add or subtract the frequency of the fixed oscillator (either 1 mc or 60 mc) and the direct dial reading. The most frequently used FM frequencies are marked in red figures on the dial. More on this point presently.

In addition to the two RF oscillators, the signal generator contains an audio oscillator which furnishes a 400-cycle audio signal for external use. It also contains a heterodyne detector, and provision for a 1 mc crystal. The crystal is not furnished with the signal generator, but can be purchased separately.

The output of the mixer tube in the signal generator is applied across an attenuator system possessing continuous and step attenuators. The output will vary considerably across the frequency range of the signal generator, and for this reason there is a meter connected across this point, so that the voltage across the attenuators may be kept constant at all times. The "RF Set" knob is used to keep this voltage constant at some arbitrary point about 6 on the meter. The "RF Set" control is not to be used to vary output; this is the function of the attenuators. If higher voltages are required for badly adjusted receivers, a "HI-RF" jack provides about 1.0 volt signal, with an impedance of 500 ohms. The impedance of the coax lead at the regular "RF" outlet is 50 ohms.

The controls on this instrument which would give the serviceman the greatest amount of trouble are the "Output Selector", "Circuit Selector", and "Modulation" controls. The following detailed description showing how the generator is set up to deliver AM and FM signals will help to clarify their application.

OPERATION -

A. To obtain Unmodulated RF (CW).

1. Set "Range" switch to the desired band and the tuning dial to the desired frequency.

2. Set "Circuit Selector" to CW.

3. Set "Output Selector" to AM - CW.

4. Set the "RF Set" control so that the meter reads 6.

5. Set the "RF Attenuator" switch and the "RF Amplitude" control to desired output. Maximum output will be delivered when the "RF Attenuator" is set to 1, and the "RF Amplitude" control is at the maximum clockwise position.

6. Connect test leads of the RF coaxial cable to circuit under test. Connect the metal shield to chassis ground.

When AC, DC receivers are being tested, an isolation transformer is inserted between the receiver and the AC line. If such a transformer is not available, then a 400 volt .01 mfd blocking capacitor should be connected between the signal generator ground and the receiver chassis.

The center lead of the coaxial cable should be isolated from the test point if a DC voltage is present here. Use a 400 volt .01 mfd. capacitor when using frequencies up to 1500 kc. Above this point a smaller capacitor may be used.

With the RF meter set to a constant reference level, the voltage across the attenuator system will be constant, regardless of frequency. To control the amount of signal in the coaxial cable, the "RF Attenuator" control will reduce the signal by multiples of 10 step-by-step, and the "RF Amplitude" control will permit smooth adjustment of the resultant signal, from zero to maximum. Maximum RF signal is available when the attenuators are set for maximum output, but these attenuators are not designed to control the "HI-RF."

B. To obtain Amplitude Modulated Output.

1. With internal modulation (0-100%, 400 cycles.)

(a) Settings same as those in the unmodulated CW output case, except that "Circuit Selector" switch is turned to "400~ AM" and the "Modulation" control is rotated clockwise to the desired percentage of modulation (Figure 39 A). The modulation control has four ranges but the only one of interest in the present set-up is the scale marked "% AM 400~.

2. With External Modulation.

(a) Settings same as those in (1), except that the "Circuit Selector" switch is set to "Ext. Mod." An external audio signal may then be connected between "Ext. Mod." binding post and ground. The external modulating frequency may be anywhere in range of 50 to 12,000 cycles. About 38 volts rms will produce 100% modulation.

3. The modulation control is calibrated to ±5% at the 30% (standard AM test modulation) point.

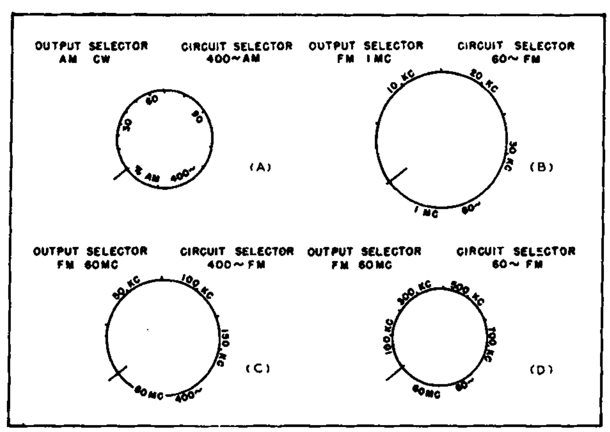



Figure 39. Modulation Dial Detail of Sylvania AM-FM Generator.

C. To use the Heterodyne Detector. *

1. Set the "Circuit Selector" switch to "Det." position, and turn the "RF Amplitude" control to 0, reducing signal at "RF" terminal.

2. Plug in a pair of headphones, preferably high impedance, into the "Phones" jack.

3. Set "Range" switch to desired band and tuning dial to desired frequency.

4. Apply the external signal between the "RF IN" jack and ground. The amplitude of the external signal should be at least .1 volt for best results. Do not apply an external signal of greater than 50 volts RF, or having a DC component of greater than 400 volts. When the frequency of the external signal and the signal generator coincide, a beat note will be heard in the headphones. At zero beat, the frequency on the signal generator dial is the same as the frequency of the external signal. Care should be taken that harmonics of either signal are not confused with the fundamental frequencies. Always use the signal which supplies the strongest beat note.

* Another name for beat detector. In this instrument a 1N34 germanium crystal is the detector.

The heterodyne detector affords the serviceman a method of checking the frequencies of unknown signals that fall within the range of this instrument.

D. To Obtain Audio Output.

1. Set "Circuit Selector" switch to "400 ~ AM" position and take off audio voltage between "AF Out" and "Ground" binding posts.

2. The audio output voltage at 400 cycles is 1.3 volts.

E. To Obtain Narrow Band FM Output for Testing AM Receivers.

1. Set the "Output Selector" switch to "FM 1 mc."

2. Set the tuning dial to the IF frequency desired, reading the red dial figures (0-600 kc). If other frequencies are desired they may be obtained by setting the black dial figures 1 mc higher than the desired center frequency.

3. By means of the "RF Set" control, ajust the output meter to a chosen reference level (about 6 on the meter scale).

4. Set the "Circuit Selector" switch to "60~ FM," and turn the modulation control to the sweep width required. (See Figure 39B).

5. The modulation control scale is calibrated to a ±5% at the 30 kc point.

This particular setting of the generator controls enables the serviceman to see the entire response curve of the tuning circuits of an AM receiver. (This operation is seldom performed because simple peaking using an AM generator and a VTVM will normally be sufficient. However, if a visual alignment is desired, this generator will furnish the necessary sweep signal.)

The red figures on the dial are used since they represent the frequencies derived from the signal mixing of the variable oscillator and the fixed 1 mc FM oscillator. Where the frequency desired is not given in red, turn the dial until its value is 1 mc higher than the frequency you wish. For example, if you want an FM signal of 8.5 mc, and this is not given in red, then set the scale to read 9.5 mc. This frequency mixed with the 1 mc FM oscillator will provide, at the output a difference frequency of 8.5 mc. (There will, of course, also be present the sum frequency of 10.5 mc which can also be used if it is needed.)

For this setting of the instrument controls, the "1 mc, 60~" scale of the "Modulation" control would be employed to set the desired sweeping range. The maximum sweep indicated is 30 kc.

F. To Obtain Wide Band FM Output for Testing FM Receivers.

1. Set the "Output Selector" switch to FM 60 mc. This brings in the 60 mc FM oscillator and mixes its output with that of the variable oscillator.

2. Set the tuning dial to the IF or RF frequency desired, reading the red dial figures. Frequencies other than those shown in the direct reading red scale have to be obtained by making your own computations, as follows:

   (a) Frequencies lower than 60 mc: Set the black dial figures to a reading 60 mc higher than the desired output frequency.

   (b) Frequencies higher than 60 mc: Set the black dial figures to a reading 60 mc lower than the desired output frequency. The reason for this procedure stems from the fact that to obtain signals below 60 mc, we are using the difference frequenices produced by the mixing of the two oscillator signals. Therefore, the black figures are set to a value 60 mc above the desired frequency. If 15 mc is required, mixing 75 mc from the variable oscillator (given in black figures) with the fixed 60 mc from the FM oscillator will give us what we want. On the other hand, to obtain signals above 60 mc, we use the sum frequencies from the two oscillators.

3. Adjust the output meter to a reference level of about 6.

4. Set the "Circuit Selector" switch to 60 cycles FM, and turn the "Modulation" control to the sweep width desired. Maximum sweep available is 700 kc. (Plus 350 kc and minus 350 kc.)

60 cycles FM means that the frequency modulation is occurring at a 60 cycle rate. This is similar to the 60 cycle sweeping of the frequency in the TV generators previously discussed in this section. When the generator of Figure 38 is being used to sweep out a response curve of an FM receiver, 60 cycle sine wave sweeping voltage for the oscilloscope is obtained from the terminal marked "AF Out (Sync)".

There is also available on this generator a 400 cycle FM position where the frequency modulating or frequency sweeping is occurring at a 400 cycle rate instead of the more conventional 60 cycle rate. This is done so that the serviceman will have a source of FM output which can be used for checking the overall performance of an FM receiver for distortion. When this 400 cycle FM modulated signal is fed into the mixer of an FM receiver, for example, and passed through the IF system, FM detector, and audio stages then a 400-cycle note will be heard in the speaker. By means of an oscilloscope connected even as far down the line as the voice coil of the receiver, you can observe any distortion of the 400 cycle modulation which might have crept in at some point in the receiver through which the signal has passed. Further, by sending the FM signal through the entire receiver, a check of distortion from antenna to voice coil can be made.

Of course, 60 cycle FM modulation might also be used in the same manner although a 400 cycle note is easier to work with (i.e., listen to) than the raspy 60 cycles.

In the generator of Figure 38, a 400 cycle sine wave voltage for the horizontal input terminals of the oscilloscope is available at the "AF Out (Sync)" post when the "Circuit Selector" switch is in the "400 FM" position.

G. External Modulation.

1. With the "Output Selector" switch set on either "FM 1 mc," "AM CW," or "FM 60 mc," the "Circuit Selector" may be set to "Ext. Mod." and the signal then will be modulated by any audio frequency signal applied between the "Ext. Mod." binding post and the "Ground" binding post, providing it is in the frequency range between 50 and 12,000 cycles. At other frequencies some modulation may be obtained, but possibly not the full amount. When using external modulation, the "Modulation" control should be turned fully clockwise, to prevent loading the signal source.

H. Very High Frequencies.

Due to the fact that harmonics are present in the output of all oscillators, a second harmonic of the AM CW oscillator will furnish output up to 120 megacycles, with some output even at higher frequencies. These harmonics can be made use of in aligning the short wave sections of AM receivers going above 60 mc, and their frequency is simply twice the frequency indicated on the calibrated dial. Considerable energy is present even at TV RF frequencies, and an AM signal may be used to produce bar patterns on picture tubes.

When the outputs of the sweep oscillator and the variable oscillators are combined, as in the procedure when FM signals are being used, numerous harmonics are available. The sum and difference frequencies will be quite strong, and their harmonics will be strong enough for most alignment work. This makes it possible to obtain useable signals up to 240 megacycles. The frequency is read by adding 60 mc to the dial reading, and multiplying the sum by two.

Visual alignment of the video RF or video IF stages of a television receiver is not possible because the maximum frequency swing obtainable from this instrument is only 700 kc. However, visual alignment of the sound IF stages of a television receiver can be carried out.

I. To Check or Calibrate, Using an Internal Crystal.

1. Turn "Output Selector" to "Xtal 1 mc," and "Circuit Selector" to "Det."

2. Plug headphones into phone jack, and turn dial for zero beat. Beats will be found for the fundamental and large number of harmonics of the crystal frequency. An external lead may be run from the "Xtal Output" to the "RF IN" jack to pick up weaker harmonics for higher frequency comparisons.

## HICKOK AM-FM GENERATOR

An AM - FM generator which is somewhat more elaborate than the foregoing instrument is shown in Figure 40. This contains, in addition to the signals provided by the previous generator, an audio signal capable of being varied between 0 and 15 kc, dual-frequency crystal control, and an output or db meter. The crystal oscillator can provide output frequencies of either 100 kc or 1000 kc and harmonics of each so that appropriate points may be checked all along the frequency dial.

The decibel (db) meter consists of a conventional copper oxide rectifier and its associated meter. The meter may be used to measure output voltage ranging from zero to 140 volts or decibel power levels ranging from -10 db to 38 db. As all of the db meter scales are calibrated on the basis of 0 db = .006 watts (6mw) when used across a 500-ohm termination, the voltage readings and db readings correspond only when the meter is connected across a 500-ohm termination. There is a blocking capacitor in the decibel meter for circuits having a DC component.


Figure 40. Another Sweep Generator Designed Principally for AM-FM Application. (Model 288, Courtesy of Hickok Electrical Instrument Co.)

A brief description of the various controls on this instrument will inidcate their function.

A. "Frequency Modulated Sweep" - A dual purpose control which is used as the AC line power switch and also as a control of the bandwidth of the sweep for frequency modulated output. To place the instrument in operation, turn the control clockwise until the line switch is closed which will be indicated by an audible click and the lighting of the pilot light. The position of this control, when not operating as a bandwidth sweep control, has no effect on the operation of the instrument.

B. "Band Selector" - A ten-position control; The first seven positions, Bands "A" through "G," select various frequency ranges from 100 kc to 110 mc, the next two positions select either the "100 kc" or "1000 kc" crystal frequency and the last position selects the "0-15 kc" audio frequency. (Note that 1000 kc is equal to 1 mc.)

C. "Frequency Adjustment" - Control of the frequency within the range selected by the "Band Selector" switch. Calibration of the dial permits interpolation of the scale if desired.

D. "Output Control" - Linear potentiometer control of the RF and AF output voltage of the signal generator.

E. "Output Multiplier" - A five-position control of the output of the signal generator. Positions "RF x 1," "RF x 10," and "RF x 100" are the three output levels of RF signal. Positions "0-15 kc AF FM," in conjunction with the "Output Selector" switch, selects either the 0-15 kc audio frequency output or any of the frequency modulated outputs. Position "400 AF" selects the 400 cycle audio voltage as an audio signal or for amplitude modualtion.

F. "FM - AM Selector" - A three position control.

1. "Amplitude Modulated" for all outputs other than frequency modulated outputs.

2. "1000 kc 30 kc Sweep" for the 1000 kc signal frequency modulated with a bandwidth of 0-30 kc.

3. "50 mc 450 kc Sweep" for the 50 mc signal frequency modulated with a bandwidth of either 0-150 kc or 0-450 kc.

F. "Output Selector" - A five position switch selecting the various types of outputs.

1. "Off Ext." for unmodulated radio frequency output or either frequency or amplitude modulation from an external source.

2. "400~ AMP" for 400 cycle amplitude modulation and for a 400 cycle, fixed audio frequency signal.

3. "400~ Freq." for 400 cycle modulating frequency used for frequency modulating the 50 mc, 0-15 kc sweep output.

4. "60~Freq." for 60 cycle modulating frequency used for frequency modulating either the "1000 kc -30 kc sweep," or "50 mc -450 kc sweep," output.

5. "0-15 kc AF" for an audio frequency variable from 0 to 15 kc.

H. "Variable Audio Frequency" - A calibrated variable control of the audio frequency output from 0 to 15 kilocycles.

I. "Synchronized Sweep Voltage" ("Gnd-Output"). Output connections for a 60 cycle voltage from the power supply for supplying the horizontal sweep of an oscilloscope. Note that a 400 cycle sine wave voltage is not available for deflecting the scope beam. If it should be desired to use the 400 cycle FM for developing response curves, it would be necessary to go internally into the instrument to obtain the 400 cycle audio source to be used simultaneously with the 400 cycle FM output. Without this change, response curves must be obtained using the 60 cycle FM sweep.

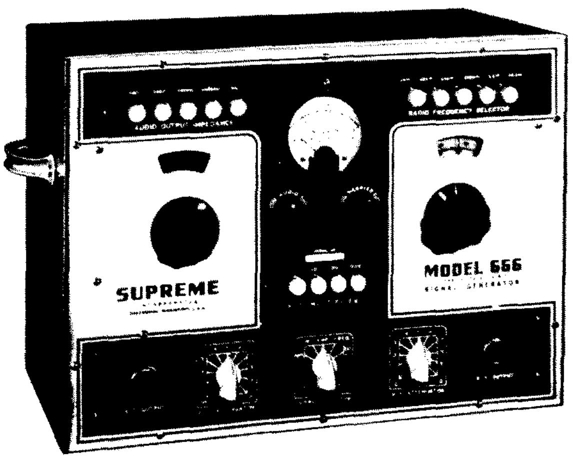



Figure 41. A Push-button Type of Signal Generator. Courtesy of Supreme Instrument Co.

J. "External Modulation (Amp-Freq.)" - Amp: permitting amplitude modulation connection from an external source. Freq: permitting frequency modulation connection from an external source.

K. "Pilot" - Indication of power being supplied the signal generator.

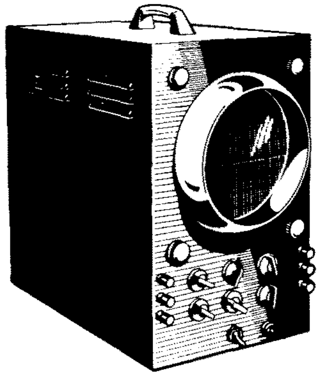
L. "Output" - Attached shielded output cable for the output signal.

M. "Decibel Meter" - (-10 to +6, +6 to +22, +22 to +38) - pin jacks for connection to the combination AC voltage and decibel meter at one of the three ranges available.

N. "Ground" - Binding post for connecting the ground of the signal generator to that of any associated equipment; also the ground connection for the "Decibel Meter."

Before we leave the subject of AM-FM generators, we might note the unit shown in Figure 41. In place of a selector switch for choosing the RF band, push buttons are employed. To choose a certain band, the appropriate push button is depressed. The exact frequency, then, within this band is obtained by rotating the dial to the proper position.

Similar push buttons are available for the "RF Multiplier" and the "Audio Output Impedance." The latter is a special transformer in the audio frequency section which offers the serviceman a choice of four selected impedances to match the input of P-A amplifiers, motion picture sound equipment, interdepartment communications systems, etc. Audio frequencies from 15 to 15,000 cycles are available.



# section four

## The Oscilloscope

### INTRODUCTION

It does not take a serviceman long to discover that one of his most valuable tools in the servicing and alignment of television receivers is the oscilloscope. For servicing, the oscilloscope is used to reveal the waveshape of the signal in each of the circuits through which it passes. Of particular interest are the video amplifiers, the sync separator circuits, and the horizontal and vertical sweep systems. In each of these circuits comparison of the signal as it is with the waveform diagrams furnished by the manufacturer provides an excellent method of determining whether or not a circuit is operating properly.

For alignment, the oscilloscope is a natural companion to the sweep generator, depicting graphically the response curve of the circuit into which the sweep signal is fed. This superior method of aligning wideband circuits not only provides an instantaneous picture of the circuit conditions as they exist, but any changes that are wrought by adjusting coil cores and/or trimmer capacitors in the circuit become immediately apparent. The technician is thus kept fully informed at all times of the condition of the circuit being worked on.

Much of the mystery which once surrounded the oscilloscope, its mode of operation and the circuits it employs, has now been replaced by everyday familiarity. This is because an oscilloscope and the deflection circuits in a television receiver operate by the same basic principles. In a television receiver, saw-tooth deflection currents (or voltages, depending upon whether there are deflection coils or deflection plates) sweep the electron beam from side to side or from top to bottom. This, too, is the action in an oscilloscope with the exception that in the oscilloscope the saw-toothed deflection voltage is applied only to the horizontal deflection plates. The vertical deflection plates receive the incoming signal. Focus and centering controls (of one sort or another) are similar in purpose in TV sets and oscilloscopes. An intensity control on an oscilloscope becomes the brightness control on a television receiver. These are some of the more obvious similarities - others will become apparent as we describe and examine many of the oscilloscopes which are currently available to the serviceman.

### BASIC OSCILLOSCOPE CIRCUITS

The heart of an oscilloscope is the cathode-ray tube, for it is on the fluorescent screen of this tube that the various waveforms applied to the unit are depicted. A beam of electrons is developed in a gun structure located at the narrow or neck end of the tube. Electrons emitted by a hot cathode are accelerated forward and as they travel through a series of metallic cylinders, they are formed into a narrow beam. This beam then travels down the length of the tube to the fluorescent screen. See Figure 1. Wherever the beam strikes the screen, visible light is produced.

As in the case of the conventional vacuum tube, the control grid regulates the number of electrons which travel past it. Since the extent of this electron flow directly affects the intensity of light which is emitted by the fluorescent screen, the illumination level is controlled by varying the grid voltage on the tube. This control is placed on the front panel of the instrument and is called the "Intensity" control. See Figure 2. Turning this knob counterclockwise will cause the trace produced by the beam to become dimmer until it finally disappears; turning the control knob to the right or clockwise will gradually raise or increase the beam intensity.

There is no one correct position for this control. Just how intense the beam should be will depend upon the amount of surrounding light. If the oscilloscope is used in an area where the light level is high, then, in all probability, the "Intensity" control will be turned well to the right. Where the surrounding light is not too bright, a less intense trace will prove sufficient. It all depends on the serviceman and where he works.

The electrons emitted by the cathode have a tendency to spread out, and it is necessary to control

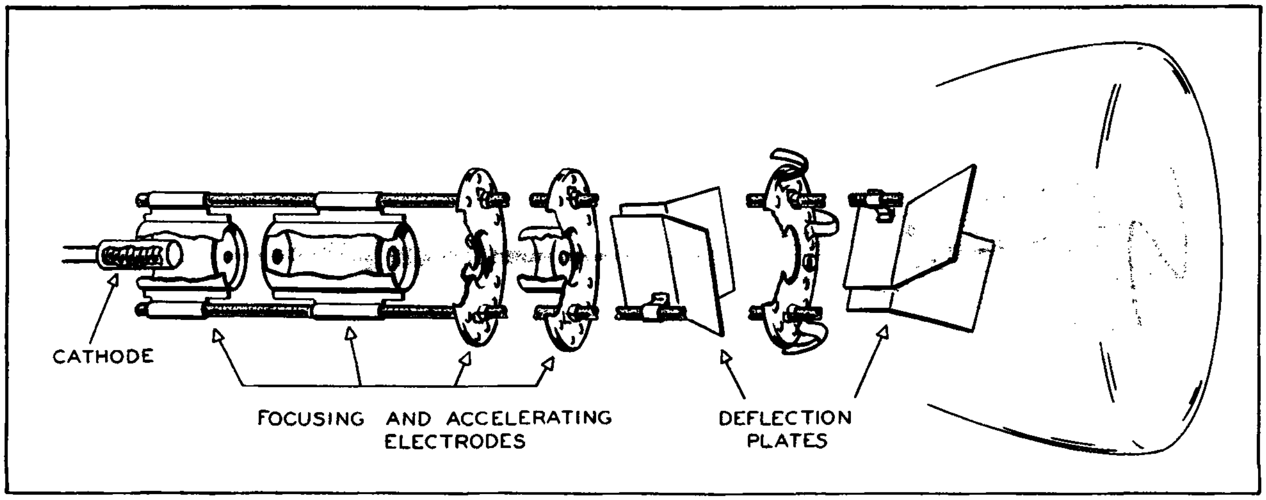



Figure 1. The Internal Structure of an Electron Gun and the Path Travelled by the Beam in Reaching the Fluorescent Screen.

and focus them into a narrow beam. This is accomplished by the focusing and accelerating electrodes, which act in the same manner as the optical lens system of a camera, except that in this case, it is an electron beam which is focused rather than a light beam. By adjusting the voltage applied to the focusing electrode, the beam diameter is controlled. The potentiometer which performs this function is also mounted on the front panel and is called the "Focus" control. See Figure 2.

After passing through the focusing and accelerating electrodes, the electron beam reaches two sets or pairs of deflecting plates which are mounted at right angles to each other. Remembering that electrons are inherently negative and that opposite charges attract and like charges repel, we can

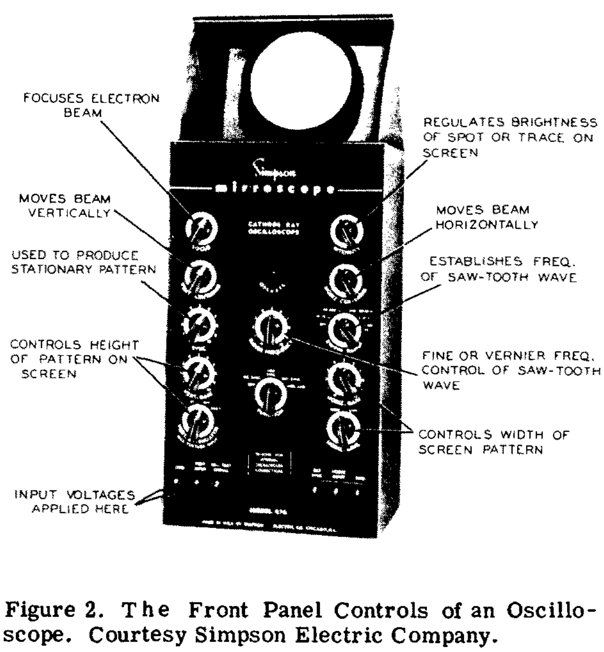



Figure 2. The Front Panel Controls of an Oscilloscope. Courtesy Simpson Electric Company.

appreciate what these plates do. Looking in at the face of the tube (Figure 3) we would see the fluorescent screen, the plates, and the white (or light) dot caused by the electron beam striking the screen.

If now we apply a positive voltage to Plate H1 and a negative voltage to plate H2, H1 will attract the beam, H2 will repel it, and the beam will move closer to H1. Therefore, the dot of light is displaced to the left. By the same token, if the reverse voltages are applied to the plates, the beam would move to the right.

If an alternating voltage is applied to both plates, the beam will continuously deflect from one side to the other. If the voltage is made to change quickly enough, the result will be a horizontal line. See Figure 4. The most common type of voltage which is applied to the horizontal deflection plates is the saw-tooth wave shown in Figure 5. From A to C the voltage rises steadily and linearly, moving the beam across the face of the oscilloscope screen at an

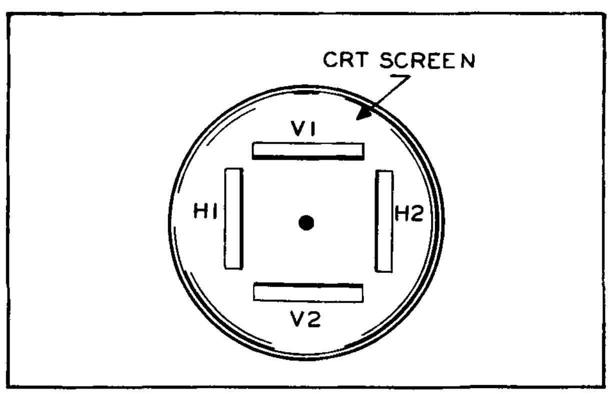



Figure 3. The Horizontal Deflection Plates (P1 and P2), the Vertical Deflection Plates (V1 and V2), and the Fluorescent Screen of a CRT as Seen Head-On. With no Deflection Voltages Applied to any of the Plates, the Electron Beam Will Strike the Screen at the Center.

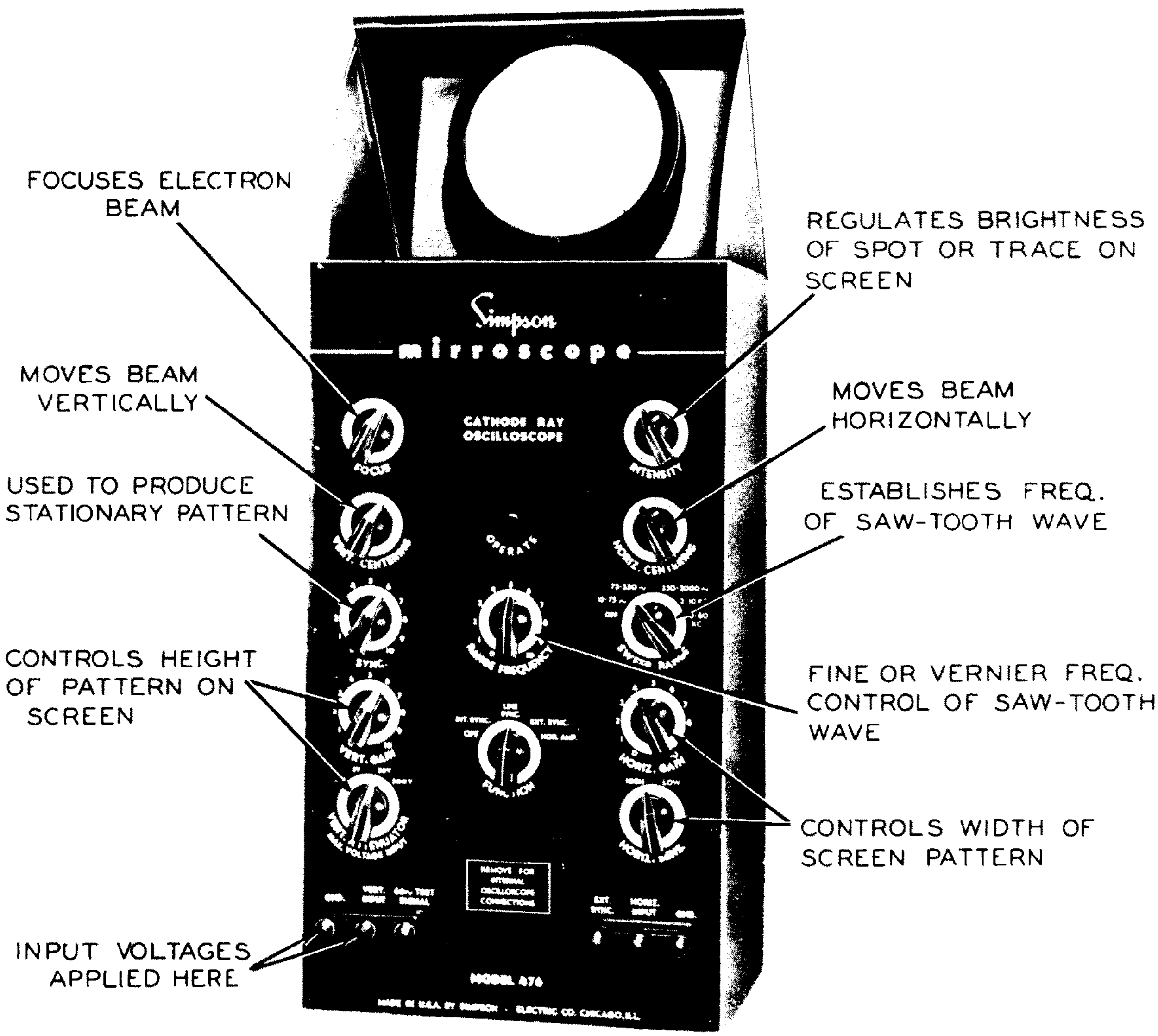



Figure 2. The Front Panel Controls of an Oscilloscope. (Model 476, Courtesy of Simpson Electrical Co.)

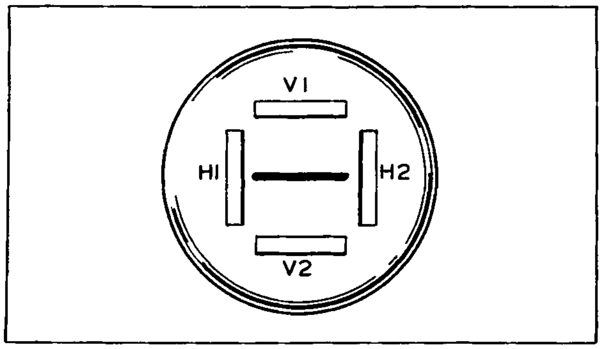



Figure 4. An Alternating Voltage Applied to the Horizontal Deflection Plates H1 and H2 Will Produce a Line on the Screen.

even rate. At point C, it drops sharply, returning to the same level as point A. This drop causes the electron beam to retrace rapidly.

Half of the applied saw-tooth wave is negative (points A to B) and while this portion of the wave is active, the beam is at some point to the left of center. At A the beam is farthest to the left, but as the saw-tooth voltage gradually rises, the beam is drawn in toward the center, reaching this point when the voltage reaches point B. As the voltage continues to rise, the forward motion of the beam brings it to the far right-hand section of the screen when the saw-tooth voltage reaches point C. From point C to point D, the saw-tooth voltage drops sharply, causing the electron beam to retrace quickly back to the left-hand side of the screen again.

We see from this sequence that the application of a saw-tooth voltage to the horizontal deflection plates moves the beam first one way across the screen, and then the other way. If this back and forth motion is repeated often enough per second, the various traces blend into each other, producing a steady horizontal line (also known as a base or axis) of uniform intensity.

To reproduce a certain waveform, say the response curve shown in Figure 6, then as the beam travels on its way from left to right, we also want it to move vertically (or up and down). This can be accomplished by applying the wave to be reproduced

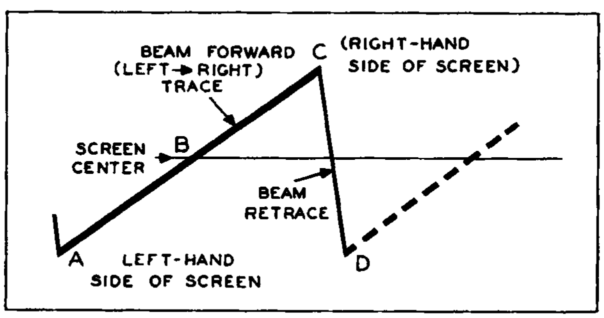



Figure 5. The most Common Type of Voltage which Is Applied to the Horizontal Deflection Plates in a CRT Is the Saw-Tooth Wave.

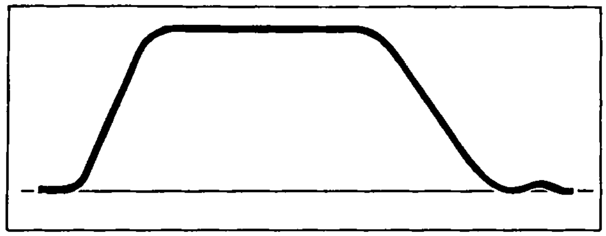


Figure 6. To Reproduce this Curve on a Scope Screen, then as the Beam Travels from Left to Right, it Must also be Made to Move Vertically.

to the vertical deflection plates. When the voltage applied to the vertical plates increases, the beam moves up; when it decreases, the beam moves down. In this way the beam moves up and down as it travels across the face of the cathode-ray tube and the wave-shape of any voltage applied to the vertical deflection plates is traced out.

It is perfectly feasible to apply waveforms to be observed directly to the deflection plates themselves and this is sometimes done (as we shall see later). However, in order to obtain any sizeable deflection of the beam, either straight across or up and down, a considerable amount of voltage is required. A much more flexible arrangement is achieved by inserting amplifiers between the deflection plates and the applied voltages. Now, with rather small input voltages, a sizeable deflection of the electron beam can be obtained and the usefulness of the oscilloscope as a test instrument is increased.

The block diagram of the oscilloscope, thus far, appears as shown in Figure 7. There is one set of amplifiers leading to the vertical deflection plates and a similar set feeding the horizontal plates. Just how many amplifier stages are contained in each system depends upon how elaborately the oscilloscope is designed. In the more expensive units there may be as many as four stages; in the lower priced instruments only two stages will be found. In practically all instances, the final or output stage is push-pull, providing balanced voltages for each set of deflection plates. The use of such balanced voltages produces a trace which is uniformly wide at both ends of the trace line. When single-ended amplifiers are used, this is not true.

Aside from a power supply, only one more circuit is needed in Figure 7 to complete the basic diagram of an oscilloscope. This is the sweep or saw-tooth generator, the stage which develops the saw-tooth wave which is applied to the horizontal deflection plates through the horizontal deflection amplifiers. Two types of saw-tooth generators are in general use today, the multivibrator and the thyatron tube. The multivibrator is a resistance-capacitance coupled oscillator in which the frequency of oscillation is determined by the values of the capacitances and resistances used in the circuit. The saw-tooth wave is developed across a capacitor which is allowed to charge (producing the trace or forward motion of the electron beam in the oscilloscope) and then rapidly discharged (producing the faster retrace portion). This multivibrator is identical in form to

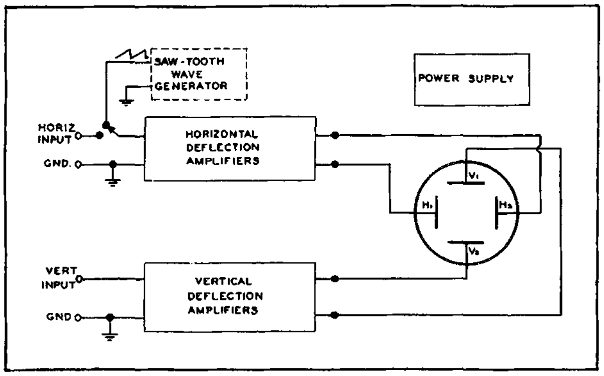



Figure 7. A Simplified Block Diagram of an Oscilloscope.

the multivibrators used in the sweep systems of the television receivers.

The thyratron tube is a gaseous tube of special construction. In the thyratron circuit, Figure 8, when the power is first applied, the capacitor C, connected across the tube, will charge up at an approximately uniform rate until it reaches a certain potential known as the ionizing potential of the tube. (Until this level is reached, the tube is nonconductive.) When the tube ionizes, it conducts heavily, effectively placing a short-circuit across capacitor C and causing it to discharge rapidly. When the potential across the capacitor, and therefore the tube, drops below a level known as the deionization level, the tube ceases to conduct and the charge again builds up across the capacitor. This deionization level is close to zero and so the voltage build-up across the capacitor C ranges between the ionizing potential at which the tube fires and the deionizing potential at which it ceases to conduct. See Figure 8. The frequency of the saw-tooth wave generated depends upon how rapidly C charges and this, in turn, is governed entirely by the relative values of C and R.

The foregoing circuits represent the basic components of every oscilloscope. Just how many front panel controls will be found on the instrument depends upon how elaborate its circuits are. In the discussion to follow, we will examine the operating controls of a number of modern oscilloscopes in order to see not only what these controls do, but how they are employed in television service and alignment work.

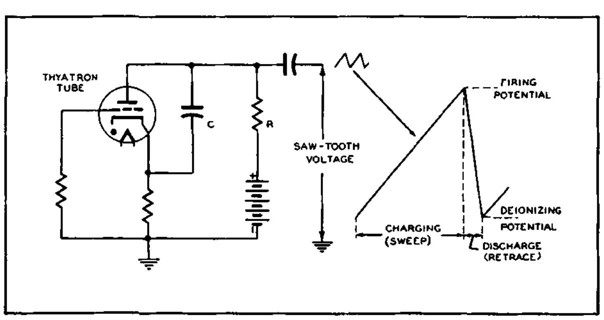



Figure 8. Thyratron Tube Method of Developing Saw-Tooth Waves.

## OSCILLOSCOPE OPERATING CONTROLS

The oscilloscope in Figure 2 contains what might be termed a typical number of controls. The "Focus" control is used to adjust the sharpness of the trace or point of light on the screen. This knob is rotated until the trace is as sharp and as clearly defined as it can be. The "Intensity" control enables the operator to adjust the brilliance of the spot or trace. The proper method of adjusting this control was previously discussed. To move the beam vertically or horizontally, "Vert. Centering" and "Horiz. Centering" controls are provided. Rotating the vertical centering knob moves the trace or pattern up or down while rotating the horizontal centering knob moves the pattern left or right. With the aid of these two controls, the pattern can be positioned anywhere on the face of the tube.

The next three controls, "Sync," "Range Frequency," and "Sweep Range," are all associated with the saw-tooth generator contained in this instrument. The simplest of the three controls, and actually the one to be set first, is the "Sweep Range" control.

In the "OFF" position, this control turns the sweep generator off and the beam appears as a pin point of light at the center of the screen. In other words, by turning the sweep generator off, we have removed all deflection voltages from the horizontal deflection plates and the electron beam impinges on the screen at a single point, usually the center.

If the beam is permitted to remain stationary at one point on the screen with even normal intensity, it will soon burn the screen, with the result that in future use this area may become insensitive and not produce any light at all as the beam passes over it.

If, in the process of working with an oscilloscope, it becomes necessary to shut off the sweep oscillator, then reduce the beam intensity until the spot is only faintly visible.

The question now arises, "When is it necessary to set the 'Sweep Range' control to the 'OFF' position?" The answer: When a special 60-cycle sine wave deflection voltage is fed to the oscilloscope from a sweep generator during an alignment. It will be remembered that this particular point was discussed in the previous section on sweep generators. The 60-cycle sine wave voltage from the generator is fed into the oscilloscope at the terminals marked "Horiz. Input" and it is used in place of the saw-tooth voltage to deflect the beam horizontally. We will return to this point again when we discuss TV receiver alignment.

Beyond the "OFF" position, the "Sweep Range" switch selects the operating frequency range for the horizontal saw-tooth oscillator. The first position beyond "OFF" is labeled 15 to 75 cycles, which means that the frequency of the saw-tooth deflection voltage produced will lie within this range.* The exact fre-

- - - -

* The frequency of the saw-tooth wave tells you how many times a second the beam sweeps across the screen from left to right and how many times it retraces. For example, a 60-cycle saw-tooth wave will move the beam 60 times per second from left to right and 60 times from right to left on retrace.

quency generated between 15 and 75 cycles will be established by the position of the "Range Frequency" control. This potentiometer is a fine tuning or vernier adjustment on the "Sweep Range" control. At the low end of its rotation the saw-tooth frequency generated is at its lowest value for any position of the "Sweep Range" switch; at the other end (extreme clockwise position), the saw-tooth frequency is at the highest value for the range chosen by the "Sweep Range" control. In the case of the 15 to 75 cycle position, this would be 75 cycles (approximately).

Sweeping ranges of this particular instrument (of Figure 2) extend from 15 cycles to 60,000 cycles. This permits us to see one cycle of any wave having a frequency between 15 cycles and 60,000 cycles. Any wave with a frequency above 60,000 cycles will develop more than one cycle on the oscilloscope screen; any wave having a frequency less than 15 cycles will develop less than one cycle during one forward trace of the electron beam.

To use the two foregoing controls to observe one or more cycles of any wave applied to the vertical input terminal (and ground, of course), set the "Sweep Range" switch to the range within which the signal frequency falls. Then rotate the "Range Frequency" control until one cycle (or two or as many as desired) appears on the oscilloscope screen.

If you don't happen to know the approximate frequency of the applied signal, it takes but a minute to try each of the five range positions of the "Sweep Range" switch until you find the best range to use. After a little practice it takes longer to explain how to do it than it does to do it.

In order to work with any pattern on the screen, the pattern should be held stationary. With the "Range Frequency" control, it is possible with some patience, to adjust the frequency of the saw-tooth generator until it exactly equals (or is an exact muliple of) the frequency of the applied vertical signal. But, unless this control is constantly adjusted, the frequency of the saw-tooth generator will change (even if only a few cycles) and the pattern will drift.

To keep the trace or pattern steady without frequent recourse to the "Range Frequency" control, a portion of the incoming signal is fed to the saw-tooth generator and serves as a synchronizing pulse which locks the generator in step with its own frequency. The "Sync" control enables the operator to vary the amount of synchronizing pulse or signal fed to the sweep oscillator. The optimum position for this control is at that point where the smallest amount of sync signal causes the pattern to become stationary. Thus, you start with the "Sync" control at zero and slowly turn it to the right (clockwise) until the pattern locks in.†

The three controls just described and especially the "Sync" control, are to be used in conjunction with the "Function" switch situated just below them.

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† It is important before using the "Sync" control to adjust the "Range Frequency" knob until the pattern is close to being stationary.

This "Function" switch is a 5-position switch which controls the power input and selects the desired horizontal deflection signal. The power is off in the OFF position of the switch and is on in the remaining four positions. In addition, the switch makes the following connections in its 5 positions:

1. OFF. Opens the circuit for the power input.

2. INT. SYNC. A linear (or saw-tooth) sweep voltage is applied to the horizontal amplifier. At the same time, a portion of the "Vert. Input" signal is fed into the sweep oscillator through the "Sync" control. If the frequency of the applied (or "Vert. Input") signal is near frequency, the pattern can be locked steady on the screen of the cathode tube.

3. LINE SYNC. The saw-tooth sweep voltage is still applied to the deflection plates through the horizontal amplifier. However, now, the synchronizing voltage is not taken from the incoming signal, but from the 60-cycle power line. The 60-cycle pulse is injected into the sweep oscillator through the "Sync" control and therefore locks the saw-tooth oscillator in sync with the line frequency. This is usable for applied signals having frequencies of 20, 30, 60, 120, and 180 cycles, and for other sub-harmonics of 60 cycles.

4. EXT. SYNC. The saw-tooth sweep voltage is still active. However, now, a synchronizing pulse can be obtained only from an external signal injected into the sweep circuit through the "Ext. Sync" terminal. The setting of the "Sync" control still determines how much of this sync pulse reaches the saw-tooth oscillator.

5. HORIZ. AMP. In this position the saw-tooth voltage of the oscilloscope's sweep generator is disconnected from the horizontal amplifier and the beam is stationary at the center of the screen in a small, round spot. To obtain any horizontal deflection of the beam, an external signal must be applied to the "Horiz. Input" terminal at the front of the oscilloscope. This signal will be amplified by the horizontal amplifier and applied to the horizontal deflection plates of the cathode-ray tube.

When the "Function" switch is in the "Horiz. Amp." position, no use is made of the internal sweep oscillator of the oscilloscope. Consequently, to prevent stray voltages from the oscillator reaching the horizontal system, it is always best to place the "Sweep Range" switch in the OFF position when the "Function" switch is set at "Horiz. Amp."

The most frequent use that the TV serviceman will make of the "Horiz. Amp." position will be in TV or FM receiver alignment. As discussed previously, nearly all sine wave sweep generators supply their own 60-cycle deflection voltage for the oscilloscope and this should be used in preference to a 60-cycle saw-tooth or sine wave voltage which the oscilloscope may be capable of supplying.*

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* An exception to this occurs when the oscilloscope contains specific provision (in the form of a phasing control) enabling it to develop a properly phased pattern. Such units will be examined presently.

On either side of the "Function" switch are the gain controls for the vertical and horizontal amplifiers. Thus, the "Vert. Gain" control adjusts the amplitude of the signal fed into the vertical pre-amplifier and hence it controls the height of the pattern on the viewing screen. The "Horiz. Gain" potentiometer adjusts the input to the horizontal amplifier to produce the desired pattern width on the cathode-ray screen. This control is effective whenever any voltages, external or internal, are applied to the horizontal amplifier.

Just beneath the "Vert. Gain" control is the "Vert. Attenuator" switch. This is a voltage divider network which limits the amount of the vertical input signal reaching the first vertical amplifier. There are four switch positions labeled: .5, 5, 50, and 500 volts. These figures indicate the maximum value of input signal that should be applied with the switch in each position. Thus, with the attenuator switch in the .5 position, no signal having an amplitude greater than .5 volts rms should be applied to the "Vert. Input" terminal (and ground). Excess voltage on any range may produce a distorted pattern or may possibly cause damage. On the other hand, setting the control pointer too high - say at 500 volts for an input voltage of 30 volts will produce a pattern which is too small. In other words, do not set the control too high or too low.

The "Vert. Attenuator" switch receives the applied signal before the "Vert. Gain" control. Hence, the attenuator switch may be considered as a rough adjustment with the gain potentiometer as its vernier.

The last remaining control on the front panel of this instrument (Figure 2) is the "Horiz. Sens." switch. This two-position switch is in series with the line from the "Horiz. Input" terminal to the horizontal amplifier and it is marked "High" for the closed position of the switch. The circuit (Figure 9) indicates that the full signal is fed to the horizontal amplifier when the switch is in the "High" position. The system is thus most sensitive at this setting and affords any applied signal maximum amplification (provided, of course, that the "Horiz. Gain" control is turned up, too.)

The "Horiz. Sens." is marked "Low" for the open position of the switch and a 1 megohm resistor is placed in series with the input to the "Horiz. Gain" control.

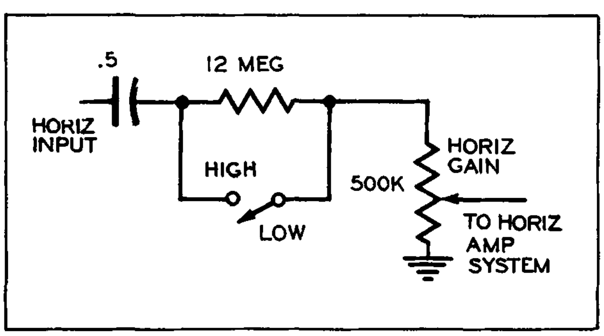


Figure 9. The Horizontal Input Circuit of the Instrument Shown in Figure 2.

These markings of "High" and "Low" can be confusing since they refer to the sensitivity of the horizontal amplifier system and not to the applied voltages. Actually, strong voltages are applied with the switch in the "Low" position because with a strong voltage, less amplification is required. On the other hand, with a weak signal, the "Horiz. Sens." switch would be set to "High."

At the bottom of the oscilloscope there are six terminal posts through which connections are made to the instrument circuits. The posts are employed as follows:

"GND." Two ground terminal posts are provided, one on each side of the front panel for grounding input circuits.

"VERT. INPUT". Any signal connected between this terminal and "GND." will be coupled through an isolating amplifier to the vertical amplifier to be used for vertical deflection.

"60-CYCLE TEST SIGNAL". A 6.3 volt, 60-cycle signal is available at this connection for any outside use including calibration of the sweep frequency of the instrument itself.

"EXT. SYNC". When the "Function" control is in the "Ext. Sync" position, any signal connected between the "Ext. Sync" terminal and the "GND." terminal will be coupled to the "Sync" control.

"HORIZ. INPUT". Any signal connected between this terminal and "GND." can be fed into the horizontal amplifier if the "Function" switch is in "Horiz. Amp." position. (Turn "Sweep Range" to OFF.)

We have now covered all the front panel controls and terminals of the oscilloscope. Also located on the front panel, at the bottom, is a cover plate marked "Remove for Internal Oscilloscope Connections." When the four mounting screws are removed and the plate taken off, a terminal board with 10 numbered terminals appears, as shown in Figure 10. Note that jumper wires connect the following terminal pairs: 1 and 6, 2 and 7, 3 and 8, 4 and 9, and 5 and 10. The jumper wires between 4 and 9, and between 5 and 10 connect the output of the horizontal amplifiers to the horizontal deflection plates; the wires between 1 and 6, and 2 and 7 connect the output of the vertical amplifiers to the vertical deflection plates; and between terminal 3 and terminal 8 they feed a

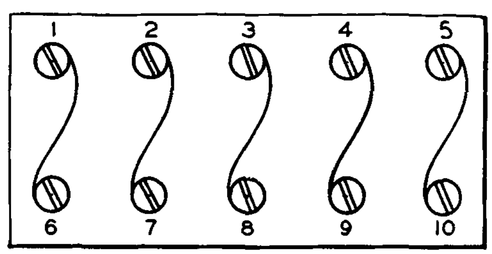


Figure 10. The Terminal Board Located Behind the Front Panel Cover Plate of the Oscilloscope Shown in Figure 2.

blanking pulse (from terminal 3) to the cathode (terminal 8) of the cathode-ray tube.

To use the plates directly, we would first remove the jumpers, thereby breaking the circuit between the vertical and horizontal amplifiers and their respective deflection plates. Next, to apply a voltage to the horizontal plates, we would connect it between terminals 9 and 10. To bring a voltage to the vertical plates, we would apply it across terminals 6 and 7.

The television serviceman will seldom have occasion to use the plates directly. This becomes necessary when the signals to be observed either have very large amplitudes or their frequencies are too high to be successfully passed through the vertical deflection amplifiers. It is also possible to use the plates directly for the measurement of DC voltages (which will not be passed by the R-C coupled vertical amplifiers). Either the vertical or the horizontal deflection plates may be used. The oscilloscope is calibrated first by the applying of a known voltage to the selected pair of plates and noting how much the spot on the screen is moved or shifted. The known voltage is then removed and the unknown DC voltage applied in its place. The deflection of the spot that this latter voltage produces is now compared with that caused by the known or calibrating voltage. From the equation below, the value of the unknown DC voltage is determined.

$$\frac{\text{D Known}}{\text{D Unknown}} = \frac{\text{E Known}}{\text{E Unknown}}$$

Where:

D Known = Distance in inches spot is moved by known voltage.

D Unknown = Distance in inches spot is moved by unknown voltage.

E Known = Value of known voltage.

E Unknown = Value of unknown voltage (to be found).

When direct use is made of the deflection plates in the oscilloscope of Figure 2, not only are the vertical and horizontal amplifiers disconnected from the plates, but the normal centering voltages are also removed. In this condition, rotation of the front panel centering controls will have no effect on the beam. In fact, the only front panel controls which will have any effect are the power on and off, the "Intensity" and the "Focus". (In some oscilloscopes, the positioning controls are effective under all conditions.)

"INTENSITY MODULATION". The cathode of the C. R. tube is connected to terminal No. 8 on the front panel board through a capacitor. Ordinarily, terminal No. 8 is connected to terminal No. 3, thereby receiving (from terminal 3) a short, sharp, positive pulse of voltage every time the beam retraces rapidly from right to left. The application of a positive pulse to the cathode of a tube produces the same result as the application of a similar negative voltage to the control grid. If the pulse is sufficiently powerful, it will cut the beam off during the retrace interval and that is precisely what happens here. This action is desirable because there is seldom any reason for having the beam produce a visible marking during the retrace interval. In fact, by blanking out the beam, the desired pattern stands out clearer.

It is not necessary to employ the cathode solely for the purpose of blanking out the retrace. If it is desired to intensify the beam during certain portions of its sweep, then negative pulses can be fed to the cathode via terminal 8. Simply remove the jumper between 3 and 8 and apply the intensifying voltage between 8 and one of the "GND." terminals. By feeding in different types of voltages, we can either brighten the trace or cut it off during certain selected portions of its cycle. This process of varying the beam intensity is known as intensity modulation and many oscilloscopes contain some provision for achieving it. While not much use is made of this facility in television service work, it is employed in frequency measurement. For those interested in this application, additional information will be found in the instruction manual which comes with their oscilloscope.

In working with oscilloscopes or in reading the instruction manuals that accompany them, it will be found that the horizontal input terminals are sometimes called the "X" axis. This terminology was borrowed from mathematics where it is customary to refer to all horizontal axes as "X" axes. By the same token, the vertical input terminals are referred to as "Y" axis. And, to complete the analogy, the intensity modulation terminal is known as the "Z" axis. Despite the names, all three systems operate as outlined above.

## HOW TO SET UP SCOPES

The foregoing discussion has dealt with the function of each control found on the oscilloscope of Figure 2. To someone who is unfamiliar with this instrument, even the relatively small number of controls can prove quite confusing unless he knows how to set the instrument up and prepare it for use. Toward that end, the following outline will prove helpful.

A. Before the power is turned on, the following controls should be set to approximately mid-position.

1. "FOCUS"
2. "VERT. CENTERING"
3. "SYNC"
4. "RANGE FREQUENCY"
5. "HORIZ. CENTERING"
6. "INTENSITY"

B. Set the "Vert. Gain" to zero and "Horiz. Gain" to 5.

C. Set "Vert. Attenuator" to 500 V position.

D. Set "Horiz. Sens" to "Low".

E. Set "Sweep Range" to 75-350-cycle position.

F. Now turn the "Function" switch from OFF to "Int. Sync" and the "Operate" pilot light should come on. Let the instrument warm up for approximately five minutes.

On the screen a single straight line should appear. Rotate the two centering controls until the line is centered on the screen. Adjust the "Intensity" control until the line is as bright as desired and then bring the line into sharpest focus by rotating the "Focus" control. If the horizontal line extends beyond the edges of the screen, it may be desirable to reduce the "Horiz. Gain" setting until the ends of the line are visible.

Thus far we have proceeded on the assumption that with the various controls set as indicated, a line will appear on the screen when the power is turned on.

But suppose it doesn't. What then?

The first thing to check is the "Operate" pilot light. Is it on? If it is, then turn next to the "Intensity" control and set it to at least three-fourths position, or possibly to the maximum clockwise position. Note whether any trace (or dot) appears on the screen.

If the trace is still missing, move the "Vert. Centering" and "Horiz. Centering" controls as the line may be off screen.

If the instrument is operating normally, these adjustments will produce a trace on the screen. Absence of the trace indicates that the unit is somehow defective.

Once the oscilloscope has been set up as indicated, it is in position to receive voltages for its vertical amplifiers. The voltage should be applied between the "Vert. Input" terminal and "GND." and the "Vert. Gain" control is rotated until the pattern occupies as much height as desired. If you find that the pattern is too small at any setting of the "Vert. Gain" control, switch the "Vert. Attenuator" to a lower position.

To produce a stationary pattern of the wave, adjust the "Sweep Range" first, then the "Range Frequency", and finally the "Sync" controls as outlined previously.

It is possible to check the vertical system of the oscilloscope before any signals are applied. To do this, run a short jumper from the "60-cycle Test Signal" terminal to the "Vert. Input" terminal. This will place a 60-cycle voltage across the vertical input terminals. Then adjust the "Vert. Gain" and "Attenuator" controls until the sine wave pattern appears on the screen.

The oscilloscope shown in Figure 2 possesses the particular shape that it does because it is also available in combination with an AM generator and an FM and TV sweep generator. See Figure 11. At the time of this writing this is the only instrument of its kind.

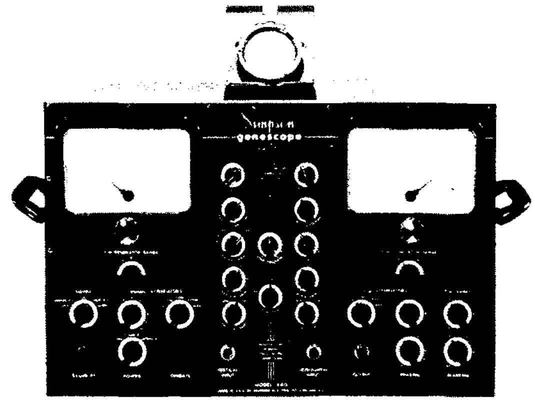

Figure 11. The Genescope - a Multi-Purpose Instrument Containing an AM Generator, a Crystal Calibrator, an Oscilloscope, and a Sweep Generator. Courtesy Simpson Electric Company.

OTHER OSCILLOSCOPES

The front panel of another oscilloscope is shown in Figure 12. This unit, which can be procured in kit form as well as assembled, contains essentially the same controls as the previous oscilloscope. However, the physical placement of the controls differs and, in some instances, their names have been altered. Thus, in place of the previous "Sweep Range", we now have "Coarse Frequency". The markings on this latter control start at 30 cycles and extend up to 30,000 cycles. Actually, you will discover, after working with different oscilloscopes, that the numbers inscribed at each position of this control are only

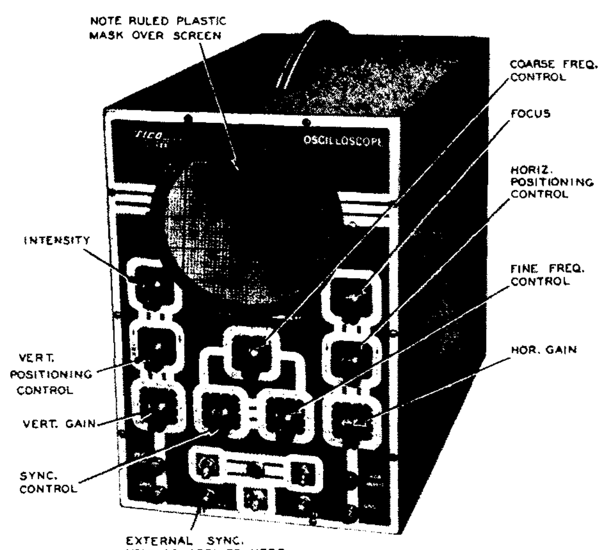


Figure 12. An Oscilloscope which Is Available in Kit Form. Courtesy Eico.

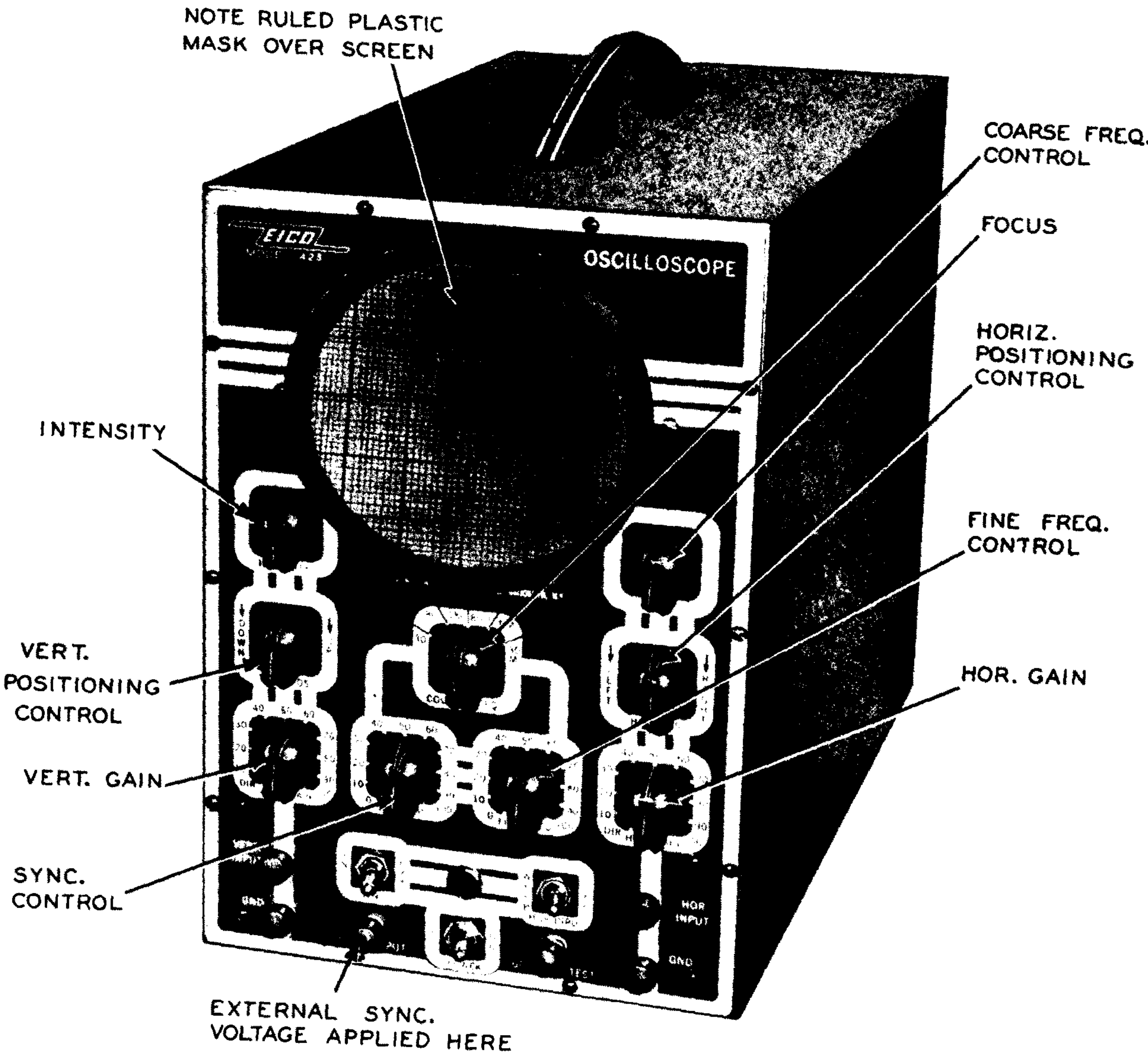


Figure 12. An Oscilloscope Which Is Available in Kit Form. (Model 425, Courtesy Eico.)

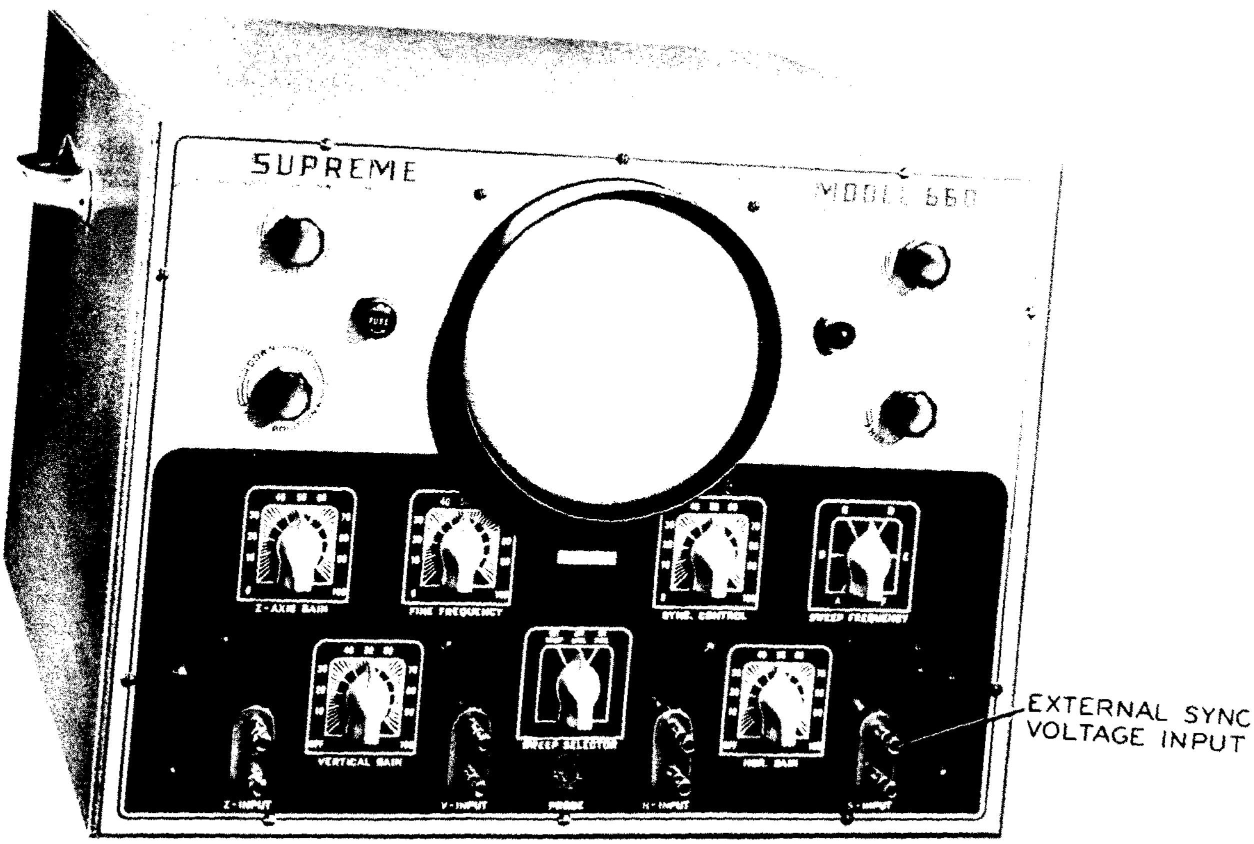


Figure 13. An Oscilloscope Containing a Special "Z Axis" Amplifier. (Model 660, Courtesy Supreme, Inc.)

approximate and in many instruments there is considerable overlap between adjacent ranges. Thus, although the lowest range of the unit in Figure 12 is marked as 30, it is possible to go somewhat below this. Also, it will be found that sweeping frequencies above 30 M, or 30,000 are attainable.

The "Fine Frequency" control in Figure 12 serves the same purpose as the "Range Frequency" knob in the previous unit. And the "Sync Amp." is the circuit which is employed to lock the horizontal sweep to the frequency of the signal being observed.

Power to the instrument is controlled by a separate switch instead of being part of a multi-position switch. The "Horiz. Input" switch connects the horizontal amplifiers to either the internal saw-tooth generator or to the horizontal input binding post. The "Sync" switch transfers the horizontal synchronization from internal sync to the "Sync Input" jack on the front panel. There is no line synchronization switch in this oscilloscope and to lock the sweep generator in with the power line frequency, a short wire would have to be connected from the 60-cycle test binding post to the "Sync Input" post. Then the "Sync" switch would be placed in the "Ext." position.

In this oscilloscope, an intensity modulation jack is located on the rear panel and is used for the same purpose as it was in the previous oscilloscope. Also on the rear panel is a terminal strip from which connections can be made direct to the vertical deflection plates. No such facility is available for the horizontal deflection plates. Connecting terminal jacks on the front panel include "Horiz. Input", "GND.", "Vert. Input", "Sync Input", and "60-Cycle Test".

Another oscilloscope, shown in Figure 13, differs in certain respects from the previous two instruments. Of minor interest is the fact that the power on-off switch is now ganged to the "Intensity" control. When this control is in the extreme counterclockwise position, the power is off. To turn the power on, rotate this knob in a clockwise direction. The pilot light will come on, indicating that the instrument is in operation. Further rotation of the knob will increase the intensity of the beam on the cathode-ray tube screen.

While this is the first oscilloscope, thus far, which employs this particular arrangement, it is a fairly common one.

The instrument contains a set of terminals on the front panel labeled "Z-Input". This is for modulating the beam. In addition, there is "Z-Axis" amplifier which will amplify any signal applied to the "Z-Input" terminals before coupling this signal to the control grid of the cathode-ray tube. The "Z-Axis Gain" control regulates the amount of voltage applied to this amplifier. When the control is in the extreme counterclockwise position, none of the "Z-Axis" voltage reaches the cathode-ray tube grid. Rotating the knob in a clockwise direction permits more and more voltage to reach the "Z-Axis" amplifier, producing a greater effect on the cathode-ray tube beam. In use, connect the desired "blanking" or "brightening" signal to the "Z-Input" terminals, and,

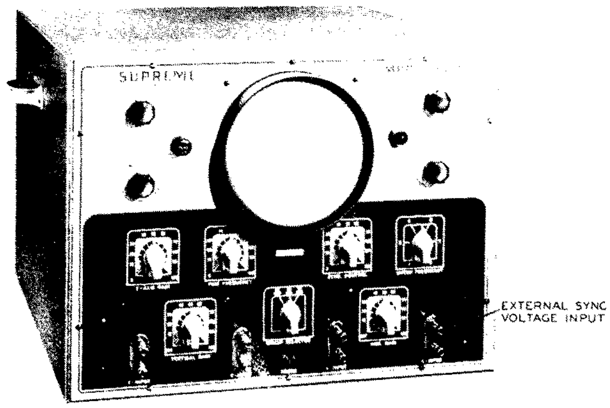


Figure 13. An Oscilloscope Containing a Special "Z-Axis" Amplifier. Courtesy Supreme, Inc.

starting in the extreme counterclockwise position, rotate the control clockwise until the desired blanking or brightening is observed on the trace. Never use more "Z-Axis" gain than is necessary, since too much blanking or brightening distorts the picture.

The "Sweep Frequency" control on this instrument is a six-position switch with the various frequency ranges identified by letters, A, B, C, D, etc., instead of the more conventional method of using the frequencies themselves. However, by referring to the instruction manual, it will readily be found that the various letters stand for the following sweep frequencies.

A. 6 cps to 60 cps

B. 20 cps to 200 cps

C. 90 cps to 700 cps

D. 550 cps to 4 kc

E. 3.5 kc to 25 kc

F. 24 kc to 150 kc

In practice, the time it takes to find the proper settings of the "Sweep Frequency" and "Fine Fre-

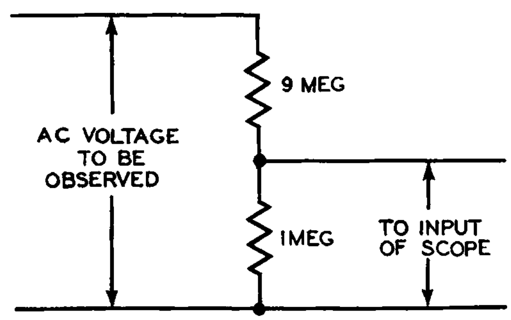


Figure 14. A resistive Voltage Divider Network Suggested by Supreme, Inc. for use with their Oscilloscope of Figure 13.

quency" controls (to obtain one cycle of the input wave on the screen) is so short that reference to the table in the manual is seldom necessary.

Incidentally, while we are on the subject of instruction manuals, it is strongly recommended that these manuals be carefully and thoroughly studied. No one knows better than the manufacturer what the capabilities of his instrument are and this information is, for the most part, found only in the manual. To illustrate the point, the oscilloscope in Figure 13 contains vertical input terminals and a vertical gain control. There is, however, no special attenuation control for handling large signals and looking in the manual we find that signals larger than 25 volts peak-to-peak should not be applied directly to the input terminals since they will produce a distorted trace. The manufacturer suggests that if it is desired to view the waveform of higher voltages, they first be reduced to a suitable value by the use of a resistive network such as shown in Figure 14. This network is so proportioned that the scope receives 1/10 of the total applied voltage.

At the bottom of the front panel (Figure 13) there is a socket receptacle marked "Probe". Into this receptacle is plugged a male socket which, in turn, is connected to a special high-frequency probe. The oscilloscope, through the socket, feeds filament and plate voltages to a small 6C4 tube contained within the probe housing. The probe, because of its high input impedance (5 megohms) and low shunting capacitance (9 mmf.), can be used to pick up RF and IF signals directly at various points within a radio receiver. The 6C4 acts as an RF cathode follower, feeding whatever signals it receives to the vertical system. (The vertical amplifiers have a response that extends out to 7 mc.) The probe cannot be used with FM or television receivers because of the very high RF and IF frequencies in these circuits.

## PHASING CONTROLS

It was noted earlier in this section that when an oscilloscope is used in conjunction with a sweep generator, a 60-cycle sine wave beam sweeping voltage must ordinarily be obtained from the generator. However, if the oscilloscope contains the proper auxiliary circuits, this extra connection can be dispensed with and the sine wave beam sweeping voltage obtained from the oscilloscope itself.

If the front panel of the oscilloscope shown in Figure 15 is examined carefully it will be found to contain a control labeled "60-Cycle Phasing". In addition, if you glance at the "Coarse Frequency" control, you will find a position, at the extreme left hand side of this scale, marked "60-Cycle Sweep". With the knob in this position, the saw-tooth oscillator is turned off and a 60-cycle sine wave voltage is applied to the horizontal amplifier. This, then, duplicates what the connecting lead from the sweep generator would do.

The next step is to be able to adjust the phase of this 60-cycle voltage in order that it may be brought in step with the sine wave driving voltage in the sweep generator. When the inphase condition is attained, essentially one trace (or response pattern)

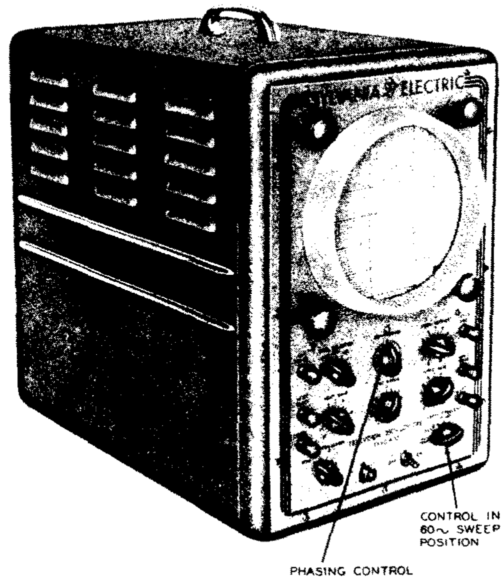


Figure 15. An Oscilloscope which can Provide its own 60 Cycle Sweep and Phasing Control. Courtesy Sylvania Electric Products Company.

will be observed on the screen. This is the function of the "60-Cycle Phasing" control on the oscilloscope of Figure 15.

At this point an interesting question could be raised: "When an oscilloscope such as shown in Figure 15 is used with a sweep generator for a circuit alignment, and the oscilloscope is made to supply its own sine wave deflection voltage, can a single response pattern be obtained by varying the sweep generator's phase control instead of the oscilloscope's phase control?" The answer is "No", because the phase control in the sweep generator varies the phase of the 60-cycle voltage that it has available for connection to the oscilloscope. This control does not vary the phase of the 60-cycle voltage which it itself uses to sweep the oscillator frequencies back and forth. And, if we do not use the 60-cycle voltage that the sweep generator has available for the oscilloscope, then, of course, the control will have no effect.

In the oscilloscope of Figure 15, the "60-Cycle-Phasing" control does not become effective until the "Coarse Frequency" switch has been set to the "60-Cycle Sweep" position.

One further point concerning this oscilloscope is the "Vert. Attenuation" switch. The switch reduces the height of the vertical trace by attenuating the signal fed from the "Vert. Input" terminals to the cathode follower. The 1:1 position applies full signal; the 100:1 applies 1/100th of the signal, etc.

## PRECISION OSCILLOSCOPE

To illustrate the wide variety of names that different manufacturers assign to controls which per-

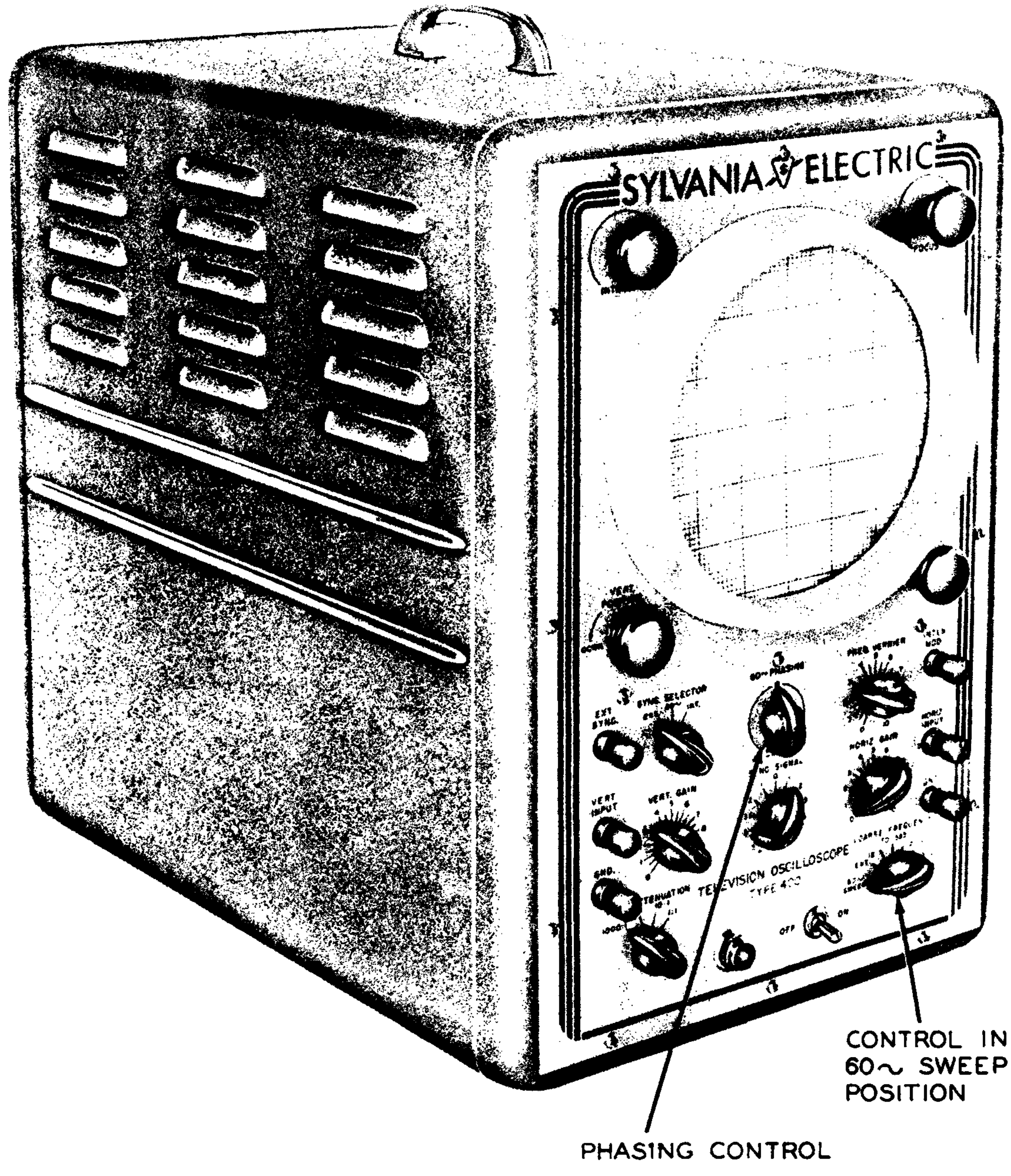


Figure 15. An Oscilloscope Which Can Provide its Own 60 Cycle Sweep and Phasing Control. (Model 400, Courtesy Sylvania Electric Products Inc.)


Figure 16. The Precision Model ES-500A Oscilloscope. (Courtesy Precision Apparatus Company.)

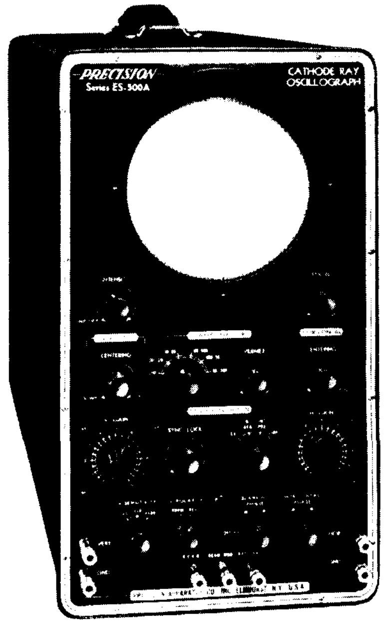


Figure 16. The Precision Model ES-500A Oscilloscope. Courtesy Precision Apparatus Company.

form exactly the same functions, the oscilloscope shown in Figure 2 used the name "Range Frequency" for the potentiometer which varied the saw-tooth sweep frequency within any given range. In the following instruments this was changed to "Fine Freq." (Figure 12), and "Freq. Vernier" (Figure 15). Now, in Figure 16, the name has been shortened to "Vernier". In general, the names most frequently employed are either "Fine Frequency" or "Vernier".

Under "Synchronization" in Figure 16 we find first the usual "Sync" control (or, as it is labeled here, the "Sync Lock") with which we can regulate the amplitude of the sync voltage applied to the internal saw-tooth generator. Next to it is a switch which, in previous instruments, was labeled as the sweep or sync selector. However, instead of having three positions, EXT., INT., and LINE, there are four positions here, with two positions for INT., i. e., INT. NEG., and INT. POS. In either position, a portion of the signal or voltage applied to the vertical input terminals is fed to the saw-tooth generator to provide synchronization or lock-in of the pattern observed on the screen.

The reason for incorporating this additional position can be seen if we examine Figures 17A and 17B. Non-sinusoidal waveforms may occasionally have a large negative voltage as compared to the positive voltage (or vice versa). If the polarity of the synchronization circuits in the scope is not selectable from the oscilloscope panel, a waveform of the type illustrated in Figure 17B could be synchronized only by its relatively small peak. In such a case, insufficient voltage might be available for synchronization and an unstable pattern could result. This instability can be overcome by designing the sync selector switch so that sync voltage can be obtained from

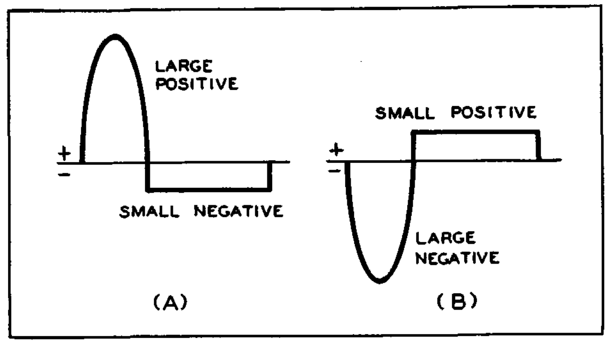


Figure 17. Non-Symmetrical Waveforms which Could Make it Difficult to Obtain Suitable Synchronization in an Oscilloscope. See text.

either the positive or negative peak of the wave to be observed.

With a sine wave or any other symmetrical waveform, the same lock-in action will be obtained with the switch in either position.

There are two knobs labeled "Horizontal Phase" and "Blanking Phase" at the bottom of the front panel. The first of these controls, "Horizontal Phase," has already been encountered on the previous oscilloscope, Figure 15, under the name of "60-Cycle Phasing". All the remarks made there are applicable here, too.

The second control, "Blanking Phase", when turned from its OFF position, applies a sine wave voltage to the control grid of the cathode-ray tube. This has the effect of intensifying the trace during a portion of the sine wave cycle, and of blanking it out during its most negative portion. The most useful application of this function is the elimination of one of the dual patterns obtained in the sweep alignment of TV and FM receivers. The 60-cycle sine wave applied to the control grid of the CRT is so phased, by means of the "Blanking Phase" control, that when the second pattern should be traced out, the beam is blanked out. This results in one pattern which is much easier to work with.

Blanking controls, it will be remembered, were previously encountered on sweep generators. When this control was turned on, the sweep oscillator was prevented from functioning during its backward sweep and, as a consequence, a single response pattern trace was produced on the screen. In essence, then, the blanking switch on the sweep generator and the "Blanking Phase" control on the oscilloscope of Figure 16 perform the same function.

There is, however, this difference. When the blanking control is in the sweep generator, the pattern seen on the scope screen will appear as shown in Figure 18A. During the backward trace, when the sweep generator is inoperative, the sine wave deflection voltage applied to the scope will bring the beam straight back across the screen, forming a base line. This base line is helpful as a reference or zero axis against which the serviceman can compare the response curve. In aligning discriminators, for example, both halves of the "S" curve should be symmetrical.

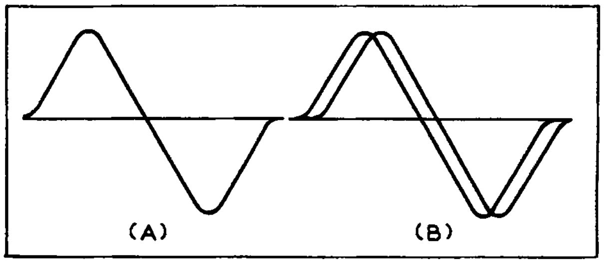


Figure 18. FM Detector Response Obtained on an Oscilloscope with Blanking Control in Sweep Generator. (B) Usual Dual Pattern with no Blanking.

By having a reference line to work against, the job of judging when the balanced condition is reached is considerably eased. Figure 18A shows the "S" curve with a base line, while Figure 18B illustrates the usual dual pattern when no blanking is employed. The advantage of the base line arrangement is evident.

Now, when the blanking control is contained in the oscilloscope instead of the sweep generator, turning it on and adjusting it will remove one of the dual patterns. However, unlike the previous arrangement, no base line will appear. The reason, of course, stems from the fact that the blanking control in the oscilloscope removes the second pattern by cutting off the C.R.T. beam. During this interval no electrons reach the screen. On the other hand, when the blanking control is in the sweep generator, the sweep oscillator stops working for one-half cycle and the generator output drops to zero. Since the oscilloscope beam is not affected, it still continues to be seen. However, with no signal voltage coming in during this interval, it moves unaffected across the screen, producing the base line. During the next forward trace, the sweep generator resumes normal output and the response pattern is produced.

To operate either type of blanking control, first produce the response pattern with the dual traces. Next, bring the two patterns as close together as possible. Then rotate the blanking control until only one trace is visible.

VERTICAL POLARITY SWITCH -

Another useful feature of the oscilloscope of Figure 16 is the "Vertical Polarity" reversing switch. This switch has two positions marked NORMAL and REVERSE. When the switch is moved from one position to the other, the pattern on the screen is flipped over or reversed in the vertical direction. Thus, if the pattern appears as shown in Figure 19A when the switch is in one position, it will appear as shown in Figure 19B when the switch is turned to the other position. This is a useful device for interpreting TV video IF and sync or sweep waveforms, especially when the manufacturer's manual shows the pattern in one position and your scope shows it in the opposite position.

Reverse patterns on the screen is a source of confusion to many servicemen. Why, for example, should the manufacturer's bulletin show the pattern pointing up when your scope has it pointing down?

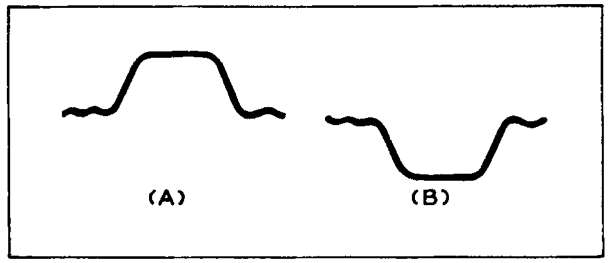


Figure 19. The Vertical Polarity Reversing Switch in the Precision Oscilloscope with Permit Curves to be Displayed in Either Direction.

Does it mean that your equipment is hooked up wrong or does it indicate a defective circuit?

Actually, the answer is neither one. The polarity of the signal at various points in a television receiver is important and in general the manufacturer attempts to show the signal as it should be at each specific point. Now, this same signal, fed to your scope may come out (at the screen) right side up or upside down, depending upon whether your scope has an even or an odd number of stages in its vertical amplifier system. Any voltage, passing through an amplifier, is reversed in phase by $180^{\circ}$. Therefore, if the signal shown in Figure 19A is fed into the grid of an amplifier, it will appear at the plate as shown in Figure 19B. Pass this second signal through one more stage and lo and behold, it is right-side up again.

As a general rule, two or any even number of stages will produce a signal at the output which has the same phase (approximately) as the input signal. By the same token, pass a signal through one or any odd number of amplifiers and its phase will be reversed.

Thus, the polarity of the wave seen on the screen of an oscilloscope will depend upon the number of amplifiers in its vertical system.

In the instrument of Figure 16, this limitation is circumvented by the polarity reversing switch. To obtain a reversal, the designers of this instrument merely reversed the connections made to the final push-pull vertical amplifier stage. See Figure 20.

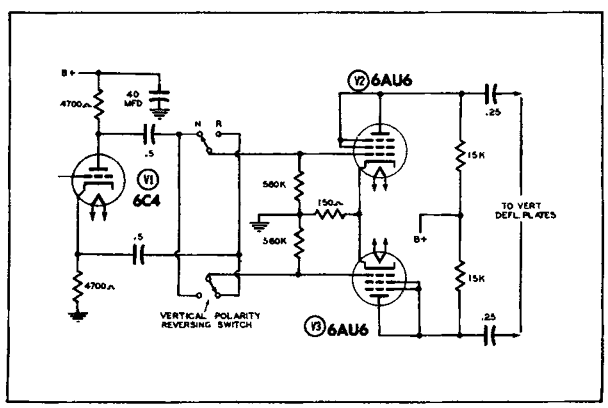


Figure 20. Simplified Diagram of the Vertical Reversing Switch Circuit in the Precision Oscilloscope.

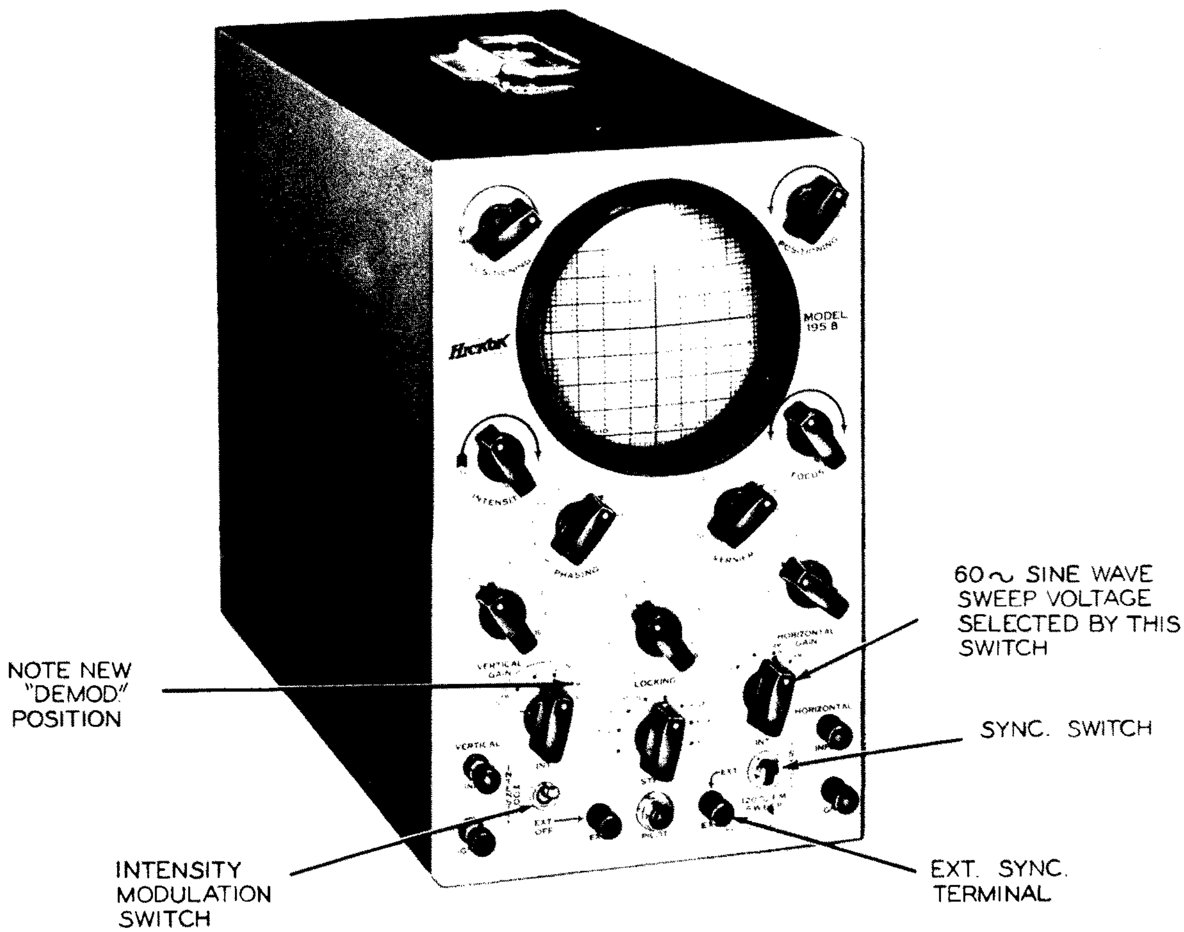


Figure 22. Hickok Model 195-B Oscilloscope. (Courtesy Hickok Electrical Instrument Company.)

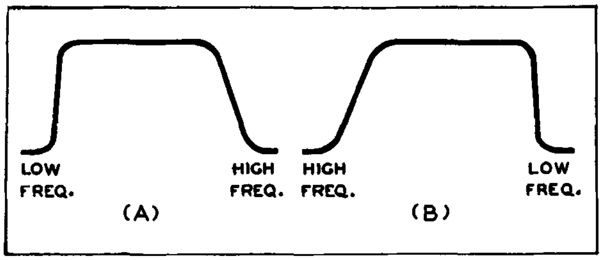


Figure 21. (A) Video IF Response Curve with the Low Frequencies at the Left and the High Frequencies at the Right. (B) Same Curve in Reversed Position.

In the NORMAL position of this switch, the grid of V2 receives its signal from the plate of V1 while V3 receives its signals from the cathode of V2. In the REVERSE position, the input signals to V2 and V3 are interchanged. Note that the same phase reversal can be incorporated in the horizontal system. Thus, one oscilloscope may show a video IF response curve with the low frequency and at the left (Figure 21A) while another may have it on the right (Figure 21B). Testbooks and service manuals usually prefer to show curves with their low frequencies at the left and high frequencies at the right and that is the way most service men come to recognize them. The curve in Figure 21B may be transformed into the one in Figure 21A by reversing the voltages applied to the horizontal deflection plates. Sometimes an oscilloscope contains such a horizontal phase reversal switch, although it is not often found.*

## ADDITIONAL OSCILLOSCOPE CONTROL NAMES

Additional changes in the names of some of the controls is encountered in the oscilloscope shown in Figure 22. Thus, what was previously known as the "Coarse Frequency" control is here labeled as the "Steps" control. Associated with this control is the "Vernier" knob. The "Locking" control is similar in operation to the previous "Sync" lock-in controls.

In the horizontal system there is a "Horizontal Gain" potentiometer and just beneath it is a 4-position selector switch (unnamed on this panel) to determine what is fed into this system. The designations at each position are as follows:

A. AMP. OUT. Any voltage connected to the horizontal input binding posts is fed directly to the horizontal deflecting plates through a DC blocking capacitor.

B. AMP. IN. The voltage at the horizontal binding posts is fed through the horizontal amplifier to the deflecting plates. This would be the position to use, for example, when a 60-cycle sine wave driving voltage is obtained from the sweep generator.

C. 60~. The horizontal deflection voltage is a 60-cycle sine wave obtained from the power supply. The position could be used, during a sweep alignment, in place of the 60-cycle driving voltage from the generator. To superimpose the two response patterns produced on the screen, a "Phasing" control is available.

D. S.S. OSC. Now the horizontal sweep voltage is derived from the internal saw-tooth sweep oscillator and may be of any frequency from 10 cycles to 25 kc.

Just below this 4-position switch is a 3-position switch (up, center, and down) governing the synchronization or lock-in of the saw-tooth sweep oscillator. When switched to the INT. position, the sweep oscillator may be synchronized at the frequency, or submultiple of the frequency, of any voltage being applied to the vertical deflecting circuits.

In the center, it is in the EXT. position and the oscillator may be synchronized from any external source of frequency. An arrow points to the binding post where this external synchronizing voltage is applied. (Note that on the left-hand side of the pilot light there is another terminal marked EXT., but this one is associated with the "Intensity Mod." switch.

The third or final position of the "Sync" control (down) is labeled 120 cycles FM and in this position, 120-cycle pulses are obtained from the power supply and used to synchronize the saw-tooth sweep oscillator. (In a full-wave power supply, the frequency of the rectified pulses is 120 cycles. In a half-wave power supply, it is 60 cycles.)

This particular position of the "Sync" switch is designed to meet the recommendations that some manufacturers of FM receivers make concerning the alignment of their sets. More information on this point will be given in a later section.

The "Intensity Modulation" switch (at the left) contains two positions - INTERNAL and EXTERNAL. The EXTERNAL position, of course, is the familiar

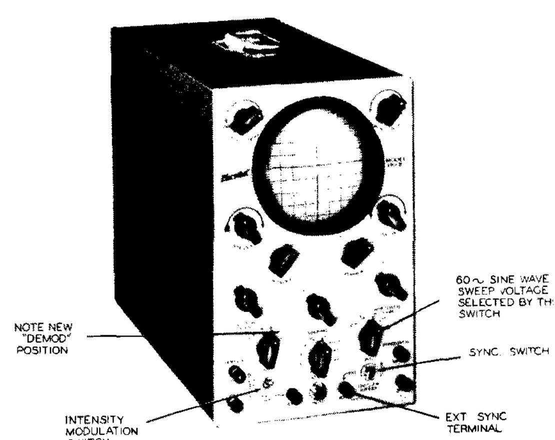


Figure 22. Hickok Model 195 B Oscilloscope. Courtesy Hickok Electrical Instrument Company.

- - - -

*Horizontal reversal of a pattern can also be accomplished by reversing the phase of the 60 cycle driving voltage fed by the sweep generator to the oscilloscope. This was previously noted in section 3.

one wherein any external voltage may be applied to the EXT. binding post and employed to intensity or blank out a portion of the beam trace. The new position, labeled INT. is used only when 60 cycles is being used for horizontal deflection and, in this position, the return trace is blanked out.

Note, therefore, that this instrument (Figure 22) contains a "Phasing" control with which to superimpose the forward and return traces (when 60-cycle sine wave deflection is being used) and an internal blanking circuit to remove the return trace. In the previous oscilloscope (Figure 16), it was further possible to adjust the phase of the blanking voltage by rotating the "Blanking Phase" control. This provided some latitude in choosing the position of the forward or backward trace to be blanked out which is not available here.

PROBES -

Before we leave the oscilloscope of Figure 22, it might be of interest to note that in the vertical selector switch (which is located just beneath the "Vertical Gain" control) there is one position labeled "Demod". When the vertical selector switch is in this position, any modulated RF voltage applied to the vertical input terminals is detected and then applied to the vertical amplifier system for presentation on the screen. In essence, we have here a built-in RF probe. Thus, in a radio receiver, any of the RF or IF signals could be applied directly to this scope.

It is important to remember, however, that because leads must be used between the vertical input terminal of the scope and the receiver, that only relatively low-frequency signals can be detected successfully. If we probed high-frequency FM and TV circuits with these same leads, circuit operation would be disturbed to such an extent that the usefulness of this arrangement would be questionable. However, for low-frequency signals, this added convenience is desirable.

There are occasions, in signal tracing and in sweep alignment, when it would be helpful if the signal at various points in the RF or IF stages could be viewed directly on the scope screen. To permit this to be done, many oscilloscope manufacturers have available RF probes which can be used in circuits operating at frequencies as high as 200 mc or more. These RF probes are similar to VTVM RF probes, containing a germanium crystal (or a miniture diode) which detects the received signal and then applies the low-frequency modulation of the signal to the vertical input terminals of the scope for screen presentation.

The principal difficulty which is encountered in using these probes is the small amount of signal which is present in the RF and IF stages of a receiver. A good oscilloscope will require about .015 volts (rms) of input signal to produce a pattern 1-inch high. Low-priced units will generally need considerably more voltage, sometimes as much as .5 volts, to produce the same size pattern. In the final IF stages of a receiver it may be possible to obtain this large a signal; seldom in the RF section, or first IF stages.

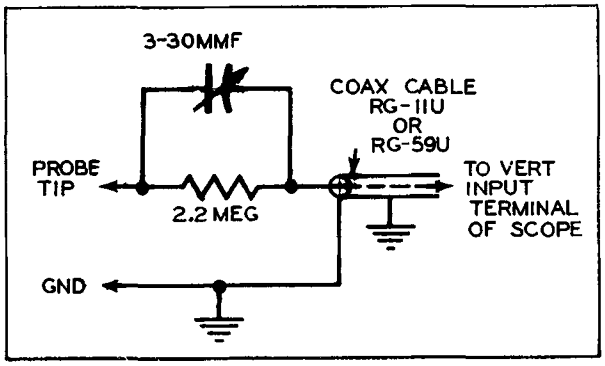


Figure 23A. Low-Capacity Probe Circuit.

The word "probe" has a variety of meanings in radio and television parlence. Thus, in VTVM's there is an RF probe and a high voltage probe. Also, the word probe is applied frequently to the test lead or prod which connects to the AC input jack and to the lead which goes to the DC input terminal. With oscilloscopes, there is the RF probe we have just discussed. In addition, there is frequently found another type of probe known as a low-capacity probe. Its purpose is to permit the proper observation of waveforms in low-capacity circuits.

The vertical input circuit of an oscilloscope contains a certain amount of capacitance - on the order of 30 to 50 mmf. To this we can add (on the average) another 25 to 50 mmf of capacitance arising from the test lead.* Thus, when you place your test prod or probe at some point in a circuit to observe the waveforms present there, you are automatically shunting this point with 80 to 100 mmf of additional capacity. In some circuits, this additional capacity will have virtually no effect on the circuit operation;

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*A pair of plain leads will shunt less capacitance across the circuit than a section of coaxial cable. However, the cable is shielded, reducing or eliminating spurious signal pickup and, because of this, is more desirable.

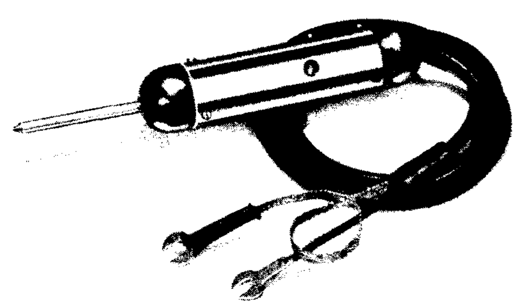


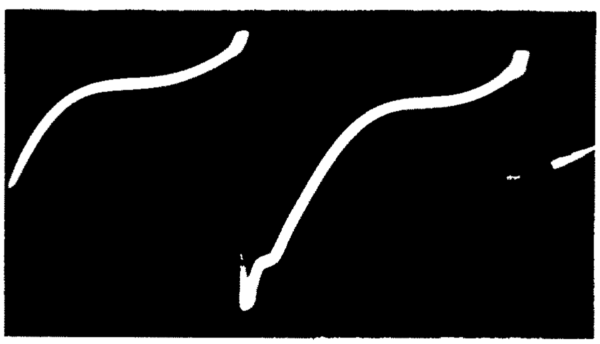
Figure 23B. How the Low-Capacity Probe Might Appear When Constructed. Courtesy Hickok Electrical Instrument Company.

in other circuits, especially where the waveforms contain relatively high frequencies (such as square sync pulses), the additional capacitance will actually alter the shape of any wave present here.

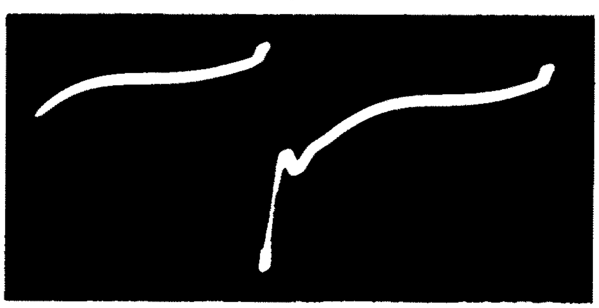
To minimize the disturbing effect of the oscilloscope test lead, a special low capacity probe can be designed. A small, semivariable capacitor and resistor, connected as shown in Figure 23A, are encased in a special housing to form a low capacity probe. The value of the capacitor will usually be about 10 to 15 mmf. while its parallel resistor will be about 2.2 meg. The reduction in shunting capacity occurs because the padder capacitor is actually being placed in series with the 80 to 100 mmf of combined capacity present in the connecting test lead and at the vertical amplifier input. And since capacitances in series produce a total value which is less than the lowest capacitor, the addition of 10-15 mmf of series capacitance reduces the effective overall capacitance to a decided improvement over the 80 mmf or so present before the addition.

One disadvantage of this arrangement is that the voltage actually reaching the vertical amplifiers of the scope is reduced in the same proportion as the input capacitance. Thus, if the total capacitance is decreased by 1/100, so is the voltage reaching the scope. In television service work, the observation of waveforms using the low-capacity probe usually is required in the video amplifier and sweep systems and in these stages sufficient voltage is available, even with the probe reduction.

The two illustrations in Figure 24 show clearly how a much truer picture of the circuit waveform is

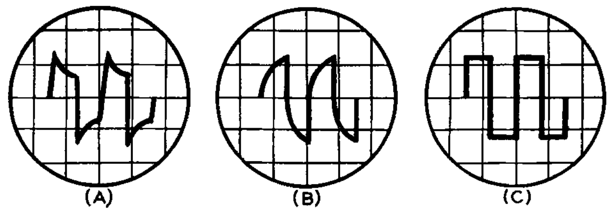


A



B

Figure 24. Wave Shown at (A) Was Obtained Without use of Low-Capacity Probe; Wave at (B) Did have Probe. Note the Difference Between the Two.



(A) (B) (C)

Figure 25. (A) Padder Capacitor Value too High. (B) Padder Capacitor Value too Low. (C) Padder Properly Adjusted.

obtained when a low-capacity probe is employed. The steep sides of the waveform, containing the higher frequency components, are much more in evidence, in Figure 24B than they are in Figure 24A. It is in the reproduction of steep sided pulses and waveforms that the low-capacity probe is most useful.

Anyone not possessing a low-capacity probe may build one from the circuit shown in Figure 23. Then connect it to the oscilloscope it is to be used with and apply a square wave to the probe. Use a frequency between 1,000 and 10,000 cycles. Adjust the padder condenser until the wave on the screen is also square.

Figure 25A illustrates a condition where the value of the padder capacitor is too high and Figure 25B where the padder capacitor value is too low. Figure 25C is the square wave as it appears when the padder is properly adjusted.

In the absence of a square wave generator, Philco recommends that the probe be connected to the video detector of a TV set known to be in good working order. Set oscilloscope for composite video signal, and adjust padder so that amplitude of vertical and horizontal sync pulses are equal. See Figure 25D. (Oscilloscope sweep frequency is set at 30 cycles to observe composite waveforms.)

Once a low-capacity probe is adjusted for a certain oscilloscope, it should be used only with that instrument. Use with any other oscilloscope should

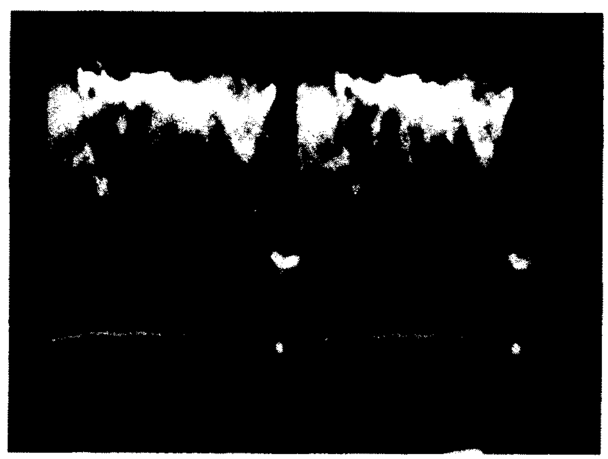


Figure 25. (D) Padder Capacitor Properly Adjusted for Normally Operating Video Detector Source.

not be attempted unless the padder is returned. It is also well to keep in mind that the probe cannot compensate for limitations in the frequency response of the vertical amplifier system of the oscilloscope.

In recognition of its usefulness, a low-capacity probe is built into the oscilloscope shown in Figure 26, Whatever voltage the probe picks up will reach the vertical amplifiers when the selector switch located just above the probe is turned to one of the three positions on the side marked PROBE. In the PROBE-1 position, the probe signal receives its greatest amplification. In the PROBE - 1/10 position, only 1/10 of the voltage of the PROBE-1 position reaches the vertical amplifier. And in the PROBE 1/100 position, even less of the signal reaches the vertical amplifier. Thus, there is a certain amount of attenuation in the probe circuit itself, plus an additional amount in the 1/10 and 1/100 positions, if desired.

When the low-capacity probe of this oscilloscope is not in use, signals are applied to the terminal marked AC. This terminal is similar to the vertical input terminals on the previous oscilloscopes. A separate attenuating system (AC-1, AC-1/10 and AC-1/100) is available for these signals.

## PEAK-TO-PEAK VOLTAGE MEASUREMENTS

In this instrument (Figure 26) we meet for the first time a feature which is finding increasing usage in television servicing. This is the "Calibrate Volts PK-PK (Peak-Peak)" control. The values shown in the various positions represent the peak-to-peak voltages which will be obtained from the "Cal Volts Out" terminal. For, example, when the "Calibrate" switch is in the 0.3 position, the sine wave voltage obtained from "Cal Volts Out" terminal is 0.3 volts, peak-to-peak. Additional peak-to-peak voltages of 1.5, 3.0, 15, 150, and 300 are also available.

Having voltages available whose peak-to-peak value is known is extremely helpful when servicing the vertical or horizontal sweep systems of television receivers. In checking through any sweep system,

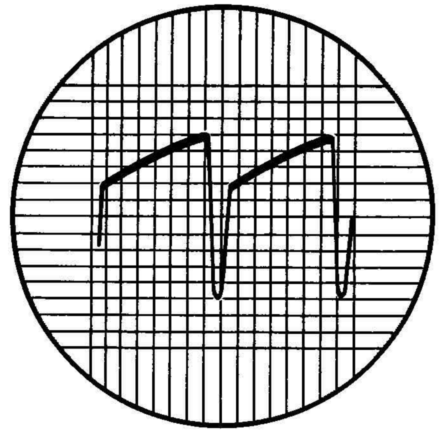


Figure 27. The Wave Shown Above Covers a Height of Ten Squares on the Ruled Mask.

two facts concerning the waveforms found there are important - wave shape and peak-to-peak amplitude. The wave shape can be determined by inspection on a scope screen; the wave amplitude, however, must be measured and having known calibration voltage on hand is one way to accomplish this. The method of measurement is as follows:

Apply the wave whose amplitude is to be determined to the oscilloscope input terminals and, with the vertical gain control, adjust the amplitude of this wave until it occupies a reasonable height --- say one-half the size of the screen. To facilitate the measurement, it is generally best to have the wave extend over a specific number of vertical squares on the screen mask. A simple figure to work with, in this respect, is 10 or 15 squares. (The wave in Figure 27 covers 10 squares.) Whatever the figure, make a specific note of it.

Now remove the signal and, without touching the vertical gain control, apply the calibration voltage to the same (vertical) input terminals. A sine wave will appear on the screen. See Figure 28A. Compare its height with that of the previous wave and if the two cover as many vertical squares, then both possess the same peak-to-peak value. Assume that this happens when the calibration switch is in the 30 volts peak-to-peak position. Then both waves have a peak-to-peak value of 30 volts. (Some servicemen like to turn down the horizontal gain control until the calibration sine wave is only a vertical line. See Figure 28B. They claim that such a line is easier to work with. Either method will give similar results since we are not interested in the horizontal spread of the wave, but only its height.

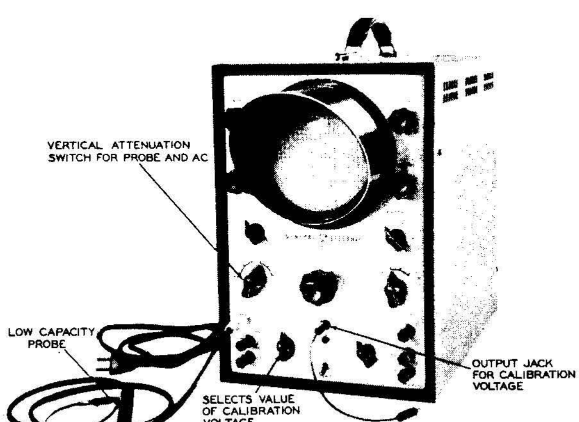



Figure 26. Oscilloscope Containing a Built-In Low-Capacity Probe. Provision is Also Available for Measuring Peak-To-Peak Values of Any Waves Depicted on Screen. Courtesy General Electric Company.

The fortunate occurence of both waves having the same peak-to-peak value is not likely to be the most common experience of the serviceman. More often than not, the amplitudes of both waves will differ. Let us say that when the unknown wave is adjusted to cover a height of 10 squares, the calibration sine wave, with the "Calibrate" switch in the 30 volts position, covers only 8 squares. Then the peak-to-peak amplitude of the unknown signal is computed as follows:

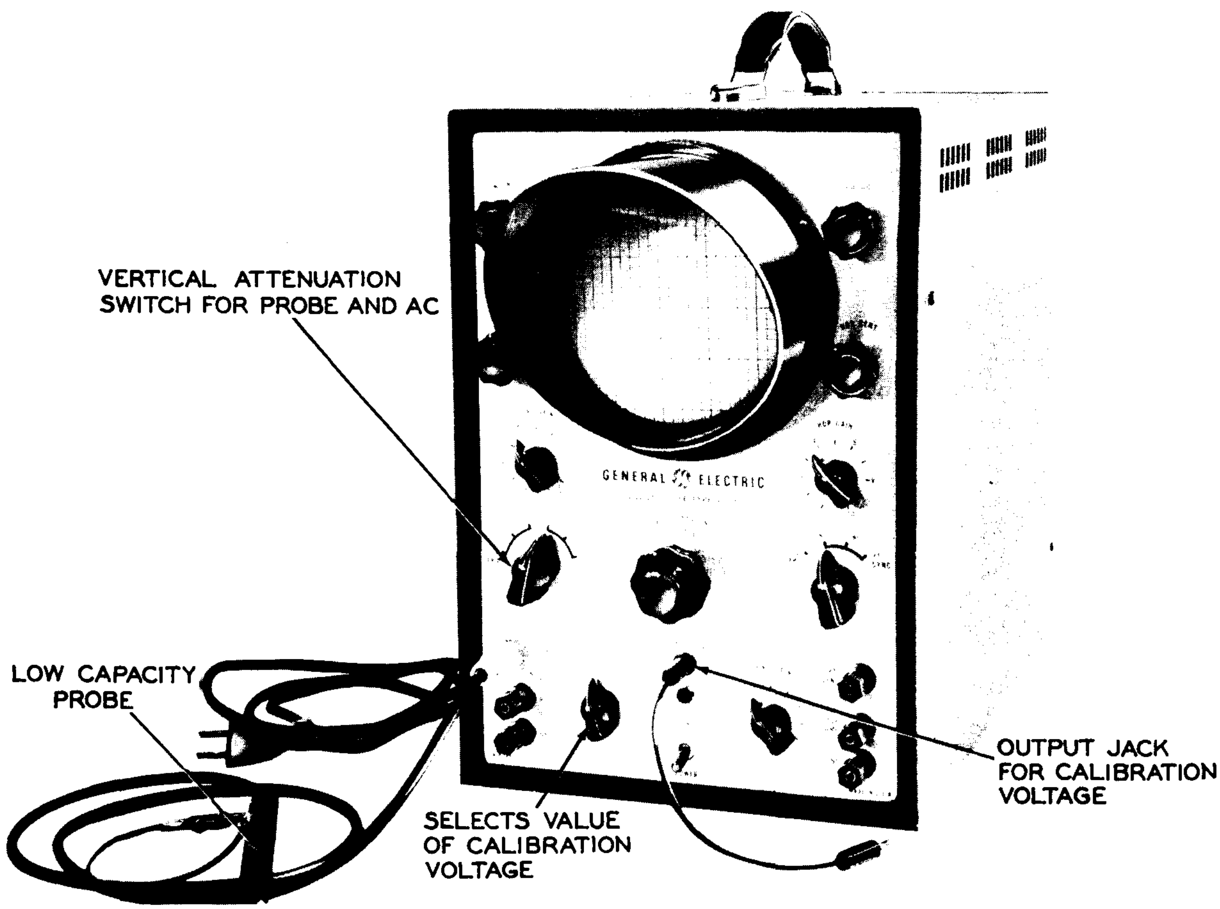



Figure 26. Oscilloscope Containing a Built-In Low Capacity Probe. Provision Is Also Available for Measuring Peak-to-Peak Value of any Waves Depicted on the Screen. (Model ST-2C, Courtesy General Electric Company.)


Figure 29. This Oscilloscope Contains a Built-In Peak-to-Peak Voltmeter Together with Several Calibrating Controls. (Model 34-31, Courtesy of Triplett Electrical Instrument Co.)

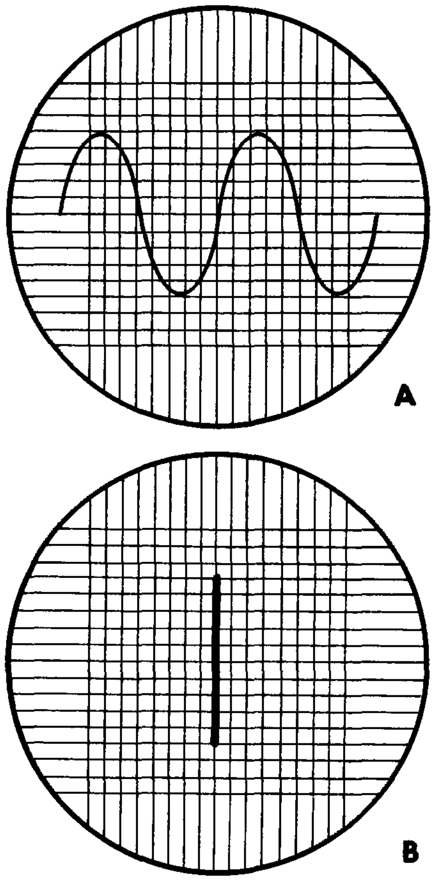



Figure 28.

$$\frac{\text{CALIBRATION Voltage Value}}{\text{No. of vertical squares it covers.}} = \frac{\text{Unknown Voltage}}{\text{No. of vertical squares it covers.}}$$

The CALIBRATION voltage value here is 30 volts, and the number of vertical squares it covers is 8. The unknown voltage covers 10 vertical squares. Hence,

$$\frac{30 \text{ volts}}{8} = \frac{X}{10}$$

then,

$$8X = 300$$

or

$$X = \frac{300}{8}$$

and,

$$X = 37.4 \text{ volts peak-to-peak. (Approx.)}$$

(The same formula would be employed had the amplitude of the calibration wave been greater than that of the unknown wave.)

Always measure unknown peak-to-peak amplitudes using calibrating voltages which approximate the unknown value as closely as possible. Not only does this lead to more accurate results, but it is also easier to work with.

The convenience of having a calibrating voltage handy to measure the peak-to-peak values of any voltage applied to the vertical input terminal is recognized in another oscilloscope (Figure 29) by incorporating a peak reading voltmeter and several controls for varying the amount of the calibrating voltage Perhaps the best way of illustrating the operation of these controls is by means of an example.

Assume there is a pattern on the screen and we wish to determine its peak-to-peak value. As a first step, we would adjust the "Vertical Gain" control until the pattern height extended over a convenient number of screen mask lines - say 10 or 20. The number makes no difference. Note the height of the pattern so that the calibration wave can be made to approach this value. Also, observe the position of "Vertical Atten. Cal." selector switch. Let us assume that it is in the second position marked 1. With this data in hand, turn the "Vertical Atten. Cal." switch to the 3V CAL. position. This removes the original pattern from the screen and substitutes in its place a 60-cycle sine wave. The peak-to-peak value of this sine wave can be read from the 0-3V scale of the voltmeter on the front panel.

Rotate the "Calibrating Voltage" control until the sine wave covers as much height as the unknown wave and when this condition is reached, the peak-to-peak value of the sine wave is simply read from the meter scale.

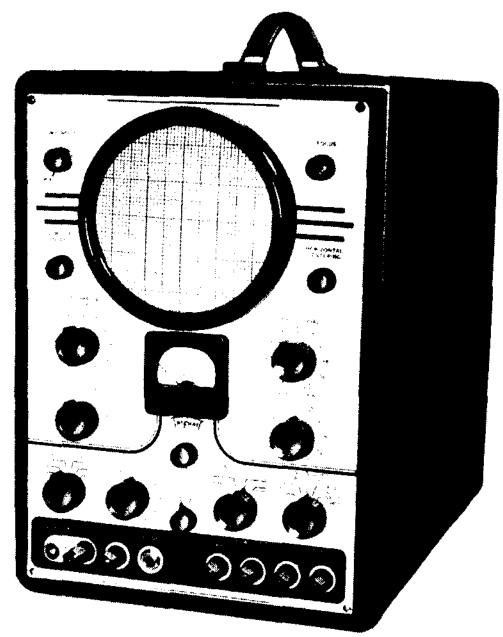


Figure 29. This Oscilloscope Contains a Built-In Peak-To-Peak Voltmeter Together with Several Calibrating Controls. Courtesy Triplett Electrical Instrument Company.

Available, too, is a 0-10 volt position of the "Calibration" switch, if more voltage is desired.

Note that it is the meter which gives you the peak-to-peak value of the calibrating sine wave. The "Vertical Atten. Cal." switch merely indicates which meter scale to read - 0-3 or 0-10.

To continue, suppose in the above example, that the sine wave occupied as much vertical distance as the unknown wave when the peak-to-peak reading on the meter was 2.5 volts. Then this value multiplied by the 1 to which the "Vertical Atten. Cal." switch was set when the unknown wave was applied tells us that the peak-to-peak value of this wave is 2.5 volts. Had the "Vertical Atten. Cal." switch been set at 10 when the original wave was applied, the meter reading (2.5 volts) would have had to be multiplied by 10 (to give 25 volts). Or, had the switch been set to the 1st position, or .1, the meter reading would have had to be divided by 10. Which brings up an interesting question. Why, for example, do we take the attenuator control setting into account here when this was not done before? The answer is to be found in the manner in which the calibration voltage is applied to the vertical system. If this calibration voltage is applied to the vertical input terminals in the same manner as the unknown wave, then obviously whatever value we determine for the calibration voltage will be the same for the unknown wave.

In this oscilloscope (Figure 29), however, the calibration voltage is applied internally and, as it happens, it is fed in at a point which is beyond the attenuation network. Therefore, when the incoming signal is attenuated, the amount of attenuation it receives must be taken into account because we wish to know the true peak-to-peak value of the voltage as it is at the vertical input terminals and not what it becomes after it has passed through the attenuator network. It is to arrive at this true value that we follow the multiplication procedure outlined above.

In this respect, remember that when a low-capacity probe is used to display a wave on an oscilloscope screen, the attenuation caused by the probe must be considered, too. If this information is not available, dispense with the probe and use an ordinary pair of leads while the peak-to-peak measurement is being made. This may result in some distortion of the waveform, but, in general, it will not alter the peak amplitude appreciably.

To the reader who wonders how to determine when to use which procedure there can only be one answer--study the instruction manual of your particular instrument. This cannot be emphasized too strongly. If you think enough of an instrument to buy it, then spend the little extra time required to learn what it will or will not do.

## OTHER PEAK-TO-PEAK MEASURING METHODS -

When the oscilloscope is incapable of supplying its own calibrated voltages, recourse may be made to a variac and an ordinary VTVM, to a special voltage calibrating instrument, or to a VTVM capable of measuring peak-to-peak values. Each method will be described in turn.

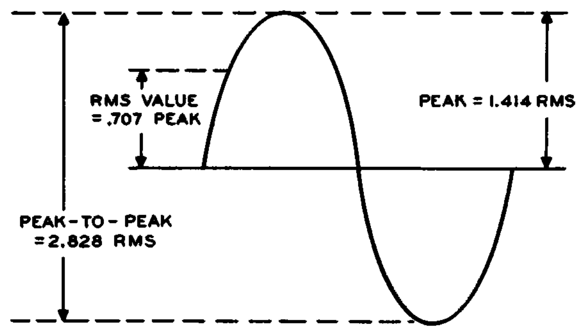



Figure 30. Relationship Between RMS, Peak, and Peak-To-Peak Values of a Sine Wave.

### A. VARIAC AND VTVM.

To start, feed the TV signal into the vertical input terminal of the oscilloscope. Then, with the wave present on the screen, adjust the vertical gain control of the oscilloscope until the display occupies a height between one-half to three-quarters of the full screen height. Note the exact number of lines that the pattern covers vertically. (In the absence of a mask, use a crayon to mark off the top and bottom of the wave.) This done, remove the signal from the oscilloscope and apply in its place an AC voltage obtained from the output of a variac. Rotate the Variac control until its sine wave equals the peak-to-peak height of the previous TV signal.

None of the controls of the oscilloscope are touched during this second operation.

Now, with a VTVM or an AC voltmeter, measure the AC voltage being fed to the oscilloscope by the Variac. The figure thus obtained is the RMS value of the wave. The peak value may be computed by multiplying this RMS figure by 1.414. See Figure 30. Since the peak-to-peak value is twice the peak value, the RMS meter reading is multiplied by 2 x 1.414 or 2.828.

To illustrate, suppose the input AC voltage applied by the Variac to the oscilloscope is 10 volts. The peak-to-peak voltage of this wave is 10 x 2.828 or 28.28 volts. If the unknown wave covers the same height on the screen, its peak-to-peak amplitude is also 28.28 volts.

When you cannot obtain a calibrating voltage whose amplitude equals that of the TV signal, the next best approach is to come as close as possible with the calibrating voltage and then estimate the amplitude of the unknown signal by comparing its height with that of the calibrating wave. The formula to use is:

$$\frac{\text{Peak-to-Peak Value of AC wave}}{\text{Screen height of AC wave}} = \frac{\text{Peak-to-Peak value of unknown signal}}{\text{Screen height of unknown wave}}$$

The screen height of both waves may be either in inches or in the number of lines or squares covered. In other words, they may be in any units, just as long as both measurements are expressed in the same units.

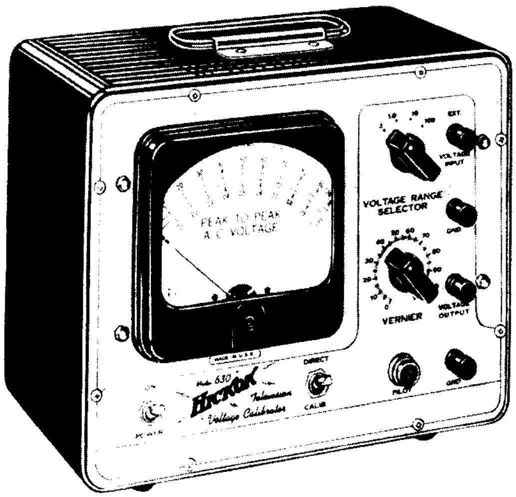



Figure 31. A Voltage Calibrator. Courtesy Hickok Electrical Instrument Company.

B. OSCILLOSCOPE CALIBRATORS.

There are, at the present time, about a half dozen voltage calibrator instruments by means of which it is possible to determine the peak-to-peak voltages of any wave in the television receiver sweep or video circuits. All are simply designed, lending themselves to quick and easy application.

The block and schematic diagrams of the calibrator shown in Figure 31 are given in Figures 32 and 33. A multivibrator using a 6SN7 tube develops a symmetrical square wave output. The multivibrator frequency is approximately 440 cycles, but this has no bearing on the application of the instrument. A low-frequency was purposely chosen to enable the square wave to be depicted on the scope screen and also to permit the use of a conventional copper oxide metering circuit. The peak-to-peak output of the multivibrator

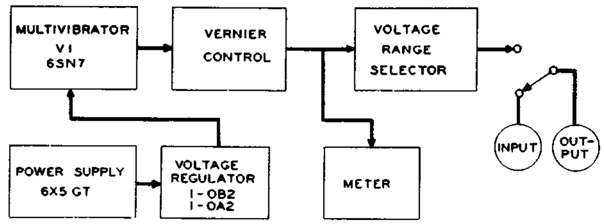



Figure 32. Block Diagram of the Hickok Model 630 Television Voltage Calibrator.

is measured by the meter while, at the same time, the wave itself appears on the scope screen. See Figure 34. When the square wave occupies the same height as the unknown wave, the peak-to-peak value is read from the meter.

Specifically, the calibrator is connected to equipment under test as shown in Figure 35. The voltage to be measured is connected to the "Voltage Input" terminals while the "Voltage Output" terminals connect to the oscilloscope. Throw the "Direct-Cal." switch to the DIRECT position. This feeds the TV signal directly to the oscilloscope where its pattern may be observed. Then adjust the vertical gain controls of the oscilloscope until the pattern occupies a suitable height.

The next step is to use the square wave in the calibrator to determine the peak-to-peak value of the TV signal. Throw the "Direct-Cal." switch to the CAL. position. This removes the TV signal from the oscilloscope and substitutes in its place the square wave of the calibrator. Actually, all you see of the square wave are the top and bottom horizontal lines. Adjust the separation of these two lines, using the "Voltage Range Selector" and "Vernier" controls, until their distance is equal to the peak-to-peak separation of the TV signal. Then simply read the peak-to-peak voltage from the meter scale. The meter range to read is determined by the "Voltage Range Selector" switch.

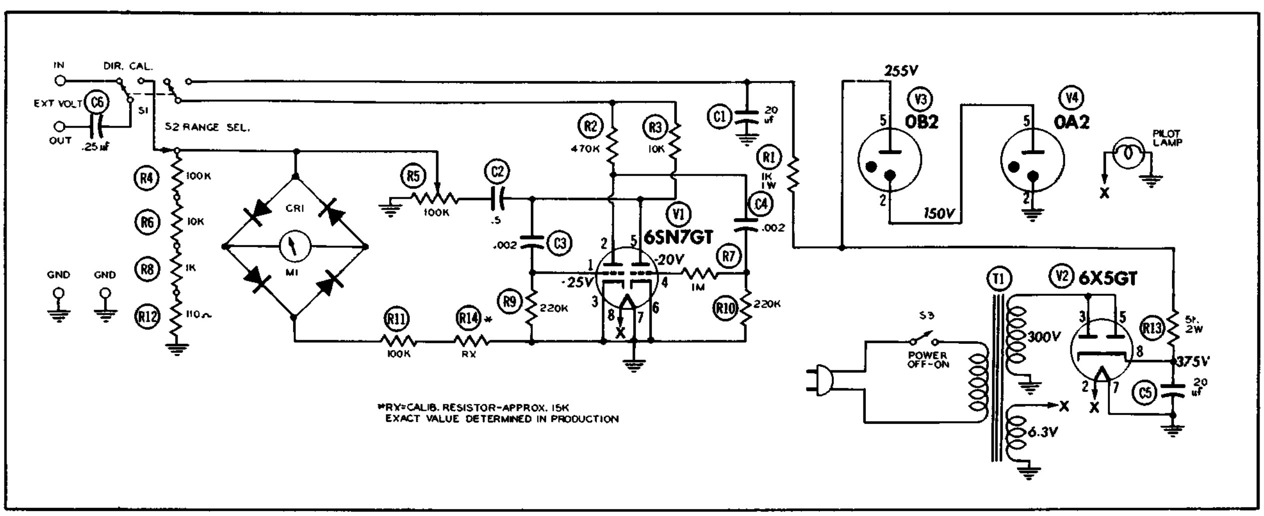



Figure 33. The Schematic Diagram of the Hickok Model 630 Television Voltage Calibrator.

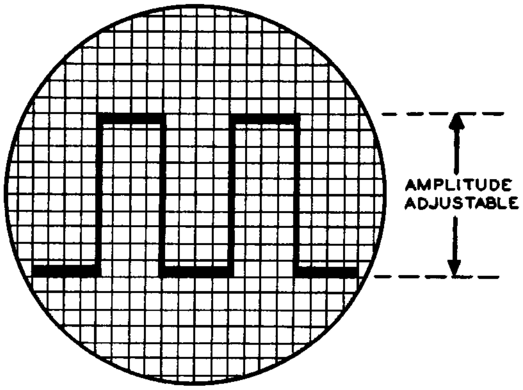



Figure 34. The Screen Presentation Produced by the Hickok Calibrator.

Peak-to-peak voltages up to 100 volts may be read directly from the meter. When the TV signal has a greater amplitude than 100 volts, the height it occupies is compared with that of the 100 volt peak-to-peak square wave using the following formula:

$$\frac{Ecal}{Dcal} = \frac{Ex}{Dx}$$

where

Ecal = calibrating voltage (i.e., 100 volts)
Dcal = number of squares or lines on scope screen covered by calibrating voltage
Ex = unknown voltage
Dx = Divisions of deflection for unknown voltage

This formula will be recognized as being similar to the estimating formulas previously given.

Another oscilloscope calibrating instrument is the Sylvania Electric unit shown in Figure 36. This, too, uses a symmetrical, square-topped wave which is controllable in amplitude from zero to 100 volts. In place of a meter, the "Volts" control is calibrated directly and the value as indicated on this dial scale, multiplied by the setting of the "Multiplier" control, represents the actual peak-to-peak amplitude of the square wave observed on the oscilloscope screen. Estimation, using the formula given previously, is required when the peak-to-peak value of the TV signal being measured exceeds 100 volts.

A modified oscilloscope calibrator using sine waves in place of square waves is shown in Figure 37. The signal to be measured is fed in at the "Input" terminals while the oscilloscope connects to the "Scope" terminals. The selector switch at the right is capable of providing six different peak-to-peak voltages; 1, 2.5, 25, 100, and 250. These values represent the maximum peak-to-peak voltages obtainable from their respective positions when the switch makes contact with them. The "Calibrating Voltage Adjustment" potentiometer at the left enables the operator to vary the voltage at each position from zero to its maximum value.

RMS and simple peak voltage values are also given on the selector switch and on the meter face.

In operation, the calibrator is plugged into an AC outlet to develop its sine wave voltages. Then, with the TV input signal and oscilloscope connected as indicated above, the instrument selector switch is set to any one of the circle positions located between each set of figures. There are six such circles and when the switch is in any one of these positions, the TV signal at the "Input" terminals passes through the calibrator and appears on the scope screen. Here its height is adjusted to cover the desired number of mask lines.

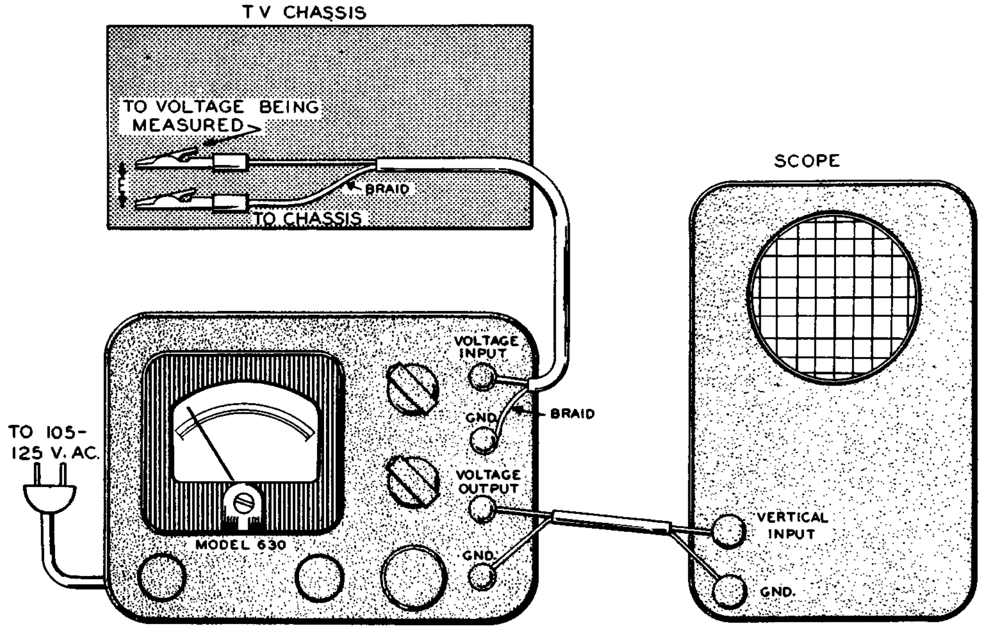



Figure 35. How the Hickok Calibrator is Connected for Use.

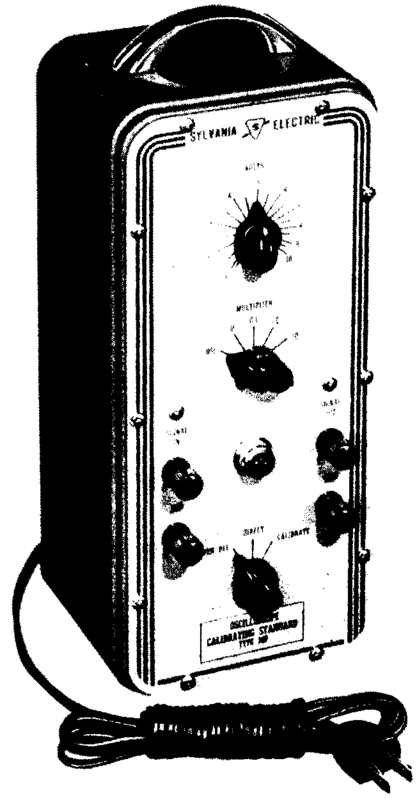


Figure 36. The Sylvania Oscilloscope Calibrating Standard. Courtesy Sylvania Electric Company.

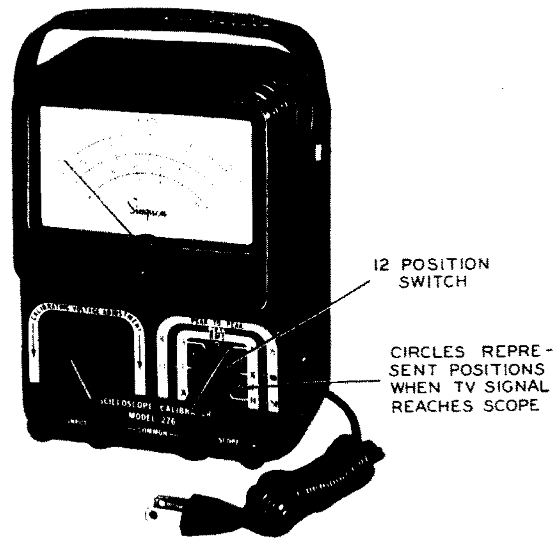



Figure 37. The Oscilloscope Calibrator Manufactured by Simpson Electric Company.

The selector switch is then turned to one of the six calibrating positions containing the peak-to-peak figures. This removes the TV signal from the oscilloscope and substitutes in its place a sine wave. The peak-to-peak value closest to that of the TV signal amplitude is chosen and the "Voltage Adjustment" knob rotated until the sine wave occupies as much height as the TV signal. The exact peak-to-peak value is then read from the appropriate scale of the calibrator meter.

Note that the selector switch of the calibrator contains twelve positions with six producing sine waves of different maximum amplitudes and six alternate positions feeding the TV signal (at the "Input" terminals) directly to the oscilloscope. This arrangement makes it very simple to alternate between the calibrating voltages and the signal under test.

C. PEAK-READING VTVM.

A VTVM which is specially designed to indicate peak-to-peak values of a wave will give this value directly when connected into the TV circuit. Precautions to observe in accepting the peak-to-peak readings of many VTVM's were given in Section 1 and it is suggested that the reader refer back to these before using a VTVM for this purpose.

BANDPASS VS. SENSITIVITY

The function of the vertical amplifiers in an oscilloscope is to amplify applied signals in order that they may be sufficiently powerful by the time they reach the deflection plates to produce a sizable pattern on the screen. The greater the amplification available in this system, the smaller the input signal needed to produce a given vertical deflection. In other words, the oscilloscope becomes more sensitive as a measuring device.

Of importance, too, in the vertical system is its bandpass or its ability to amplify a range of frequencies. The signals whose wave shapes are protrayed on the oscilloscope screen are those found in television receivers, i.e., square waves, saw-tooth waves, and video signals, to mention the more common ones. Each of these waves contain a number of frequencies and to accurately depict their wave shapes, every frequency contained in the wave should be passed by the vertical amplifier system. For accurate television signal observation, this can mean a 4-mc (or more) bandpass.

The objectives, then, in designing an amplifier for use in the vertical system of an oscilloscope are wide bandpass and high amplification. Unfortunately, for any given circuit, bandwidth x gain is a constant which means that if we increase the bandpass by a certain amount, we decrease its gain by the same factor. Thus, one works against the other and if we desire a wide bandpass, we must make up for the resultant gain reduction by adding more amplifier stages. This, in turn, raises the cost of the instrument.

Most manufacturers of moderately priced equipment resolve this conflict by designing the vertical system amplifiers to possess a nominal bandpass (between 300,000 cycles and 1,000,000 cycles). Sever-

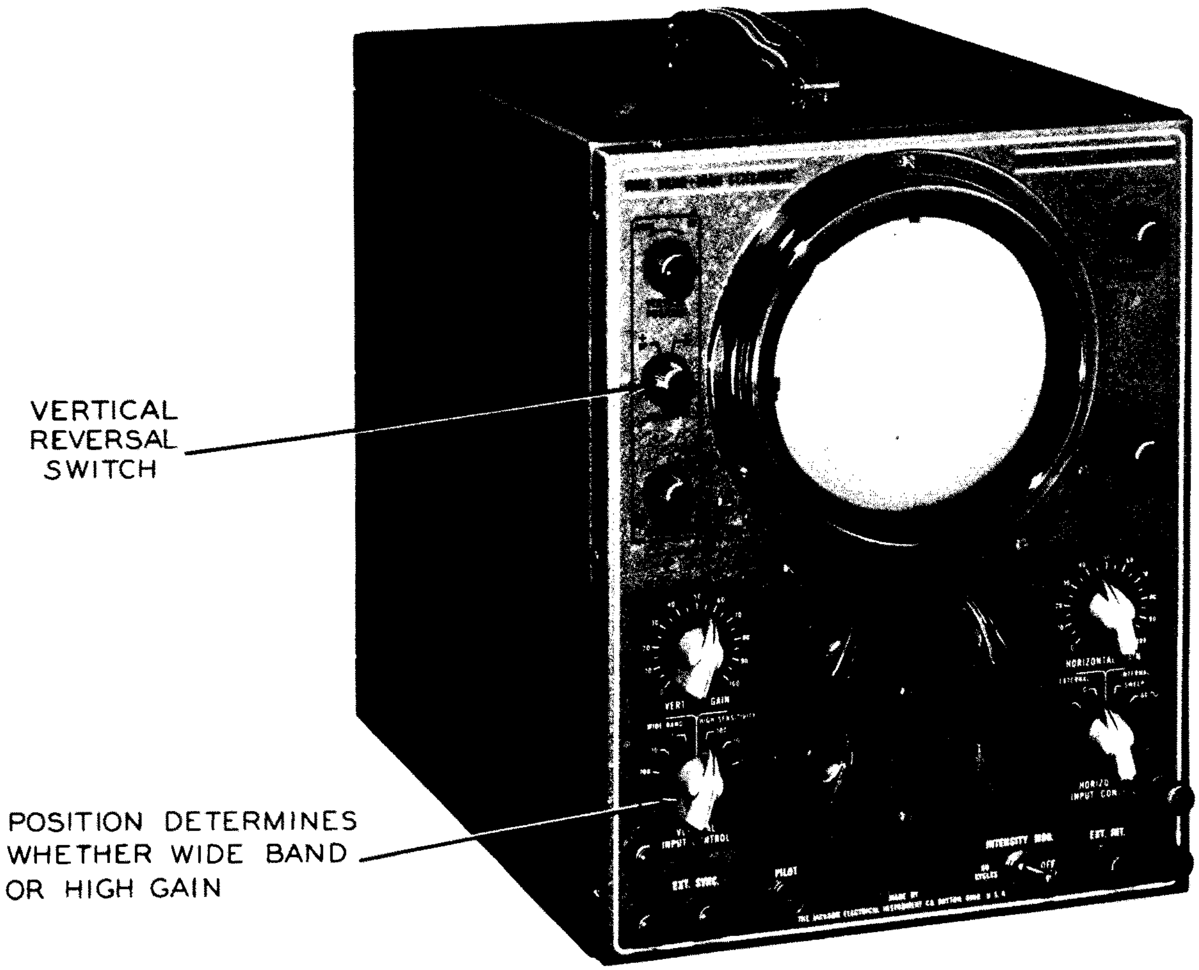



Figure 38. An Oscilloscope Capable of Providing Either Wide-Bandpass (4 mc) or High Gain. (Model CRO-2, Courtesy of Jackson Electrical Instrument Co.)

al manufacturers permit the instrument user to choose between high sensitivity and wide bandpass by providing a suitable switching arrangement. This, for example, is true of the oscilloscope shown in Figure 38. The "Vertical Input" control has three positions where the vertical system possesses a wide bandpass (response uniform within 10% from 20 cycles to 4.5 mc) with a fair amount of gain and three positions where the bandpass is reduced (uniform within 10% to 100 kc), but the gain is up. For each of these positions, attenuation ratios of 100:1, 10:1, and 1:1 are available.

In the oscilloscope of Figure 29, there is a switch at the rear by means of which the bandwidth of the vertical system can be widened from its normal value of 2 mc to a special value of 4 mc. However, in the 4 mc position, the system gain is reduced in half.

This matter of bandpass is a source of confusion to many servicemen. Just how wide should the vertical system bandpass be for suitable application to TV receiver servicing? The answer to this can be found by analyzing where (and how) the oscilloscope is employed. Broadly speaking the scope is used either in conjunction with a sweep generator to trace out the response curve of a circuit or it is used in servicing to show whether or not a signal is present at a certain point in a circuit and, if so, what its shape is.

Oscilloscope use with a sweep generator requires that it be capable of depicting a waveform having a repetition frequency of 60 cycles -- this being the rate at which the response pattern is swept out. Hence, the vertical system bandpass should extend down below 60-cycles, preferable to 30 cycles or less. The lower this limit, the more linear the response will be at 60 cycles.

For servicing, the oscilloscope finds its greatest application in checking voltage waveforms in stages located beyond the video second detector. These include the video amplifiers, sync separator stages, and the vertical and horizontal sweep systems.

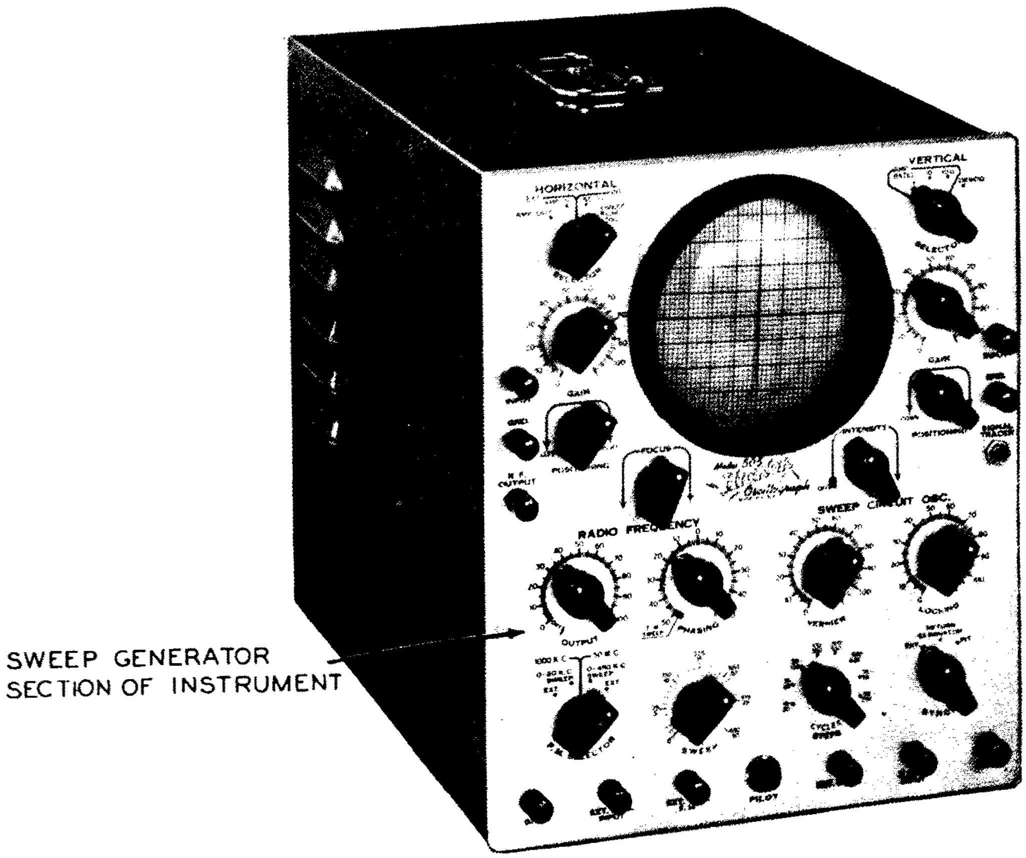



Figure 39. An Oscilloscope Containing a Modified Sweep Generator. (Model 505, Courtesy of Hickok Electrical Instrument Co.)

In all but the video amplifier stages, the fundamental frequencies are low (either 60 cycles for the vertical sweep system or 15,750 cycles for the horizontal sweep system). The rectangular pulse or saw-tooth waveforms in both systems have components that extend to the twentieth harmonic (or so) and taking this into consideration only requires that the bandpass be uniform to a maximum of 315,000 cycles (15,750 x 20 = 315,000).

In the video amplifier stages, the full 4.0 mc video signal is present, but in everyday servicing you are interested primarily in determining whether the video signal is present rather than accurately depicting its wave shape. Hence, any oscilloscope which possesses a uniform vertical frequency response in excess of 300,000 cycles will be suitable for television receiver servicing.

Understandably, the greater the vertical bandpass, the more desirable the instrument, but the 300,000 cycle figure may be looked upon as representing a value below which it is not desirable to go.

## SPECIAL FUNCTION OSCILLOSCOPES

The instruments we have discussed thus far in this section have been concerned solely with those functions that an oscilloscope would normally be called upon to perform. (The Genescope shown in Figure 2, of course, is three instruments in one and is not designed to be used principally for any one purpose, such as the other units are.) However, there are available certain oscilloscopes which will perform other duties that are not ordinarily considered as being within the province of an oscilloscope. One such unit is shown in Figure 39. In addition to being an oscilloscope, there is also available here a modified sweep generator.

The controls for this sweep generator are positioned in the lower left-hand corner of the front panel under the general heading of RADIO FREQUENCY. Contained within this instrument is and RF oscillator which can operate at a fixed frequency of 1,000 kc (1 mc) or at a frequency of 50 mc, depending upon the position of the "FM Selector" control. A reactance tube is connected to this oscillator and by means of this circuit the frequency of the oscillator can be shifted back and forth 60 times a second. At 1,000 kc, the frequency sweep range is 0-30 kc (depending upon the position of the "Sweep" control) and at 50 mc, a sweep as wide as 450 kc is possible. Thus, what we have here is an FM oscillator capable of operating at one of two frequencies, 1,000 kc and 50 mc.

Three controls on the front panel are associated with the FM oscillator: "FM Selector", "Sweep", and "Output". The "FM Selector" is a four position switch controlling the frequency modulated RF output:

a. 1,000 kc: 0-30 kc SWEEP - the 1,000 kc RF signal is frequency modulated with a sweep variable from 0-30 kc.

b. 1,000 kc: EXT - the 1,000 kc RF signal may be frequency modulated from an external source.

c. 50 mc: 0-450 kc SWEEP - the 50 mc RF signal is frequency modulated with the sweep variable from 0 to 450 kc.

d. 50 mc: EXT - the 50 mc RF signal may be frequency modulated from an external source.

The "Sweep" control determines the sweep range of the FM oscillator. When the FM oscillator is operating at 1,000 kc, this control varies the sweeping range continuously from 0 to 30 kc. When the output frequency is 50 mc, the sweep is continuously adjustable from 0 to 450 kc. This control is also in the circuit when external modulation is employed.

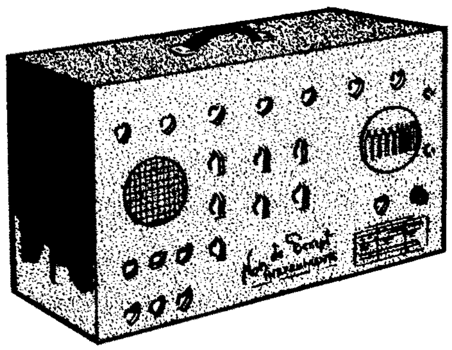
The "Output" control in the OFF position serves as an off-on switch for the RF oscillator. In the 0-100 position, it serves as a control of the RF output level.

At first glance, the usefulness of an FM oscillator which is capable of generating only two frequencies may hardly seem to justify the additional cost and effort necessary to include it in the oscilloscope. And this would be true if that is all this particular circuit did. However, a triode mixer is also included with the oscillator and external RF signals may be fed to this triode for mixing with the output of the FM oscillator. Thus, suppose the FM oscillator is operating at 50 mc and another generator is connected between the "EXT.OSC. Input" and "GND" terminals (both located at extreme lower left-hand corner of the front panel). If the external generator is set to 60 mc, its signal will mix with the frequency modulated 50 mc signal in the mixer tube developing and making available at the "RF Output" terminal a 10 mc FM signal. 10 mc is the difference frequency although, as a matter of fact, the sum frequency (50 mc + 60 mc) of 110 mc will also be present and may be used, if desired.

Thus, we have a flexible arrangement whereby a wide variety of output frequencies may be generated, limited only by the frequency range of the external oscillator. The frequency modulated signals so produced may be fed to a receiver and its response curve determined by feeding the receiver output back to the vertical input terminals of this same oscilloscope.

The remaining controls on this instrument, including the "Phasing" control, deal exclusively with the oscilloscope. They are, in fact, quite similar to the controls on the instrument shown in Figure 22, both units having been manufactured by the same firm.

The oscilloscopes covered in this section are those which are designed primarily for use in radio and television servicing, and therefore are the instruments of greatest interest to the TV technician. Available but not mentioned are a host of other oscilloscopes, many highly specialized for specific industrial or engineering applications. There is probably no other single test instrument which is as versatile as the oscilloscope. Its range of application is truly science wide.



# section five

## Special Television Test Instruments

SPECIAL TV TEST INSTRUMENTS

The vacuum-tube voltmeter, the AM signal generator, the sweep signal generator, and the oscilloscope are the four basic test instruments of the television serviceman. Without them repairing television receivers would be more or less of a haphazard affair filled with uncertainty. You would frequently find yourself wondering whether a set has been completely repaired or whether there was still something else that could have been done. On difficult jobs you would be forced to spend many needless hours locating the trouble. Certainly no one who expects to be a successful serviceman can afford to be without suitable test equipment.

There are, in addition to the foregoing instruments, other units which will perform specific jobs that arise either in connection with the servicing or alignment of television receivers, or in their installation. It is helpful, for example, to know the approximate strength of a received signal when erecting an antenna array. This can be done with a field strength meter. Or, a composite video signal generator would be of considerable assistance when used as a substitute for regular TV signals which may be off the air. These and other instruments, while they may not be as basic in application to all phases of television servicing as the instruments previously described, are not to be dismissed as so much fluff. They serve a very definite purpose and are well regarded by the men who have occasion to use them. Television servicing is a highly specialized and competitive field, and any device which will improve the efficiency of an operation is definitely worthwhile.

In this section we will consider some of the more important specialized instruments which are available to the service technician.

### MARKER GENERATORS

The purpose of a marker generator, we know by now, is to provide known frequencies with which to probe and identify the various sections of a response curve.

The function of the marker generator is an important one in the alignment of television receivers and actually such generators should properly be considered as a basic TV service instrument. In essence this was done in Section 2 since marker pips can be provided by any AM generator of suitable range.

The reason for withholding the description of marker generators until this section is due to their sepcific designation as marker generators by their manufacturers (rather than AM signal generators) and because they contain certain special features which could not be fully appreciated until after sweep generators had been examined. Just what these are will be brought out as each instrument is examined.

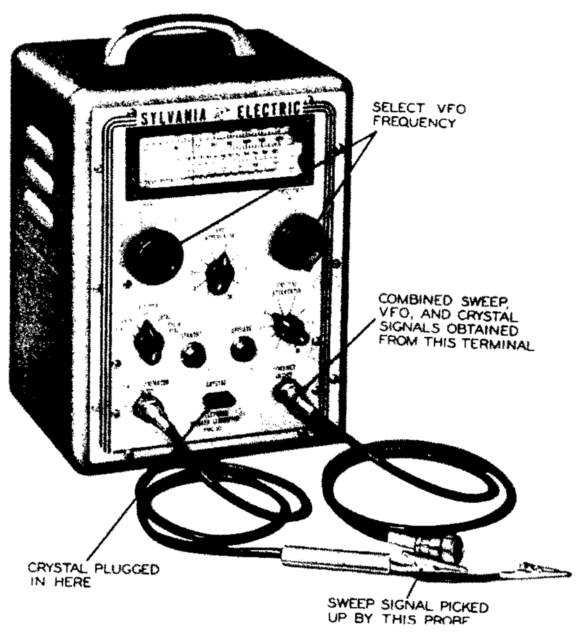



Figure 1. Sylvania Television Marker Generator. Courtesy Sylvania Electric Products, Inc.

A marker generator manufactured by Sylvania Electric is shown in Figure 1. Contained within the unit are two separate oscillators: a variable frequency oscillator (vfo) capable of generating frequencies from 15-240 mc in four bands (labeled A, B, C, and D on the front panel) and a crystal-controlled oscillator which will operate with plug-in crystals having fundamental frequencies in the range of 2-20 mc. The crystal oscillator is used for the alignment of intercarrier TV receiver sound systems (to be described later) and for checking the calibration of the vfo. The output of each oscillator is individually controlled by attenuators.

A five-position "Selector" switch is used to turn power on or off and to choose the type of output desired. In the STANDBY position only the filament voltage is applied to the various tubes, while in the three operating positions which follow, the plate voltage is also applied. Indicator lights are used to denote STANDBY and OPERATE positions.

By means of the "Selector" switch it is possible to choose the output of the vfo and crystal oscillators separately or in combination. Thus, two marker pips may be obtained by the simultaneous use of both oscillators. Crystal controlled IF markers may be obtained from the harmonics of a crystal of appropriate frequency inserted in the panel socket. For example, if the receiver being worked on has a video carrier IF value of 26.4 mc, a crystal with a fundamental frequency of 13.2 mc will, on the second harmonic, produce the 26.4 mc signal. The vfo can then be set at some other frequency to provide another identifying pip.

A feed-through connection is provided for the sweep generator signal, enabling both marker and sweep signals to combine. No attenuation is suffered by the sweep signal in this process while the amount of marker signal which is injected into the sweep signal can be controlled by its respective attenuator.

To check the frequency response curves of a television receiver using this marker generator, we would proceed as follows. Set the "Selector" switch to the position labelled STANDBY and allow the unit to warm up. Connect the output of the sweep generator to the marker generator connector labelled "Sweep Generator Input". Connect the output of the marker generator to the circuit under test in the manner designated for the sweep generator. See Figure 2. Proceed to display the TV receiver response curve on the oscilloscope using the sweep generator only. Set the "Band" switch to the proper position. Adjust the marker generator dial to correspond with the center frequency of the sweep signal generator. Set the "Selector" switch to the position marked VFO. Observe the oscilloscope and advance the "VFO Attenuator" until the marker pip appears. If the marker pip is broad or fuzzy, shunt the input to the oscilloscope with a .001 mfd. capacitor. The output of the marker generator should be kept at a minimum to avoid distortion of the response curve. Adjust the vfo marker pip to the desired position on the response curve and read the frequency from the vfo scale.

To check the calibration of the vfo against the crystal, we would proceed as follows. First we would feed the signal output of a sweep unit into this marker generator and then feed the combined marker and sweep output into the circuit under test. See Figure 2. An oscilloscope would then be connected to the other end of the circuit and adjusted so that the response curve would be displayed on its screen.

Next, a crystal is selected having either its fundamental or a harmonic of its fundamental frequency lie within the pass-band of the curve displayed on the oscilloscope and this crystal is inserted into the crystal socket of the marker generator. The "Selector" switch is set to the position marked XTAL & VFO. The "Crystal Attenuator" control is adjusted until the crystal marker pip appears on the response curve.

Now, adjust the vfo marker pip to coincide with the crystal marker pip and check the frequency indicated on the dial against the crystal frequency (or the harmonic which is being beat against). Slight inaccuracies can be corrected by adjusting a vfo trimmer.

Another way of checking the vfo against a crystal, without using a sweep generator, is to feed both vfo and crystal signals into the video IF system of a television receiver. An oscilloscope is placed

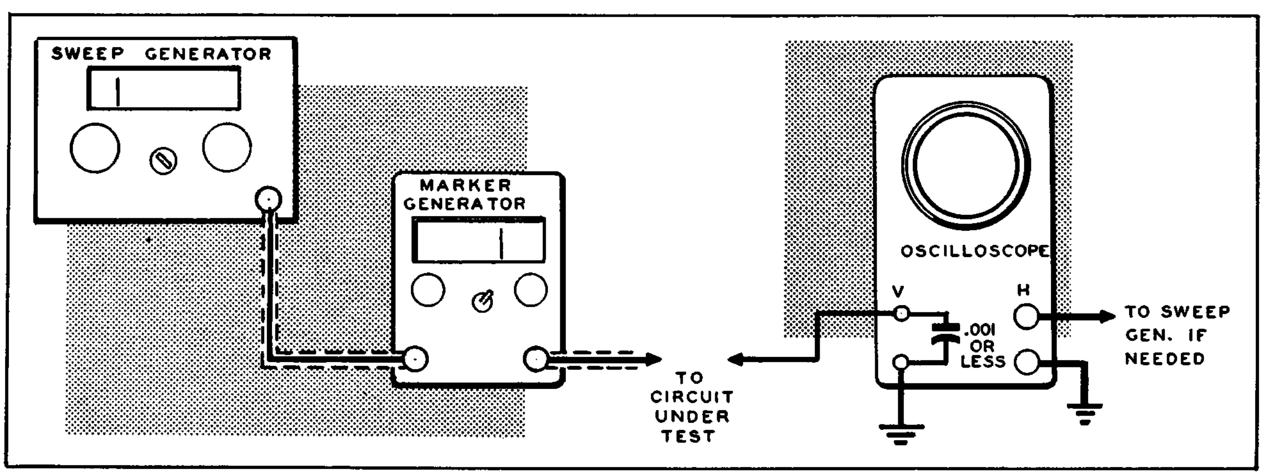



Figure 2. Connecting Sweep Generator to Marker Generator.

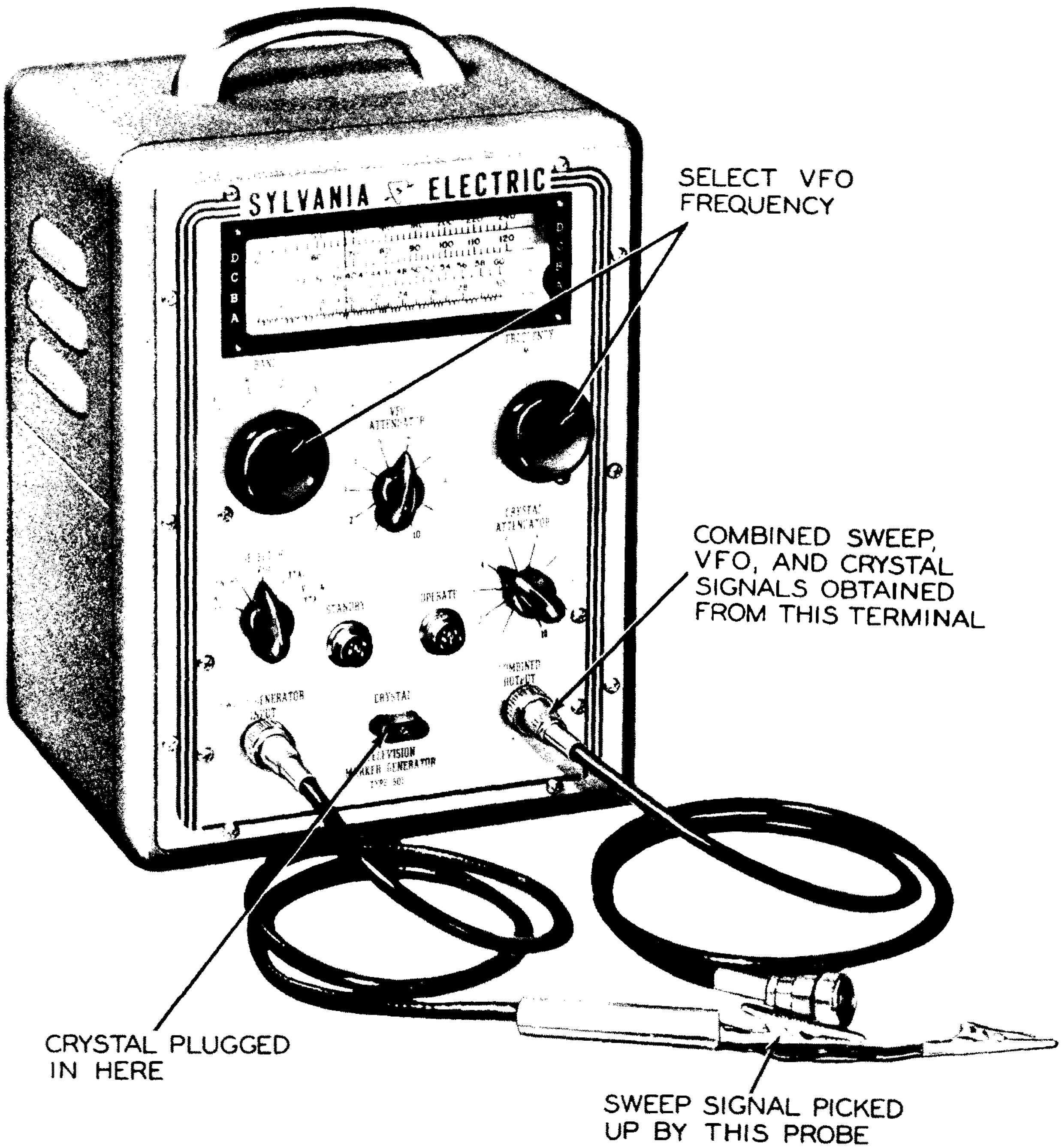



Figure 1. Sylvania Television Marker Generator. (Model 501, Courtesy of Sylvania Electric Products Inc.)


Figure 4. A Versatile Marker Generator. Included Is a Crystal-Calibrated Variable Frequency Oscillator, Two Crystal-Controlled Oscillators, a Modulator Stage for Internally Modulating the Output at Audio and RF Frequencies, and an Audio Amplifier with Internal Speaker. (Model WR-39C, Courtesy RCA.)

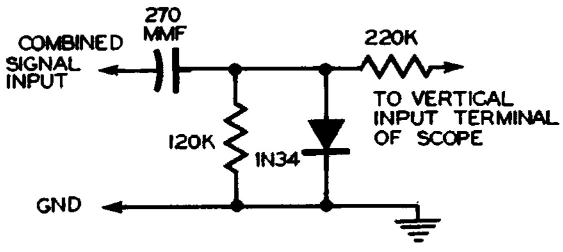



Figure 3. A Crystal Detector which can be Used for Zero Beating Two Signals, as Described in Text.

across the video second detector load resistor. Then the vfo frequency is varied until zero beat is observed on the oscilloscope screen. The reading of the vfo scale should be at or close to the crystal oscillator frequency or a multiple thereof.

Crystal calibration of the vfo can also be carried out by feeding the combined output of the vfo and crystal oscillator into the detector network shown in Figure 3 and then transferring the demodulated signal to the vertical input terminals of an oscilloscope. When the vfo frequency coincides with the crystal frequency or one of its harmonics, a zero beat pattern will be observed on the scope screen.

RCA TELEVISION CALIBRATOR -

The number of functions which a marker generator can be designed to perform is limited only by the ingenuity of the designer and the selling price

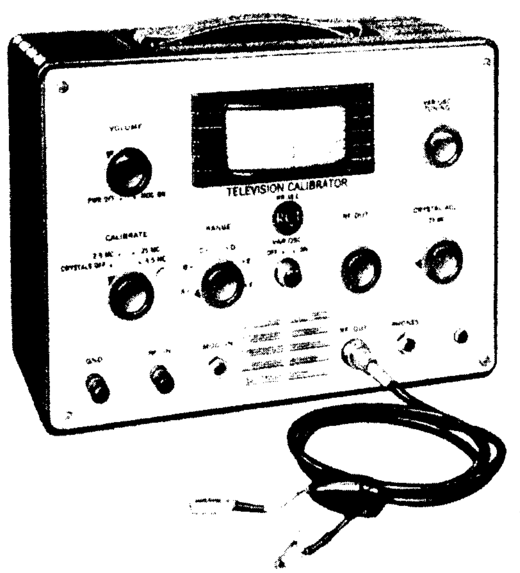



Figure 4. A Versatile Marker Generator. Included is a Crystal-Calibrated Variable Frequency Oscillator, Two Crystal-Controlled Oscillators, a Modulator Stage for Internally Modulating the Output at Audio and RF Frequencies, and an Audio Amplifier with Internal Speaker. Courtesy RCA.

which he wishes to place on the instrument. The instrument shown in Figure 4 is a combination of the following:

1. A crystal-calibrated TV marker generator with dual markers for all TV frequencies.

2. A bar-pattern generator for making linearity adjustments.

3. A re-broadcast minature transmitter for checking all 12 TV-channels.

4. A heterodyne frequency meter including amplifier and speaker.

5. A signal generator operating on fundamentals in all TV bands.

6. A dual crystal standard with three crystals supplied.

The variable frequency oscillator which is the primary source of marker signals has a range from 19 mc to 240 mc on fundamentals, and twice this on second harmonics. In addition, there are three crystals, .25 mc, 2.5 mc, and 4.5 mc, which can be employed for calibration, for producing additional marker pips, or for alignment of the sound IF system of intercarrier receivers. Zero beating facilities are provided in the form of a built-in speaker or, when the signal is weak, headphones may be plugged in. A jack is also provided to permit insertion of an external modulating voltage of any frequency when modulation of the output frequency of the variable-frequency oscillator is desired. Finally, the instrument may be utilized for checking the vertical and horizontal linearity of a television receiver. This latter application is somewhat outside the province of marker generators and so the manner in which it is achieved may be of interest.

The instrument is tuned to the picture carrier frequency (of one of the 12 channels) and the "Calibrate" switch is set to .25 mc. This causes the .25 mc crystal oscillator output to modulate the output of the variable frequency oscillator. When this signal is

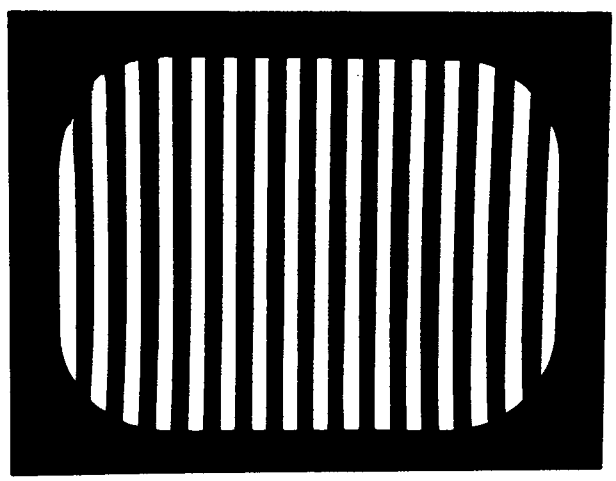


Figure 5. Vertical Bars to Check Horizontal Linearity.

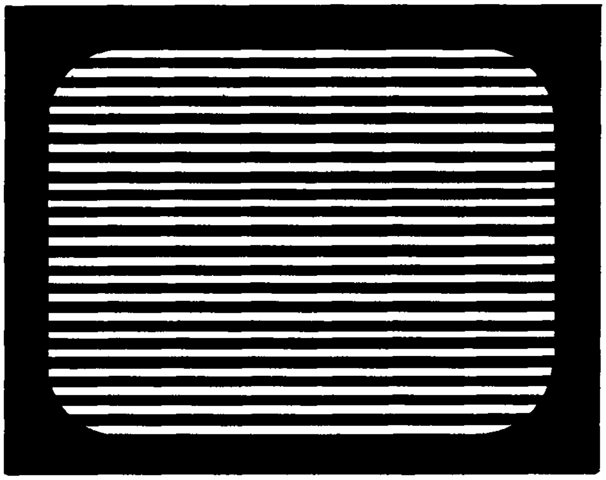


Figure 6. Horizontal Bars Designed to Check Vertical Linearity.

applied to a television receiver, a vertical bar pattern of approximately 16 bars will appear on the receiver screen. See Figure 5. If the bars are all evenly spaced, the horizontal motion of the scanning beam is linear; if the spacing is uneven, the horizontal linearity requires adjustment.

To check the vertical linearity, the "Calibrate" switch is turned to the CRYSTALS OFF position and an audio oscillator is plugged into the "Mod. In" jack. If the audio frequency is set at 1200 cps, 20 horizontal bars will appear on the receiver screen. See Figure 6. If the vertical motion of the scanning beam is linear, the bars will be evenly spaced from each other; non-linearity will reveal itself by unevenly spaced bars.

ALTERNATE METHOD OF MARKER INSERTION -

In all of the previous applications of marker generators, their signals were passed through the circuit under test together with the sweeping signals. Extreme care must be observed at all times that the marker signal amplitude is kept low enough so that it does not disturb the response curve.

Another difficulty that is frequently encountered with this method of marker insertion is the disappearance of the marker pip when it passes through a depression produced by a trap circuit. Thus, in Figure 7, the pip will be visible as long as it is kept above the level of the dashed line, A-B, but when it drops down into one of the dips produced by the video traps the pip energy is absorbed (along with the sweep signal at that frequency) and very little if any of the

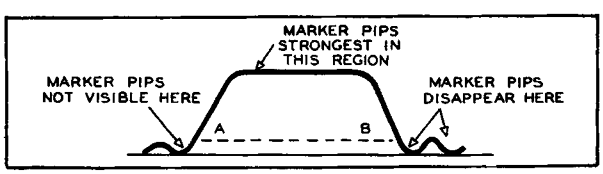



Figure 7. When the Marker Signal Passes Through the Circuit Under Test, it is Frequently Difficult to Discern the Marker Pips Below Level A-B.

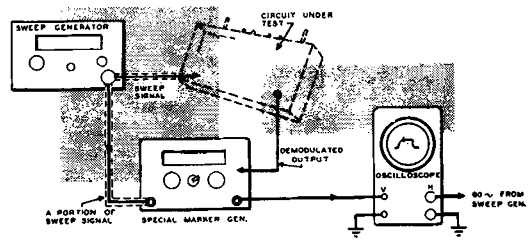



Figure 8. Marker Pip Amplitudes Can be Kept Constant Across the Entire Response Curve by not Passing Marker Signal Through the Test Circuit. See Text.

marker will be seen on the screen. This makes it difficult to determine whether or not the trap circuit is adjusted exactly on frequency. It also means that the pip amplitude will vary at different points along the response curve (just as the curve amplitude does) and this necessitates frequent adjustment of the marker signal amplitude.

It is possible to circumvent these difficulties by not passing the marker signal through the test circuit at all. The set up for the equipment is shown in Figure 8. The signal from the sweep generator is fed to the circuit under test in the normal manner. At the same time, a small portion of the same sweep signal is fed to a special marker generator.

Within the marker generator the sweep signal and the marker signal are mixed together and detected producing the same pip they would have, had they both been sent through the test circuit and its detector. This pip is then combined with the detected output of the circuit under test and fed to the vertical input terminals of an oscilloscope. Because the same sweep signal is used with the marker generator and the test circuit, the position of the pip on the response curve will be where it would have been had it been passed through the test circuit. However, now the pip amplitude is constant over the entire response curve, even in valleys produced by trap circuits, or at other points near the response baseline.

For a marker generator to be employed in this manner, it must contain facilities for accepting the sweep signal, for mixing it with the marker voltage and then combining the resultant pip with the demodulated signal from the circuit under test. This necessitates a special design, such as that possessed by the marker generator shown in Figure 9A.

A block diagram of this instrument is shown in Figure 9B. A modified Colpitts type oscillator comprises one half of a 12AT7 tube. A 15 position gang switch provides the means of switching any one of twelve crystals or three tuneable circuits into the grid of the oscillator. For greater frequency stability, the crystal fundamentals are kept low and harmonic outputs are used for the desired picture carrier frequencies. The following list gives the crystal fundamental and harmonic used for each channel.

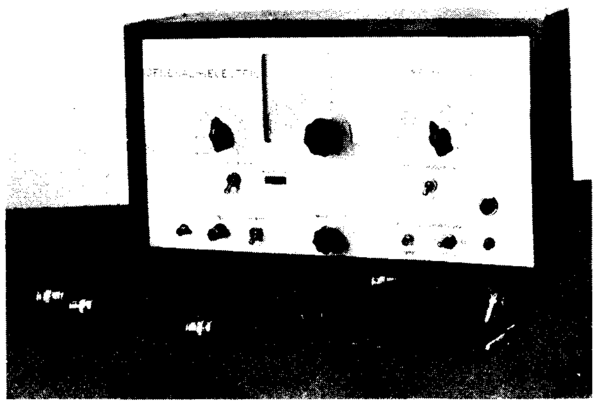


Figure 9A. A Special Marker Generator Designed to Develop Marker Pips Independently of the Test Circuit. Courtesy of General Electric Company.

| Channel | Crystal Fundamentals | Picture Carrier | Crystal Harmonic |
|---|---|---|---|
| 2 | 18.416 mc | 55.25 mc | 3rd |
| 3 | 20.416 mc | 61.25 mc | 3rd |
| 4 | 22.416 mc | 67.25 mc | 3rd |
| 5 | 25.750 mc | 77.25 mc | 3rd |
| 6 | 20.812 mc | 83.25 mc | 4th |
| 7 | 21.906 mc | 175.25 mc | 8th |
| 8 | 22.656 mc | 181.25 mc | 8th |
| 9 | 23.406 mc | 187.25 mc | 8th |
| 10 | 24.156 mc | 193.25 mc | 8th |
| 11 | 24.906 mc | 199.25 mc | 8th |
| 12 | 25.656 mc | 205.25 mc | 8th |
| 13 | 26.406 mc | 211.25 mc | 8th |

The output of the picture carrier oscillator is taken from the cathode and fed to the grid of the mixer modulator tube (the other half of the 12AT7 tube).

A sampling of the sweep generator output is cabled to the marker generator. This voltage is applied to the grid of the sweep coupling tube, which prevents any interaction between equipments. The output of this tube is taken from its cathode and fed to the cathode of the mixer modulator stage.

Since the mixer modulator grid is being driven by the picture carrier oscillator across a large value grid resistor, it is biased to the non-linear portion of its operating curve. Thus, the tube acts as an untuned detector and demodulates the combined signals applied to it. The pip output appears at the plate load resistor and is transferred to the grid of the first marker amplifier stage.

There are three stages of marker amplifiers and as the pips pass through, they are shaped and sharpened to produce a clearly defined marker indication when they are subsequently presented on an oscilloscope screen. Control of the marker output is accomplished by the "Marker Size" control wired into the grid circuit of the last marker amplifier. The output of the final marker amplifier tube is fed to the cathode of the superimposing section.

The output of the receiver being aligned is connected to J3 which injects the signal on the grid of the superimposing section. The detected marker signals are fed to the cathode of the same tube and the combined output appears at J4 to be transferred to the vertical input of the test oscilloscope.

4.5 AND 1.5 MC OSCILLATOR -

The crystal used in the crystal oscillator grid circuit is a triplex cut and normally oscillates at 4.5 mc. By changing the plate tuning, it will also oscillate at 1.5 mc. The plate load switching is done with the 3-position "Crystal Modulator" selector switch. B+ can be removed by actuating the ON-OFF switch located just below the selector switch.

The output of the crystal modulator is fed to the plate of the modulator tube where it plate modulates the picture carrier oscillator output, producing sideband markers ±4.5 mc from the picture carrier to show the relation of picture carrier to audio carrier. See Figure 10A. In the 1.5 mc position, markers are produced every 1.5 mc across the response curve, allowing the operator to check adjacent channel re-

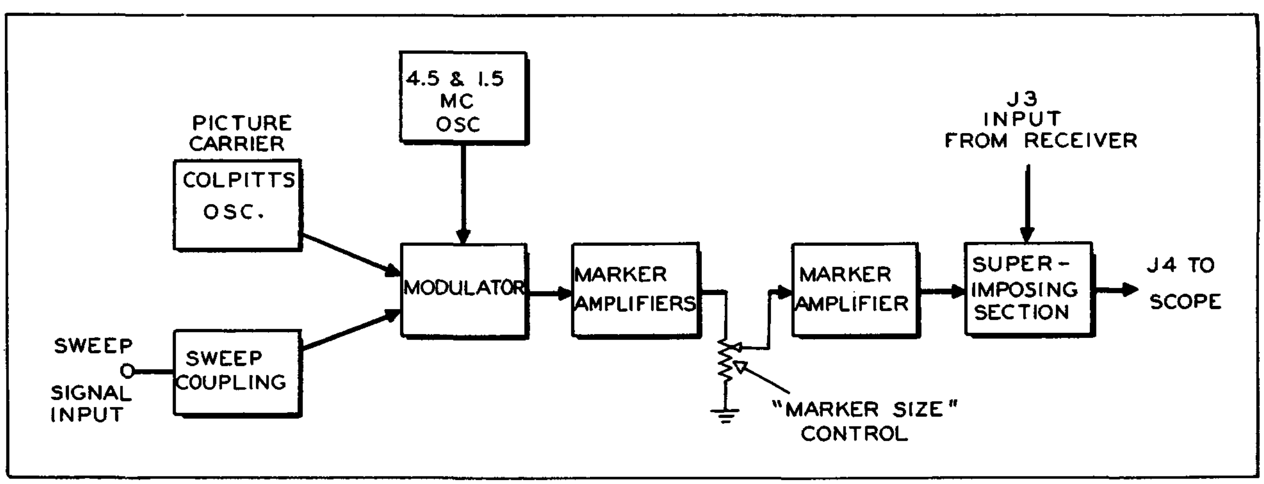



Figure 9B. Block Diagram of The G. E. Marker Generator.

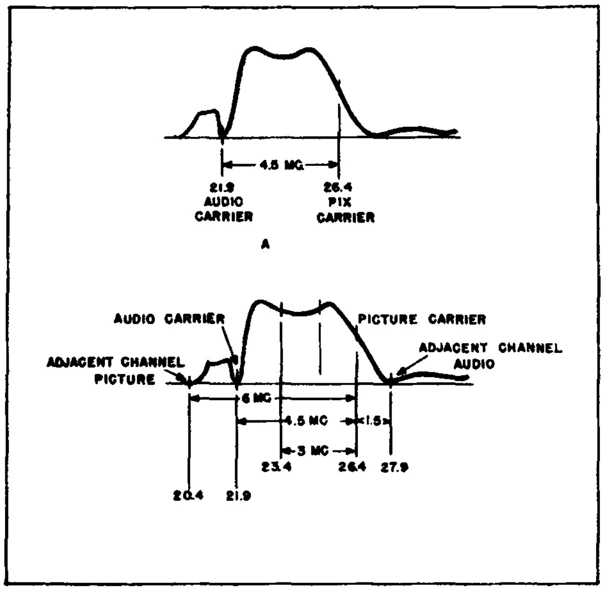



Figure 10.

sponse and band pass characteristics. See Figure 10B. The reader will find it interesting to study Figure 10B because it demonstrates very effectively the following relationships that exist between adjacent channel signals:

1. Picture carrier of one channel is 1.5 mc from sound carrier of lower channel. 67.25 mc is the picture carrier of channel 4; 65.75 mc is the sound carrier of channel 3.

2. Picture carrier and sound carrier of same channel separated by 4.5 mc.

3. Adjacent picture carriers are separated by 6.0 mc.

Hence, by knowing the frequency of the picture carrier oscillator, it is a simple matter to check the remainder of the response curve by noting the position of each 1.5 mc marker.

Another marker generator that can be employed in the same manner is the unit shown in Figure 11. The signal from the sweep generator is applied to the input terminal where a portion of it is fed to an RF buffer amplifier. The rest of the sweep signal appears at the output terminal from which point it is fed to the circuit under test.

Within the marker generator, the abstracted portion of the sweep signal passes through an RF amplifier to a 6AK5 variable oscillator and detector stage. The resultant beat note obtained from the mixing of the sweep and marker signals is passed through a tuned 10 kc network to a 6J6 dual audio frequency amplifier and thence to the "Pip Output" terminals of the instrument. By means of a low-capacity shielded lead or a twisted pair, the pip signal is taken from these terminals and applied to the vertical input terminals of an oscilloscope where it combines with the demodulated response signal

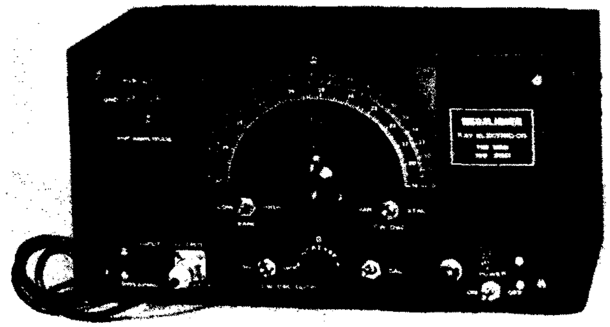


Figure 11. Another Special Marker Signal Generator. Courtesy Kay Electric Company.

from the circuit under test. The set-up of the instruments is shown in Figure 12.

Note that with this instrument, combination of the pip signal and the response voltage from the test circuit does not occur in the marker generator (as in the previous instrument), but at the vertical input terminals of the oscilloscope. All other phases of this operation, however, are similar.

The frequency range of the continuous or marker oscillator extends from 19 to 49 mc in two bands--10 to 30 mc and 30 to 49 mc. A separate crystal oscillator generates a frequency of 4.5 mc for alignment of the sound system of intercarrier receivers and for adjusting 4.5 mc video traps. Also, harmonics of 4.5 mc may be employed to check the calibration of the variable (CW) oscillator.

UHF SWEEP-MARKER GENERATOR -

With the opening of the ultra-high frequencies (470 - 890 mc) to television broadcasting, special sweep and marker generators designed to operate within this range will be required by the television service man and the television engineer. At the time of this writing very few popular priced UHF generators have made their appearance, and so it is difficult to judge what their price range will be or how they will differ from their VHF counterparts, especially in the oscillator section of the instrument. Information has been released on the RCA WR-40A UHF Sweep-Marker generator and it may be instructive to examine its features to see what has been done along these lines.

The WR-40A (shown in Figure 13) is a sweep oscillator with built-in marker oscillator and crystal calibrator. The generator also includes mixers and adders for superimposing markers upon the response curve after the signal has passed through the tuner under test.

The sweep frequency oscillator in this instrument employs a type 5675 UHF pencil-type triode in a modified cavity resonator circuit and is continuously tuneable from 470 to 890 mc. It is frequency

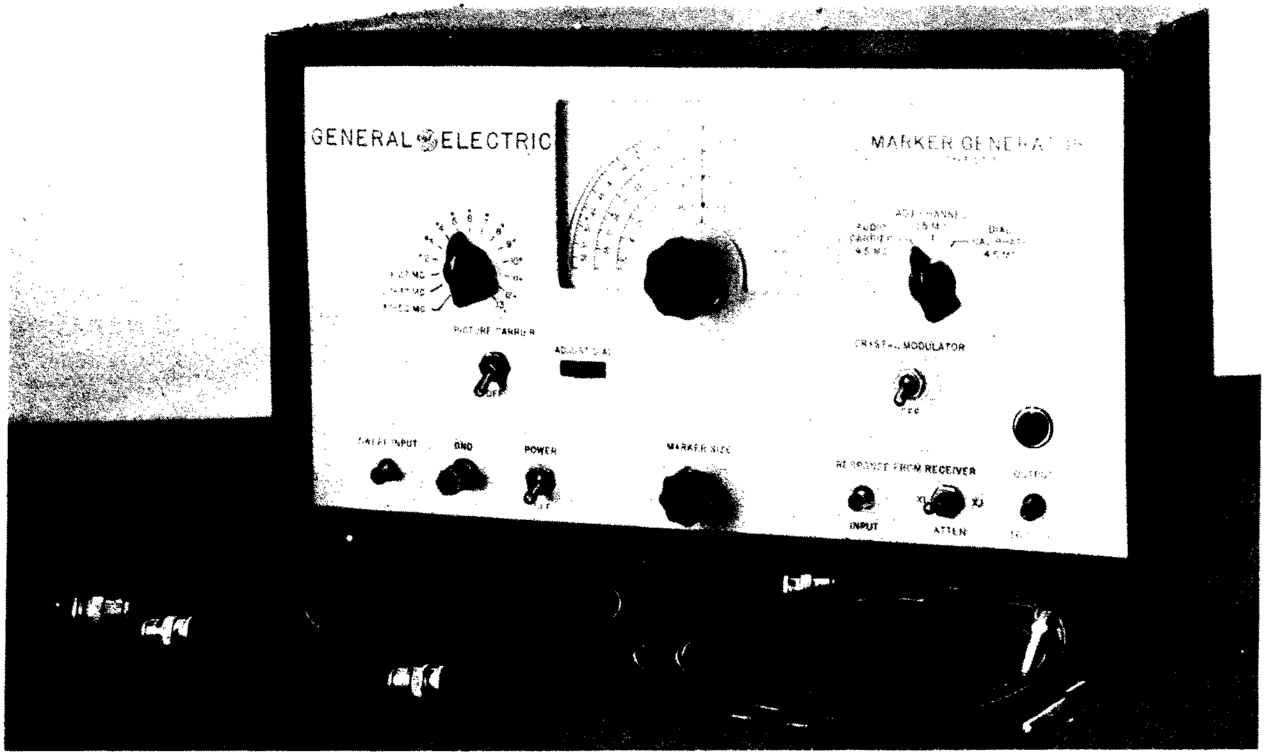



Figure 9A. A Special Marker Generator Designed to Develop Marker Pips Independently of the Test Circuit. (Model ST-5A, Courtesy General Electric Co.)

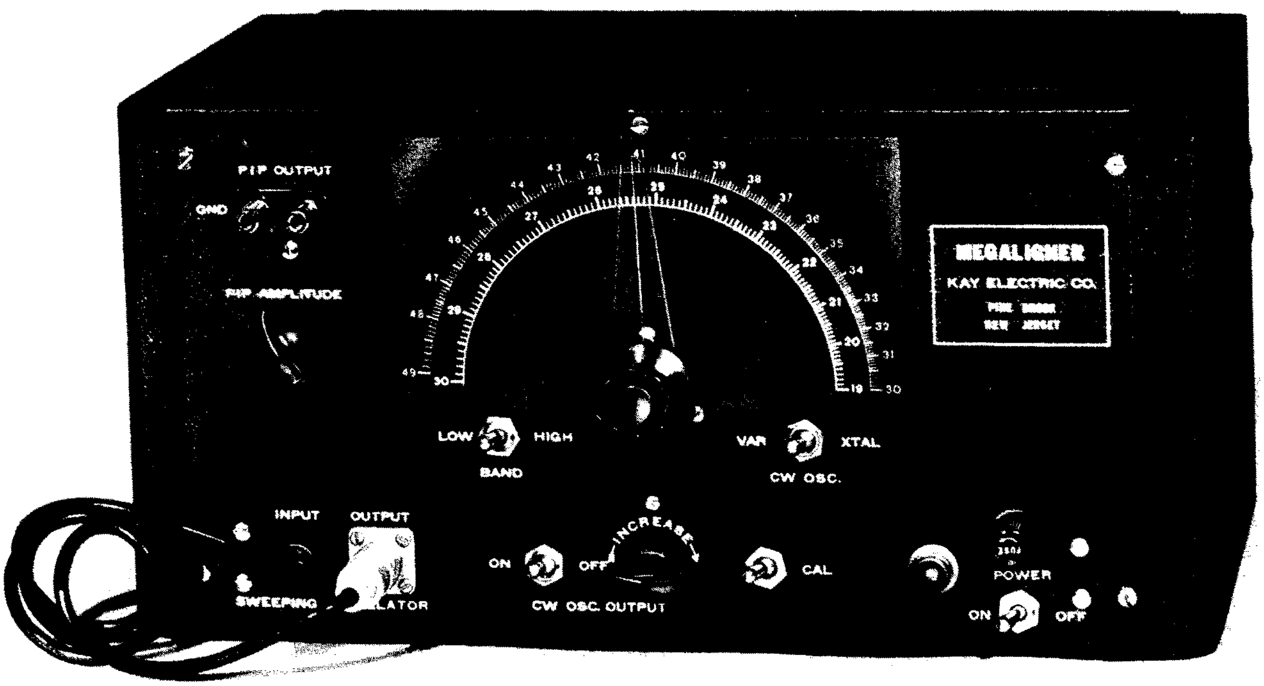



Figure 11. Another Special Marker Signal Generator. (Megaliner, Courtesy of Kay Electric Co.)

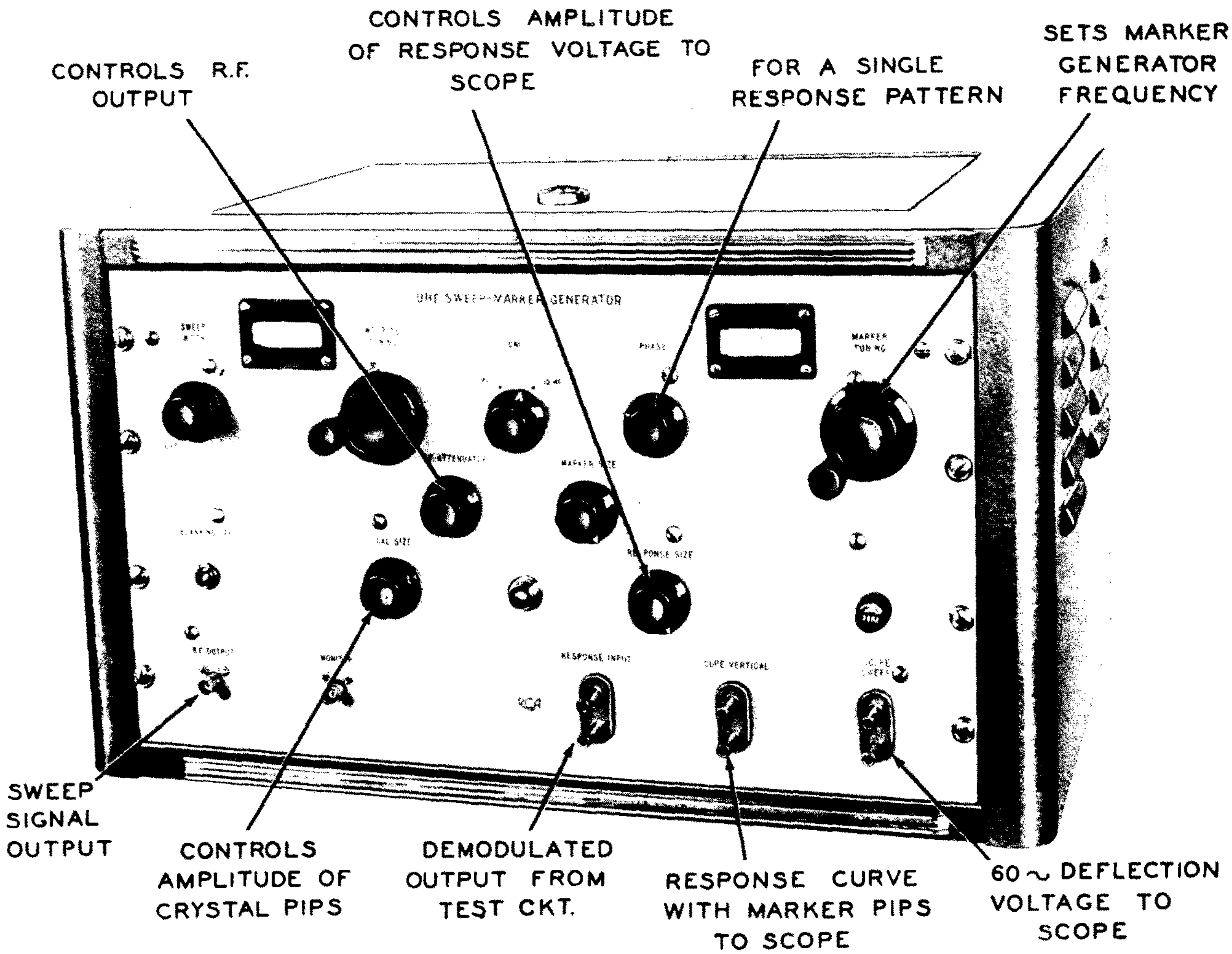



Figure 13. A UHF Sweep-Marker Generator. (Courtesy of RCA.)

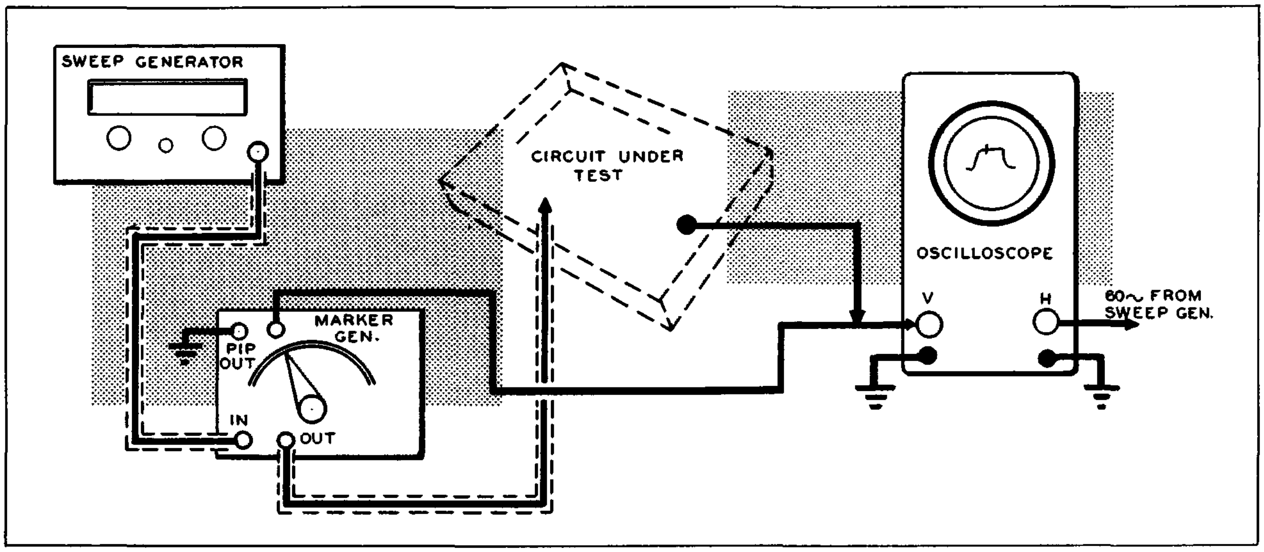



Figure 12. Instrument Set-Up Using the Marker Generator Shown in Figure 11.

modulated by a vibrating device which varies the inductance of the cavity to provide a linear frequency deviation up to 45 mc. The cavity is designed to have very low leakage, and a capacitance adjustment in the cavity compensates for shifts in calibration when it is necessary to replace the oscillator tube. Blanking of the sweep oscillator is included to give a reference base line. The blanking voltage is controlled by a push-button on the front panel so that it may be easily removed for precise setting of the phasing control.

The marker system included in the instrument consists of a variable frequency oscillator similar to the sweep oscillator and a crystal calibrator which provides 1 and 10 mc calibration pips throughout the UHF TV band. The crystal calibrator consists of a 10 mc crystal oscillator, a 1 mc locked-in oscillator, and a three tube harmonic generator. A sensitive amplifier together with mixers and adders is used to superimpose the variable frequency and crystal

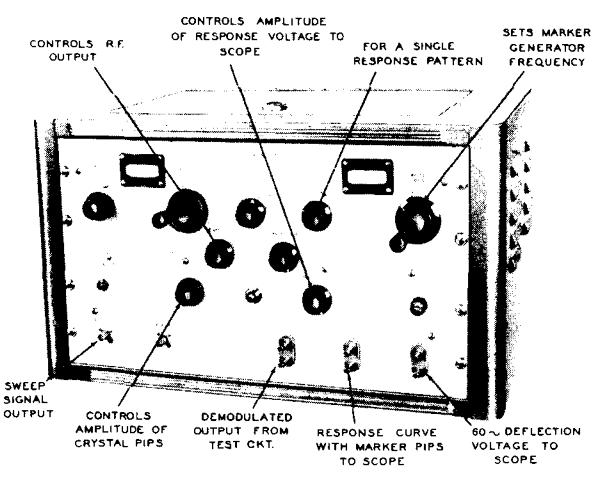



Figure 13. A UHF Sweep-Marker Generator. Courtesy RCA.

markers on the response curve for observation on an oscilloscope screen.

From the block diagram of the generator, Figure 14, we see that the output of the sweep oscillator, V9, goes to three different points in the circuit. One portion of the sweep oscillator connects directly to the RF output terminal from which point it is fed to the circuit under test. Another portion of the sweep oscillator signal goes to a crystal mixer - CR2 - where it combines with the marker signal to form a pip. The final connection from the sweep oscillator is made to CR1, a crystal mixer where the output from the crystal calibrating circuits is combined with the sweep signal to form a series of pips spaced at 1 or 10 mc intervals, depending on the crystal oscillator chosen by the "Cal" switch.

The pips produced by the marker section of the instrument and the pips produced by the calibrating section are each separately shaped and amplified and then combined in V7B. At the same time, the demodulated output from the tuner (which is the response curve of this tuner) is brought back to the instrument via the "Response Input" terminal and amplified by V8B. From here the signal goes to V8A where the marker and/or crystal pips are added and then the combined signal goes to the vertical input terminals of an oscilloscope. See Figure 15. The horizontal sweep frequency for the oscilloscope is also obtained from the front panel of this generator.

Note that none of the pips pass through the test circuit and hence cannot affect the amplitude of the response curve. Furthermore, all pips are equally visible at every point on the curve.

## TV SIGNAL SUBSTITUTE INSTRUMENTS

Lack of a television signal hampers the service man by preventing him from performing an air check on a receiver before it leaves the shop or from conducting certain tests while he is repairing it. Without a signal he may be unable to determine what the

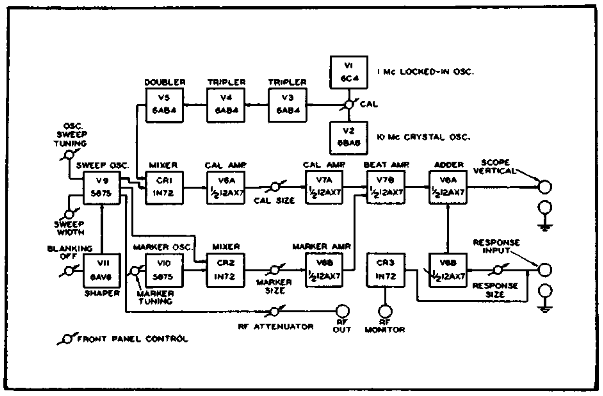



Figure 14. Block Diagram of the RCA UHF Sweep-Marker Generator.

defect is; or, if the set repaired, he may be unable to make final adjustments on certain operating controls which frequently require some correction, however slight. Into this category fall the vertical and horizontal hold, linearity, and size controls. In the pages that follow, a representative group of instruments are described, instruments which will provide partial or total substitution for a TV signal.

LINEARITY CHECKS -

In a properly adjusted television receiver, the electron scanning beam travels from left to right and from top to bottom at uniform rates of speed. Any speeding up of the beam will cause the picture to stretch out while any slowdown will result in image compression. Either effect is labeled as non-linearity and in the absence of a component defect can usually be corrected by adjustment of the corresponding linearity controls.

To determine whether non-linearity exists in either sweep section of a television receiver, we must first produce a test pattern (preferably) or a picture on the screen. Non-linearity cannot be determined by using a raster alone. In the absence of a received signal, linearity checks can be performed in several different ways. The simplest approach is to take an audio generator and connect it across the load resistor of the video second detector stage. If we set the generator frequency to 60 cycles, then half the screen will be light and half will be dark. See Figure 16. This is so because it takes the electron scanning beam approximately 1/60th of a second to travel from the top of the screen to the bottom and in this time the applied 60 cycle sine wave will have passed through one-half positive cycle and one-half negative cycle. If we assume that the positive half cycle is active first, then the top half of the screen will be bright. During the succeeding negative half cycle, the beam current reaching the screen will decrease, possibly reducing to zero. Therefore, the screen during this half cycle will be dark.

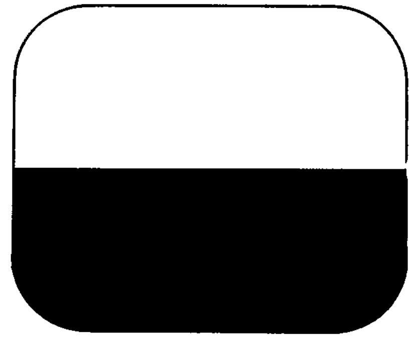


Figure 16.

To increase the number of bars on the screen, we need only raise the frequency of the generator. When the frequency reaches 660 cycles, its voltage (which, remember, is reaching the grid of the picture tube) will pass through eleven complete cycles in the time it takes the beam to travel once from top to bottom of the screen. We will thus see eleven white and eleven black bars, all horizontal. This is shown in Figure 17.

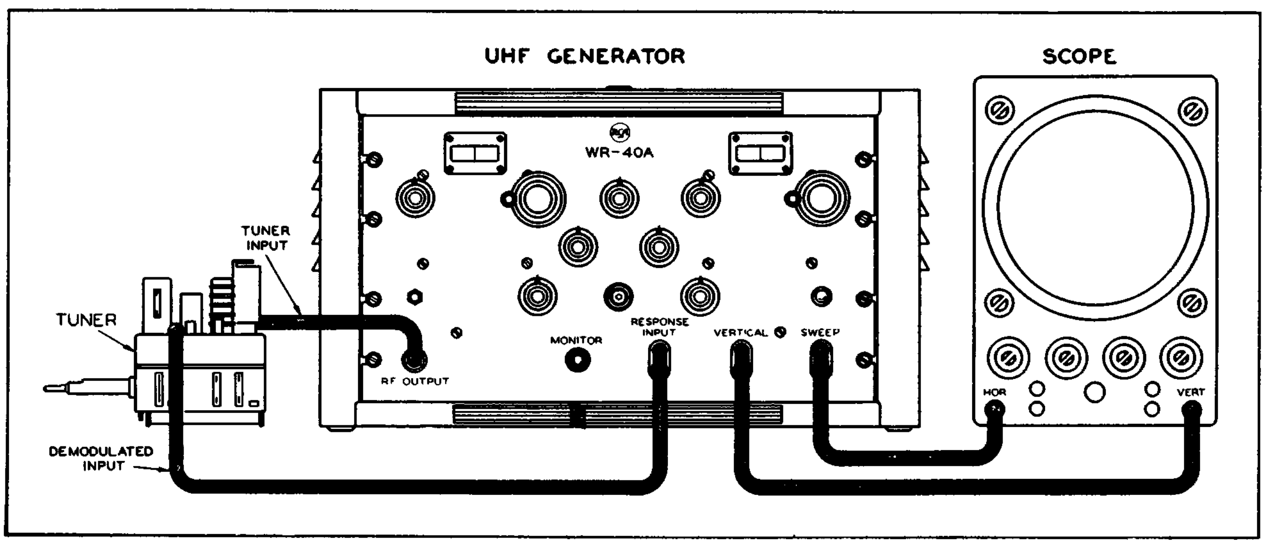



Figure 15. The Manner in Which the UHF Generator is Employed to Align a UHF Tuner. Courtesy RCA.

Figure 17.

Generally, it is desirable to have 20 or so bars on the screen obtained by raising the audio generator frequency to 1200 cycles or higher. In this way the bars are not too thick and the vertical linearity can be adjusted accurately. The pattern observed on the screen will be stationary because some of the signal applied across the video second detector load resistor will find its way into the sync circuits and stabilize the vertical sweep oscillator. (Sync take-off points are almost always placed after the video detector.)

To check the horizontal linearity of a set, we must develop a series of vertical bars across the face of the tube. See Figure 18. This can be achieved by raising the frequency of the applied sine wave until it affects the electron beam during the scanning of a single line. We know that lines are scanned out at the rate of 15,750 per second. Hence, in order to blank out portions of a line while the beam is moving across the face of the tube, the frequency of the applied signal should be higher than 15,750 cycles. A good value to use is 315,000 cycles, this being 20 times 15,750 and therefore capable of producing 20 vertical bars. However, any multiple of 15,750 may be used, as desired.

To obtain a signal of 315 kc, an RF signal generator will be needed since few audio generators extend this high. The output leads of the generator are connected across the video detector load resistor as discussed above. When the signal frequency is an exact multiple of 15,750, the vertical bars will be stationary on the screen because the horizontal sweep oscillator of the receiver will be held in synchronism with the signal.

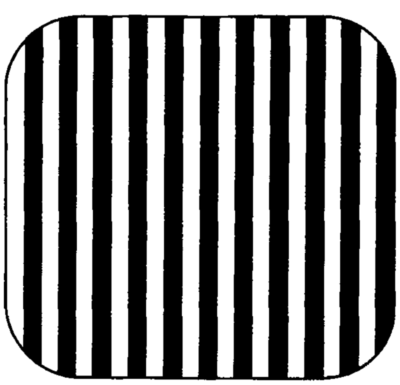


Figure 18.

We can obtain results similar to the above by connecting an RF generator to the antenna terminals of the receiver, setting its frequency to the video carrier value of any of the twelve channels, and then amplitude modulating this signal first with a 1200-cycle voltage (for a vertical linearity check) and then with a 315 kc voltage (for a horizontal linearity check). This was substantially the method suggested for several of the generators in Section 3 and for the RCA Television Calibrator earlier in this section. Modulating frequencies other than 1200 cycles and 315 kc may be used, the only difference being a change in the number of bars developed on the screen. Several of the instruments to follow will have their own facilities for producing screen patterns to check linearity, but the end results will usually be quite similar.

Thus, consider the cross-bar generator shown in Figure 19. This generator contains two oscillators: a VHF oscillator which will tune from channel 2 through channel 6 and a low frequency oscillator which can be set at either 1100 cycles (approx.) or at 362.25 kc. The output from the low-frequency oscillator is a series of pulses and these are fed to the VHF oscillator where they amplitude modulate the signal developed here. This modulated RF signal is then applied to the antenna input terminals of a receiver. The pattern appearing on the receiver screen will consist of a series of vertical or horizontal bars depending upon whether the low-frequency oscillator is set for 1100 cycles or 362.25 kc.

It will be noted that the VHF oscillator in the instrument tunes only through channels 2 to 6. Linearity in a receiver is independent of channel setting and if a receiver is adjusted for proper linearity on the low channels, it will retain this linearity on the high channels. By designing this instrument only for low band operation, its usefulness remains unaffected, while its cost can be kept down.


Figure 19. A Cross-Bar Generator which can be Employed for Setting the Linearity Controls of a Television Receiver and for Limited Servicing of the Vertical and Horizontal Sweep Systems. Courtesy Superior Instrument Company.

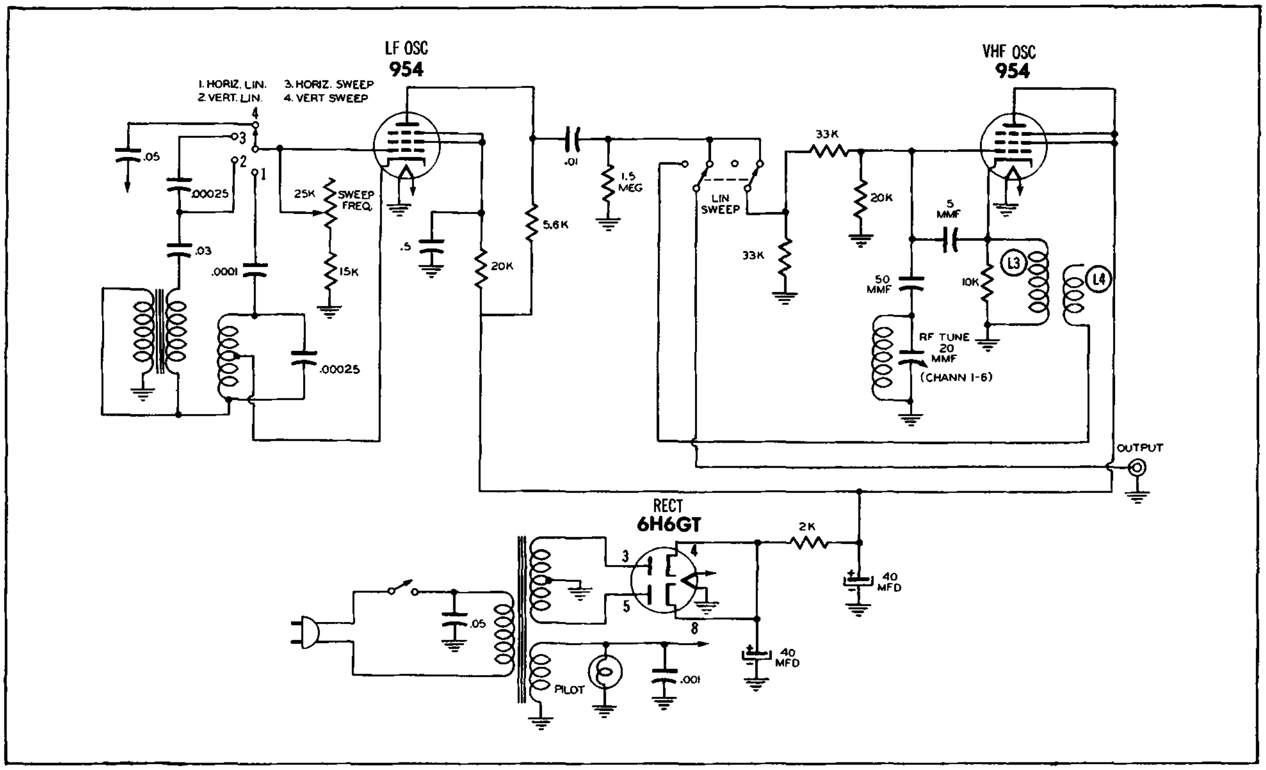



Figure 20. The Schematic Diagram of the Superior Cross-Bar Generator.

CHECKING SWEEP CIRCUITS -

It is also possible to employ the cross-bar generator to supply pulses directly to the vertical or horizontal systems of a television receiver for checking purposes. In this case the output pulses are obtained directly from the low frequency oscillator. For checking the horizontal sweep system, the oscillator frequency is set at 15,750 cycles; for checking the vertical sweep system, the low frequency oscillator is converted to an amplifier and a 60-cycle voltage from the filament transformer is passed through it. The amplifier distorts the wave into an approximate saw-tooth shape. This is then fed to the vertical sweep system to be tested.

The usefulness of the cross-bar generator in checking the sweep systems of a television receiver lies in its ability to substitute its own pulses for those which would ordinarily be produced by the receiver sweep oscillators. Thus, if the high voltage in a receiver is missing and the serviceman wishes to determine whether this is due to the failure of the horizontal oscillator, he can connect the output of this generator to the point in the receiver where these pulses would normally be present. If the high-voltage reappears, then either the oscillator is inoperative or else the circuit path from the oscillator to the point where the bar generator is connected has been broken.

The reader will recognize that there are other servicing methods for the same problem which would not require use of a bar generator. However, this facility is available in this instrument and may be used, if desired.

A circuit diagram of the generator is shown in Figure 20. The VHF oscillator is a grounded-plate Colpitts with signal take-off achieved capacitively by means of the stray capacitance existing between $L_3$ and $L_4$. (The word capactive here is not an error.) The low frequency oscillator is a Hartley in position 1 of the 4-position switch, operating near 362.25 kc to produce 23 vertical bars. In position 2, the oscillator becomes a blocking oscillator functioning at some harmonic of 60 cycles (to produce horizontal bars). In position 3, the oscillator generates a fre-

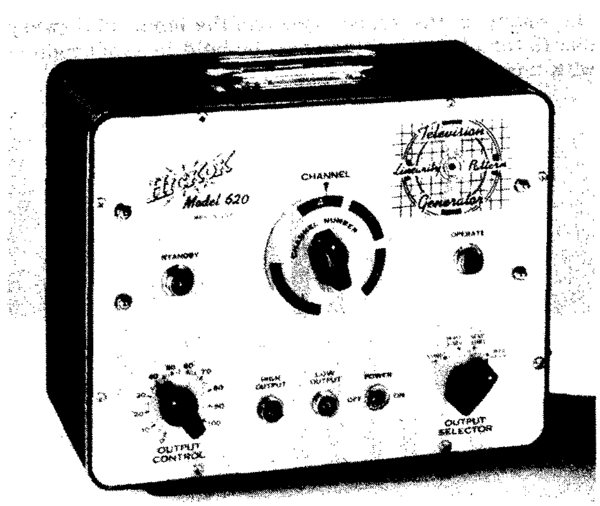



Figure 21. The Hickok Linearity Generator.

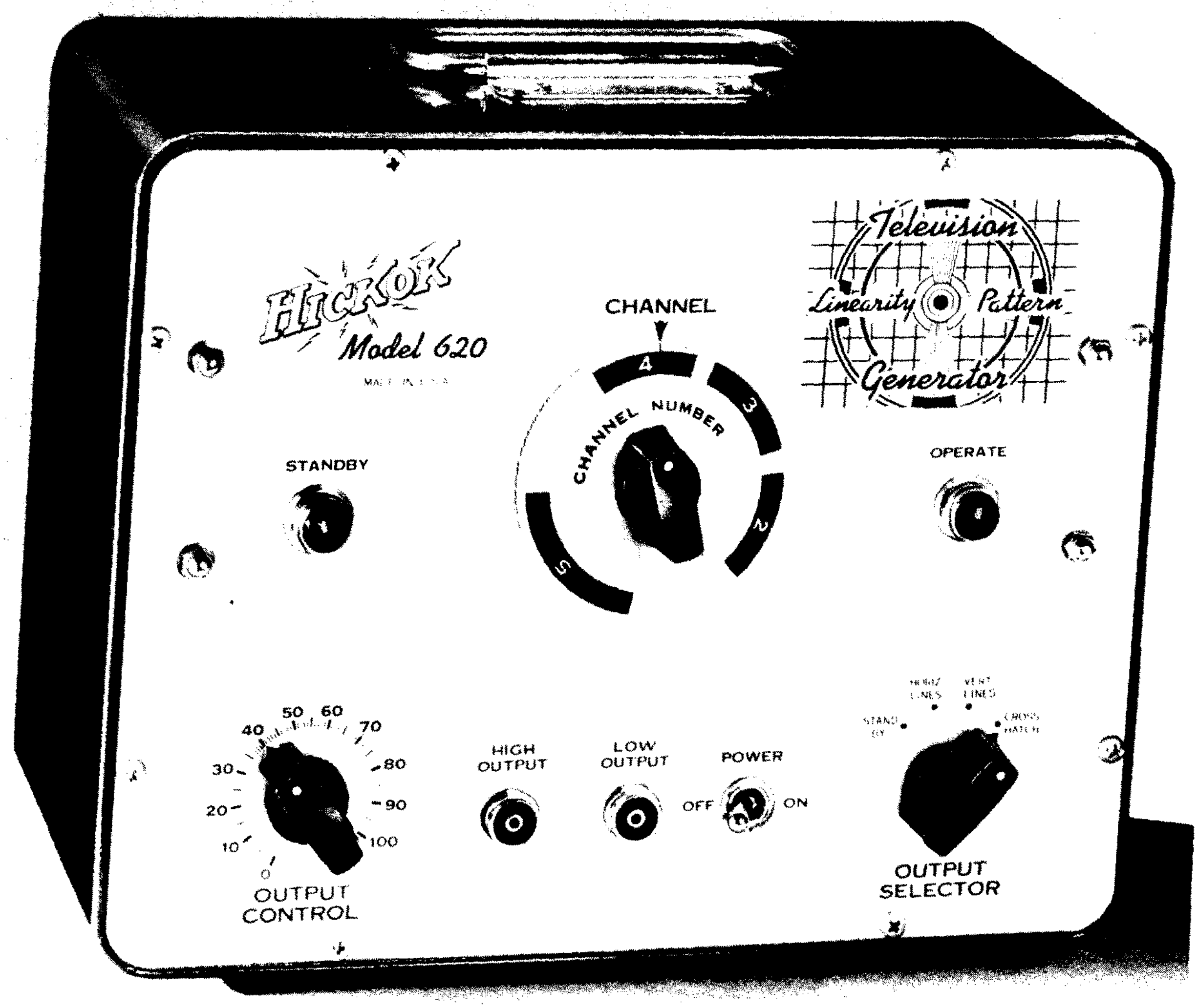



Figure 21. The Hickok Linearity Generator. (Model 620, Courtesy Hickok Electrical Instrument Co.)

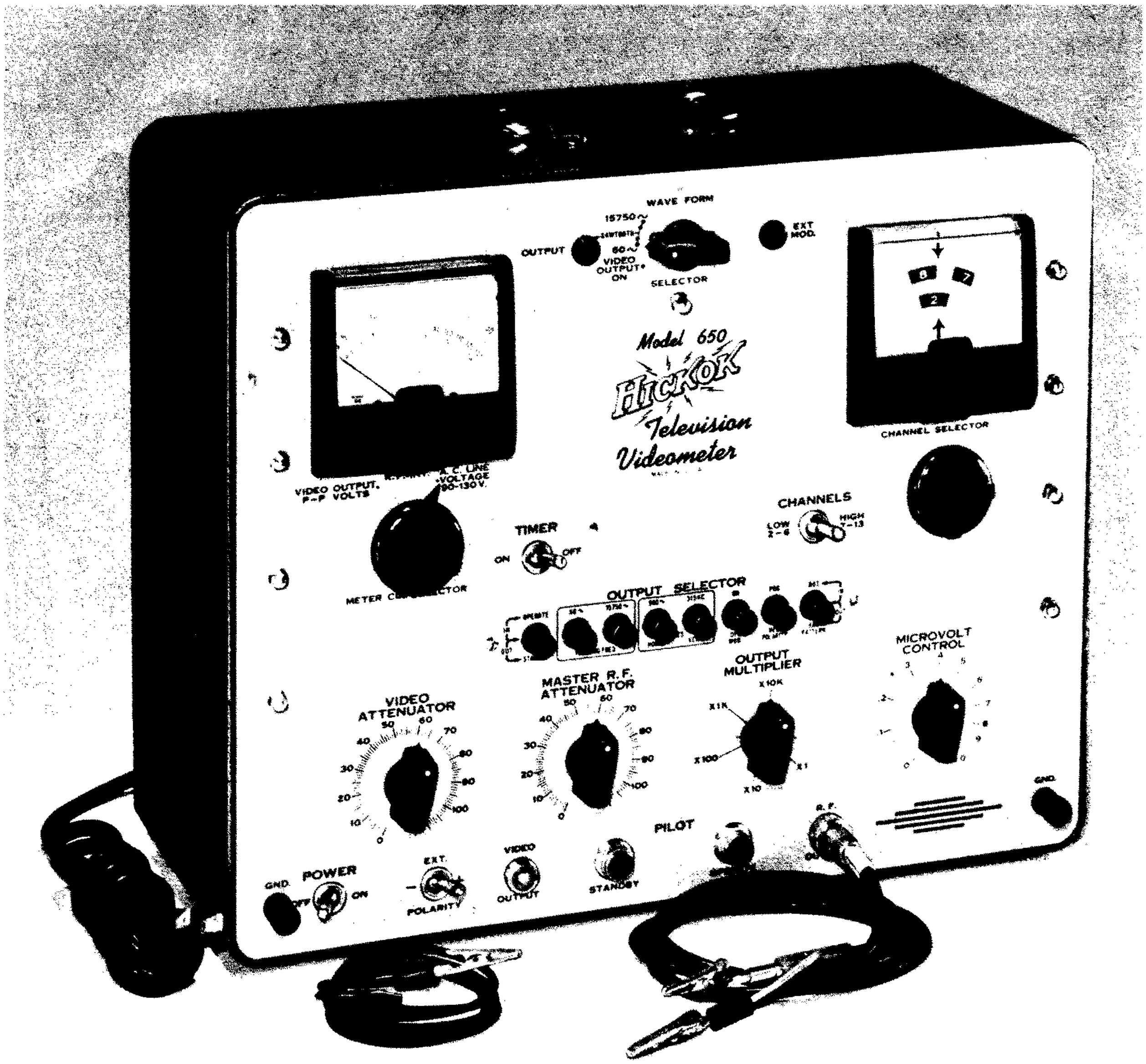



Figure 24. An Elaborate Servicing Instrument Designed to Enable the Serviceman to Carry out a Series of Tests on a Television Receiver. Some of its Features Are Discussed in the Text. (Model 650, Courtesy Hickok Electrical Instrument Co.)

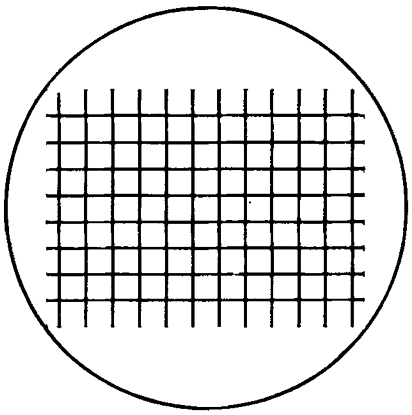


Figure 22. A Cross-Hatch Pattern Possessing the Proper 4:3 Aspect Ratio.

quency near 15,750 cycles, while in position 4, the stage becomes an amplifier to distort the 60-cycle voltage obtained from the filament transformer.

The "Linearity-Sweep" switch determines whether the output will come from the VHF oscillator or from the low-frequency oscillator.

Another linearity pattern generator is the unit shown in Figure 21. This instrument will operate on channels 2, 3, 4, and 5, and provide either vertical or horizontal bars separately, or in a cross-hatch combination, as shown in Figure 22. There are 9 horizontal lines generated and 12 vertical lines providing a cross-hatch pattern possessing the proper 4:3 aspect ratio. This will enable the serviceman to adjust the height and width controls of the television receiver.

The vertical and horizontal bar frequencies are crystal-controlled, and consequently the vertical and

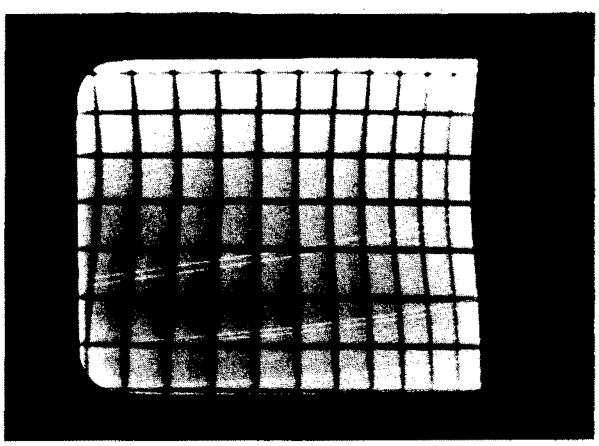


Figure 23. A Cross-Hatch Pattern is a very Sensitive Indicator of Hum in a Television Receiver.

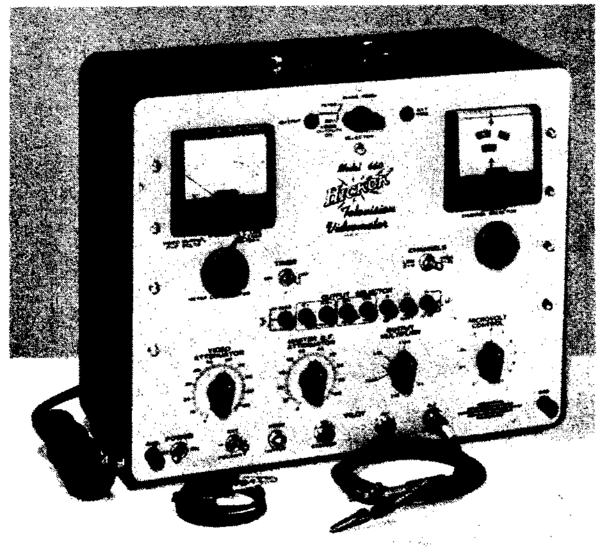


Figure 24. An Elaborate Servicing Instrument Designed to Enable the Serviceman to Carry out a Series of Tests on a Television Receiver. Some of its Features are Discussed in the Text. Courtesy Hickok Electrical Instrument Company.

horizontal hold controls in the receiver can be adjusted for correct lock-in. The horizontal hold control will lock the pattern in horizontally in only one position. However, the vertical hold control will lock the pattern in at several points. Only one point is correct: that is, when the vertical oscillator frequency is 60 cycles, This setting can be found quite readily. When the vertical hold control is properly set, the crosshatch pattern will be absolutely motionless. If the vertical hold control is misadjusted, the pattern will appear shaky.

A crosshatch pattern is a very sensitive indicator of hum in either the horizontal or vertical deflection systems. If 60-cycle hum is present, the vertical bars will show a slight sine wave ripple, one sine wave per height of screen. See Figure 23. A 120-cycle hum will produce two sine waves per height of screen.

## TELEVISION VIDEOMETER -

The Television Videometer (Figure 24) can be considered as an elaboration of the previous linearity and cross-bar generators. Thus, it will produce horizontal or vertical bars separately, a crosshatch pattern or a dot pattern. The latter is shown in Figure 27. There are also available 60 cycle and 15,750 cycle saw-tooth voltages, permitting this instrument to serve in place of the receiver saw-tooth generators. RF signals covering channels 2 to 13 can be internally modulated by the signal shown in Figure 25. (This is the crosshatch signal in voltage form.) By means of a high-frequency probe and an oscilloscope, this signal can be traced through the RF and IF stages of a television receiver. When the probe is placed at a point in either system, the waveform shown in Figure 25 should appear on the scope screen. Absence or distortion of the signal indicates that the circuit is defective.

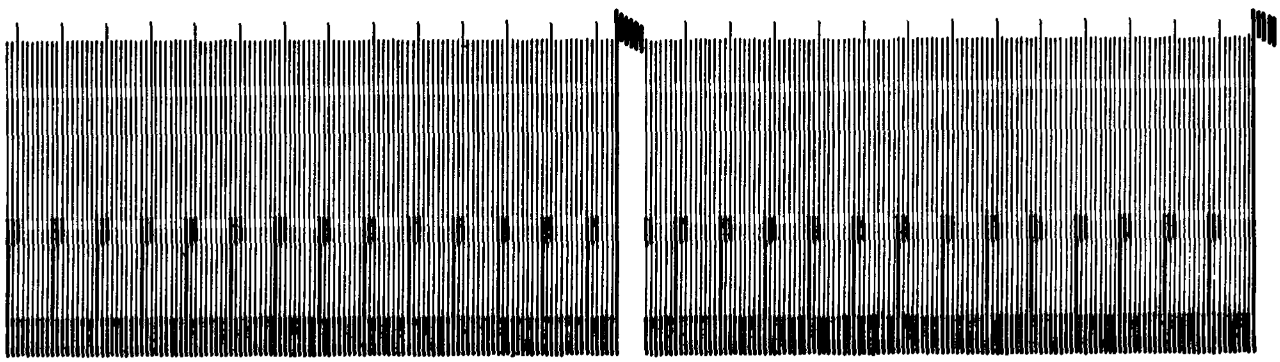


Figure 25. The Voltage Waveform of the Cross-Hatch Signal.

The number of tests which can be made with this instrument are indicated, in part, by the following illustration taken from its instruction manual.

A. Checks on Frequency Response

1. High Frequency Response. The vertical lines of the crosshatch pattern are produced by sharp 3.4 kc pulses, and to faithfully reproduce these lines, the receiver circuits must be capable of passing at least the tenth harmonic of 3.5 kc, which is 3.15 mc. The pattern in Figure 26 illustrates how a loss of high frequency response would show up. Note that the edges of the vertical lines are blurry whereas they should be distinct.

2. Low Frequency Response. If, in viewing the dot pattern the picture shading gradually gets darker from top to bottom of the raster, the low frequency response is poor. See Figure 27. This may be due to a grid resistor in the video amplifier decreasing in value or a coupling capacitor of decreased value.

3. Phase Distortion. Black vertical lines with a white trailing edge would indicate phase distortion in the receiver. See Figure 28. This may be caused by improper RF-IF alignment or excessive high frequency phase shift in the video amplifier.

B. Degree of Isolation Between Sweep Circuits

In viewing the crosshatch pattern, the vertical lines or bars appear bent at the crossover points with the horizontal lines or bars as in Figure 29, it is an indication that the horizontal bar frequency (900 cycles) is disturbing the horizontal oscillator in the TV receiver. The cause is an inadequate high-pass filter in the sync circuits permitting low frequency components to interfere with the horizontal oscillator. Another cause would be direct interaction between the two sweep systems due to stray fields.

In addition to the foregoing, such things as ripple or raster fold-over, horizontal phasing misadjustment, picture blooming, and hum in the various stages will all be made evident on the crosshatch or

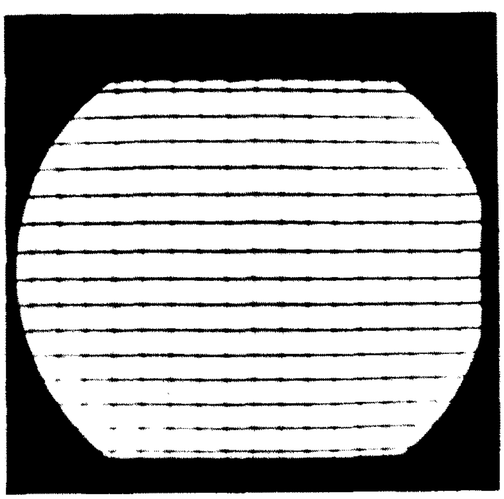


Figure 26. Loss of High-Frequency Response in the Video System as Indicated by the Cross-Hatch Pattern.

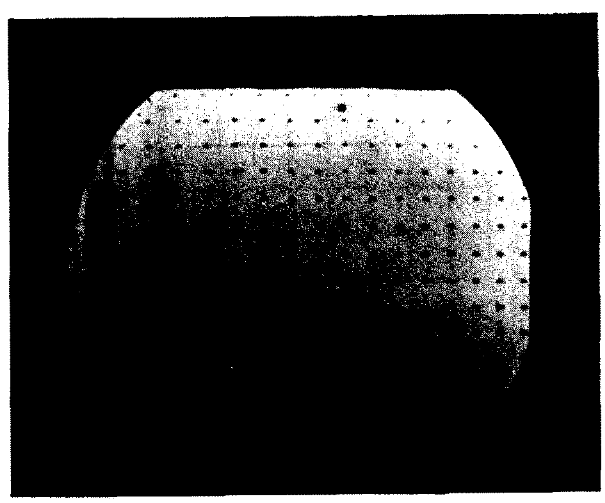


Figure 27. Poor Low-Frequency Response.

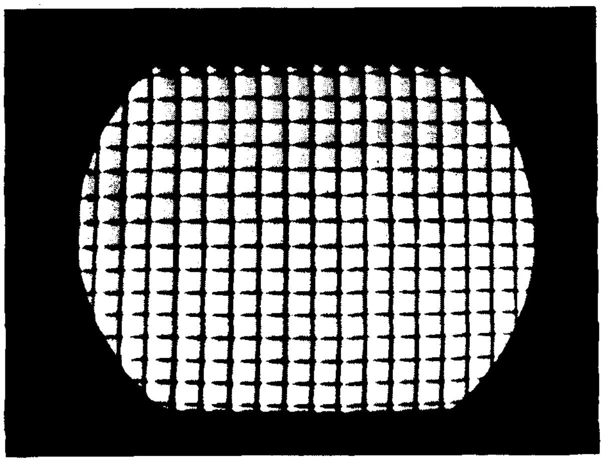


Figure 28. High-Frequency Phase Shift as Indicated on Cross-Hatch Pattern.

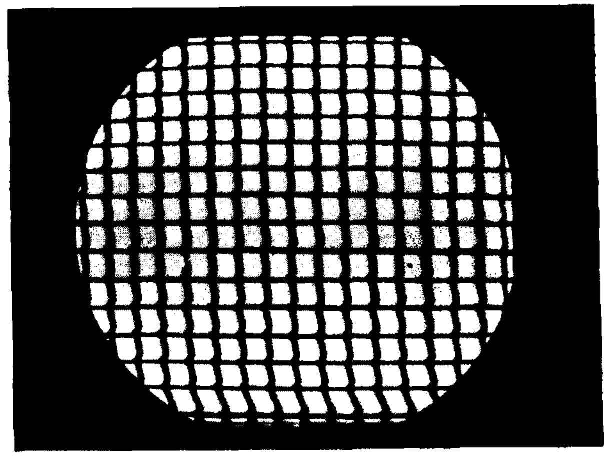


Figure 29. Poor Isolation Between Horizontal and Vertical Deflection Circuits.

dot patterns, enabling the serviceman to deal with them whether or not a station is on the air.

COMPOSITE VIDEO GENERATOR -

The Videometer will produce a crosshatch and a dot pattern, and crystal-controlled 60 cycle and 15,750 cycle pulses, but it will not produce a video signal containing all the sync, blanking, and equalizing pulses in the form specified by the FCC. Such a signal can be obtained from the composite video generator shown in Figure 30. In addition, video modulation is provided in the form of precisely spaced pulses that appear on the picture tube as a grating composed of small black squares. Since the blanking and equalizing pulses are contained in the signal, these may be viewed on the picture screen, too.

This type of generator can readily be used with a monoscope to produce a complete video test pattern. Small broadcast stations and receiver manufacturers use this combination extensively, the former for broadcasting and the latter for developing a suitable test signal for production line testing positions. The serviceman can use the instrument for many of the tests previously described for the Videometer. Note, however, that the composite video generator does not, in itself, contain an RF oscillator and therefore its signals could not be fed through the front stages of a television receiver. However, the video signal from this generator can be employed to amplitude modulate the RF carrier of an RF generator of suitable range and in this way enter a receiver through its front end.

## TV FIELD STRENGTH METERS

No television receiver is better than the antenna system to which it is connected. By the same token, no matter how elaborate the antenna is, unless it is positioned where it can intercept the maximum amount of signal, it will be unsatisfactory.*

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*Radio and Television Maintenance Magazine, December, 1950, page 9.

All of which boils down to one pertinent question. In erecting any antenna, how can you be sure that it is being placed where the signal is strongest? The best answer, to date, is a field strength meter, such as the Simpson unit illustrated in Figure 31. A field strength meter is essentially a miniature receiver. The television signal from the antenna is fed into the input terminals of the instrument where it goes through the same processes of amplification, conversion, and detection as it does in a normal receiver. The voltage which the signal develops at the output of the second detector is then applied to a microvolt meter. By calibrating the meter in terms of input voltages, rather than the actual voltage developed at the detector, we can read directly the strength of the signal at the antenna.

The meter used in this instrument has a 4-1/2-inch scale, calibrated evenly from 0 to 50 microvolts. Fifty microvolts input will produce full-scale deflection, a desirable feature for those concerned with fringe area installations. By means of a multiplying switch, the meter can be converted to read up to 500, 5,000 or 50,000 microvolts extending the usefulness of the instrument into areas where the signal strength is high.

The manner in which a field strength meter is used is quite simple. The transmission line from the antenna which ordinarily goes to the receiver is attached to the input terminals of the instrument. There is provision for a 300-ohm balanced line or for a 75-ohm unbalanced, coaxial line, as the case may be. With the meter power on, the antenna is moved about until the point is found where the signal level is greatest. This is governed by the orientation of the antenna and the height of the antenna. While it is generally true that the higher the antenna, the greater the signal developed it will also be found in many places, that as the antenna is raised, the signal will go through successive maxima and minima.

With the meter connected to the receiver end of the transmission line, you know exactly what the television set receives. This is important, because


Figure 30. A composit Video Generator. (Model 665, Courtesy Supreme, Inc.)

it is only the voltage which actually reaches the receiver that is responsible for the picture you see. There may be 1,000 microvolts at the antenna, but if your set only receives 50 of these microvolts, the picture developed will be snowy or otherwise defective.

INSTRUMENT APPLICATIONS -

It is common practice for installation men to judge the comparative strength of the signal received in various location by observing the quality of the picture. This is satisfactory where the difference in signal strength is large and the signal intensity is high. It is quite unreliable, though, where the available signal is weak. And to the man living in a weak signal area, every microvolt is important.

Field strength meters have also been profitable used in customer relations. Servicemen who come in frequent contact with the public they serve know only too well that every service call is, in part, set servicing and, in part, customer servicing. Sometimes it is difficult to say which is most important. It is not unusual for a retailer to blame a poor antenna installation for a poor picture--or for an installation crew to blame the set. A field strength meter will resolve such disagreements once and for all. The meter here serves the customer in the same manner as a counter tube tester.

A money-saving application of the meter is to permit wider use of one-man installation crews. It is customary in most organizations to have two men install an antenna. One man walks about the roof with the antenna while the other man sits at the set and observes the picture. When the best picture is obtained, the man at the set relays this information to the man on the roof and the antenna is erected at the designated spot.

However, the rapid rate of television expansion, coupled with the current expansion of the armed forces, and the increase in war work have combined to reduce the number of men available to the television service industry. One solution to this shortage is a number of one-man installation crews equipped with field strength meters. With a meter, one man can readily locate those points where the signal intensity

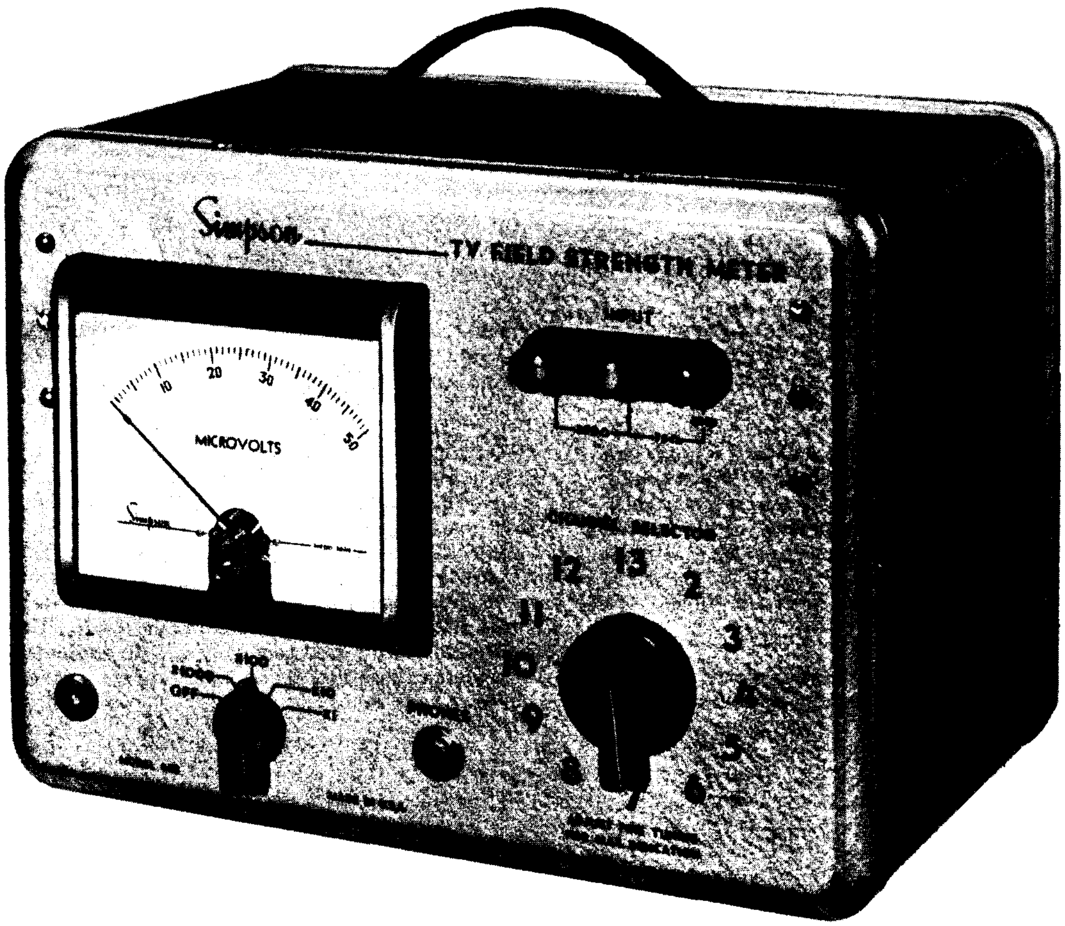



Figure 31. The Simpson TV Field Strength Meter. (Model 488, Courtesy Simpson Electrical Company.)

is greatest. Erection of the antenna at this point, with a lead-in running to the set, will complete the job. If ghosts are encountered, the antenna can be moved to another spot, again revealed by the meter. The installation man, by walking about the roof and observing the changing signal intensity, can form a mental image of how the signal strength varies from point to point. If ghosts appear in one section, the antenna can be moved to another spot where the signal level is still usable.

There are, in addition to the foregoing applications, such additional uses as comparison of various boosters, comparison of transmission lines to determine which introduce the least loss, determination of which antennas are better suited for a certain installation, etc. To the man who is daily concerned with antenna installation, a field strength meter soon becomes almost indispensable.

CIRCUIT DESCRIPTION -

The block diagram of the meter in Figure 32 shows its operation. The front end of the unit contains a Standard Coil rotary turret tuner with a 12-channel switch. As in television receivers, there is a fine-tuning control to enable the operator to tune in each station for maximum meter indication. The incoming signal is amplified by an RF amplifier (6AG5) and then converted to 26 mc (approx.) by mixing with a local oscillator signal.

Following the mixer is a 2-stage IF system peaked to 26 mc. This is equivalent to the video IF system in a television receiver, except that the stages are sharply peaked here, since we are primarily concerned with the carrier and not the sidebands. The signal is detected by a IN34 crystal and the peak value of the video signal--as established by the incoming sync pulses--is then indicated by the meter. A rotary switch underneath the meter permits the

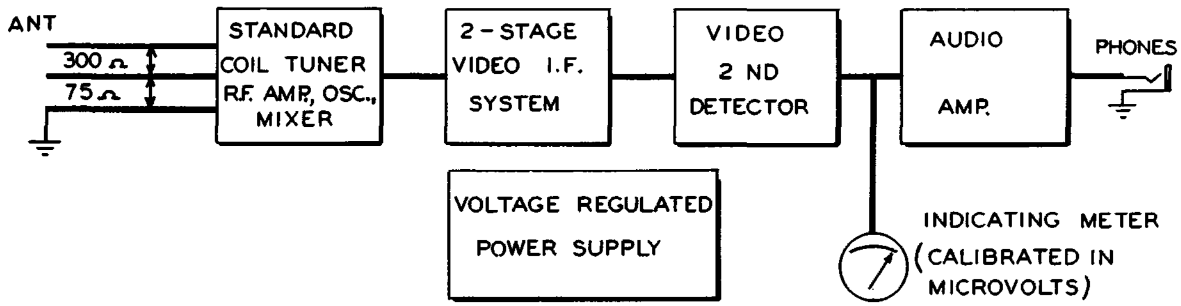



Figure 32. Block Diagram of the Simpson Field Strength Meter.

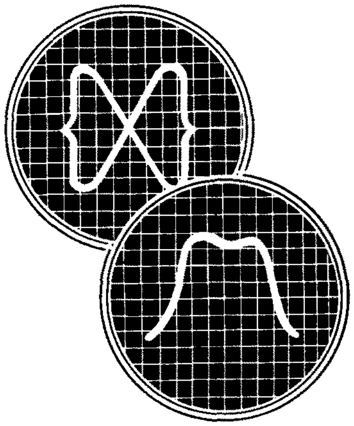
proper shunt to be brought in for an on-meter reading. In the last, or off, position of the rotary switch, a short is placed across the meter to prevent damage to the movement when the unit is not in operation.

A 6AU6 amplifier beyond the video second detector output receives whatever signal is developed by the detector and feeds this signal into a phone jack. The purpose of this stage is to permit identification of interference signals, when these are encountered. In the absence of interference, only the 60-cycle vertical sync buzz will be heard when earphones are plugged into the jack.

The sound carrier of any station except those on channels 6 and 13 may be received by switching the channel selector to the next higher frequency channel and adjusting the fine tuning control to the low frequency end of its range.

CONCLUSION -

The survey of special TV test instruments in this section is indicative of the different types of units which are available for television service work. No attempt has been made either to cover all such units or to fully explain what any one can do. Neither of these fit in with the objective of this book. However, sufficient information is given to indicate to the serviceman just how these instruments can ease the burden of his labor.



# section six

## Television and FM Receiver Alignments

TELEVISION & F.M. RECEIVER ALIGNMENT

### INTRODUCTION

The Federal Communications Commission in their regulations covering television broadcasting limit the video frequencies which may be transmitted to a maximum of 4 mc. This means that the television signal may contain all video frequencies from 0 up to and including 4 mc. All broadcast station equipment is designed to pass all 4 mc. It may happen from time to time that full use is not being made of this bandpass, possibly because of the character of the signal or misadjustment of the equipment. However, with all transmitter units in proper operating condition, 4 mc will be passed.

In the receiver, conditions are somewhat different. Manufacturers have found that acceptable pictures can be obtained with a bandpass as low as 3 mc (2.5 mc on small screen tubes) and many of them have taken advantage of this to effect economies at the expense of picture quality. The serviceman will have to take cognizance of this fact when he aligns a receiver in order that he does not waste time trying to obtain a 4 mc response from a circuit designed for 3 mc. The serviceman's job is to return the set to its normal operating condition; he is not charged with the responsibility of redesigning the circuit, no matter how badly this is needed in some instances.

Information concerning the bandpass of a television receiver is also useful in detecting trouble. A circuit or system that should possess a 4 mc bandpass may properly be suspected of containing trouble if it indicates only a bandpass of 2.5 mc. This knowledge is important although, unfortunately, it is not as readily available as it should be.

The wide bandpass characteristics of television receivers coupled with their higher operating frequencies make them somewhat more critical in alignment and adjustment than AM radio or FM receivers and it is quite common to find sets which are poorly or improperly aligned. This is perhaps the greatest single defect which is present in today's millions of television receivers.

The technique of properly aligning a television receiver is not a simple one to acquire. Not only must the technician be familiar with television circuitry and operation, but what is just as important, he must be completely familiar with the instruments he uses. It is perhaps as much on this latter point as the former that many servicemen fall down and it is the purpose of this section to aid the serviceman to acquire mastery of this skill as much as possible.

The alignment of a television receiver is most conveniently performed in the following order:

1. Sound Detector
2. Sound IF transformers
3. 4.5 mc trap or take-off coil (in Intercarrier receivers)
4. Video IF traps, if any
5. Video IF transformers and coils. (This includes mixer transformer.)
6. Overall video IF
7. RF Section

Some manufacturers specify a somewhat different order but the general approach remains substantially the same. In the paragraphs to follow, the type of equipment which is needed to accomplish the alignment of each portion of a TV receiver will be considered together with specific instructions on how this equipment is connected and how the adjustments are made. In all instances, typical circuits will be employed.

### SOUND DETECTOR

The sound signal broadcast by a television station is frequency modulated and consequently the sound detector must be an FM detector. In common use today are two types of FM detectors: The ratio detector and the Foster-Seeley discriminator. While both circuits differ considerably in design, they do possess the same "S" type of response and this is the indication which the serviceman is seeking when aligning these circuits.

A typical Foster-Seeley discriminator is shown in Figure 1. The demodulated audio output from this

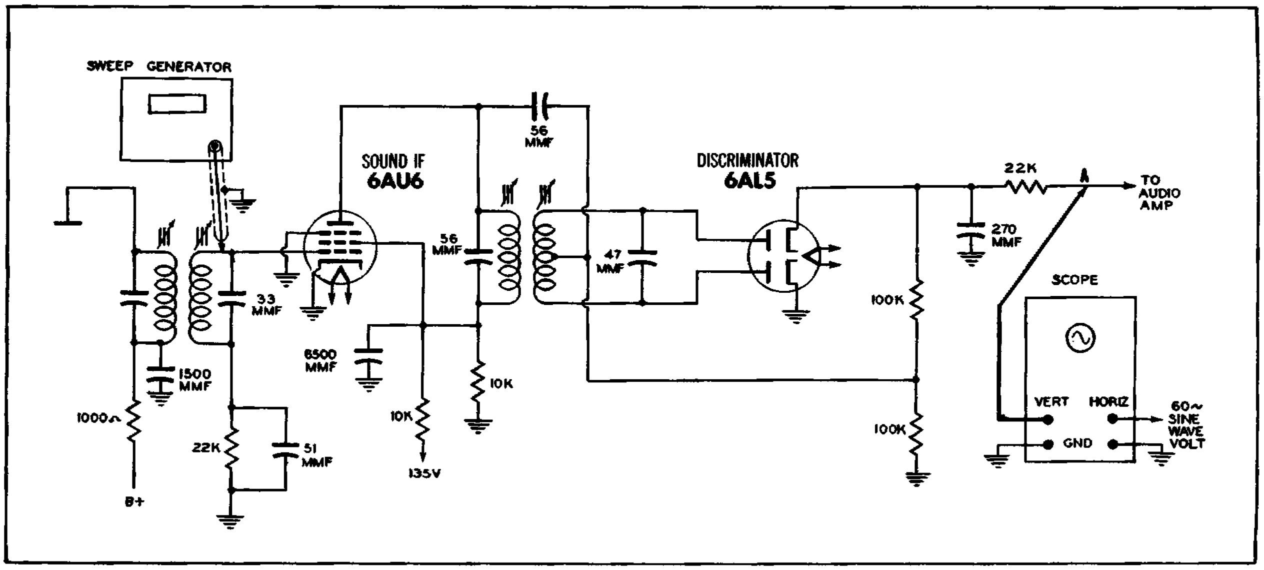



Figure 1. The Manner In Which the Response Pattern of a Foster-Seeley Discriminator Would be Obtained.

circuit appears between point A and ground (or chassis) and if we connect the vertical input terminals of an oscilloscope between these two points the circuit response pattern will appear on the screen. The sweep or frequency-modulated signal from the generator would be fed into the system at the grid of the last sound IF amplifier. If a ratio detector is being employed in the receiver, the instrument set-up remains substantially the same (see Figure 2). In both circuits the oscilloscope vertical input terminal connects to the point where the audio signal leaves the FM detector; the oscilloscope ground lead attaches to the receiver chassis.

Let us look closely at both the sweep generator and the oscilloscope because that is primarily what we are interested in here. Prior to obtaining any circuit response pattern on the scope, we would set its controls so that a scanning trace was visible on its screen. The procedure for doing this was described previously in Section 4. The vertical gain control would initially be set at mid-position or slightly beyond, permitting the scope to produce a sizeable pattern with moderate input signals. The vertical attenuator, if such a control is available, might initially be set to its most sensitive position. (When you are working with a scope which is not too sensitive, it might be best to set the vertical gain control also for maximum amplification.)

The sweep generator should be connected with its "hot" output lead going to the grid of the last sound IF amplifier and its ground connecting to the receiver chassis. The generator frequency would be set at the sound IF carrier value--say 21.00 mc if this happens to be its frequency. The sweeping range required is 1 mc or perhaps somewhat more although it is not recommended that this extend beyond 2 mc at the most. The RF output control could be turned to its maximum position initially in order that some in-

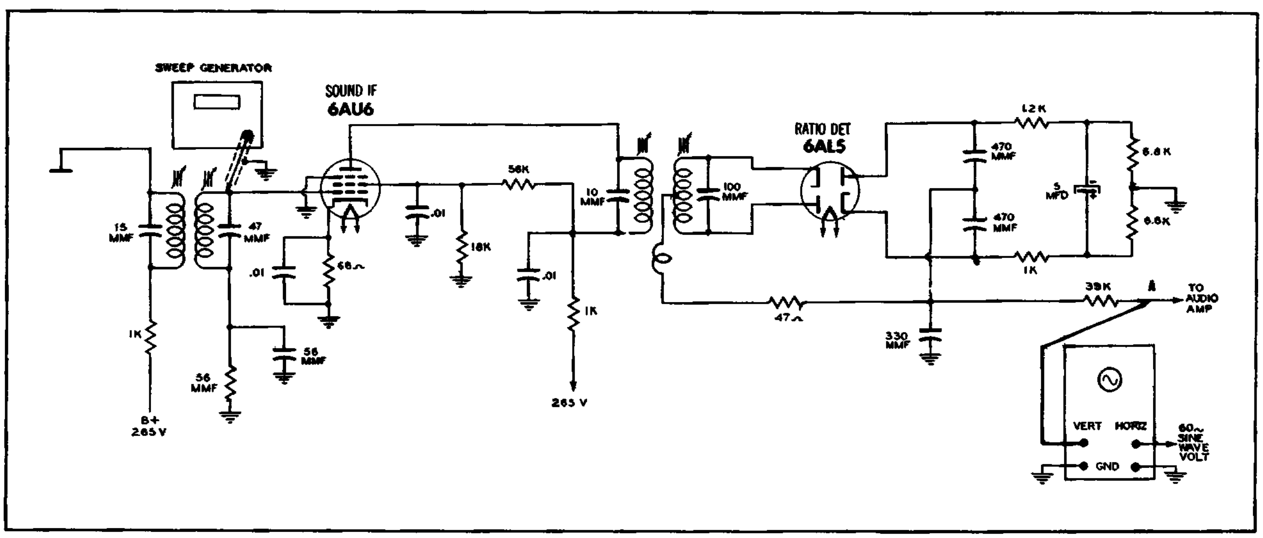



Figure 2. The Manner in Which the Response Pattern of a Ratio Detector Would be Obtained.

dication will be obtained on the scope screen if the circuit is operating. It has been found that it is better, at the start, to have both instruments going full blast and then to tone each down as needed rather than to work up to the proper level. The brute force approach appears to be better suited for the beginning technician perhaps because the appearance of some indication is a quieting and reassuring factor psychologically. (Not to be overlooked is the low signal output of many low priced sweep generators. These units frequently have to be run "wide open" at all times.)

Thus far nothing has been said about the insertion of a marker signal and indeed nothing should be done along these lines until a normal indication is obtained on the scope screen. By keeping the number of complicating factors as low as possible, the chances of confusion are minimized.

The sweep generator is now set up to apply its signal to the circuit under test and the oscilloscope is connected to receive whatever output is obtained from the FM detector. However, before any power is turned on in the receiver, there are several other steps to be taken. First, a lead should be connected from the horizontal sweep voltage terminal of the sweep generator to the horizontal input terminal of the oscilloscope. This will feed in a 60-cycle sine wave driving voltage to the oscilloscope and cause the scanning beam to move in step with the signal generator's sweeping voltage. A ground lead should connect both instruments although if the two are properly grounded through the receiver chassis, the additional connection may not be necessary.

Next, set the oscilloscope controls so that this sweeping voltage drives the beam across the screen in place of the instrument's internally generated sawtooth voltage. If the scope possesses its own 60-cycle sine wave deflection voltage and phase control (such as the units shown in Figures 15, 16, 22, and 39 of Section 4), the driving voltage from the sweep generator will not be required. In this case, you would simply set the scope controls to provide the desired sine wave sweep.

Another step to be taken before the alignment is begun is to prevent any signal other than that developed by the sweep generator from reaching the circuit under test. To do this, pull out one of the prior sound IF tubes. If the set is of the transformerless type and the tube filaments are series connected, tube pulling would open the filament circuit. In this case signals can be prevented from reaching the discriminator by unsoldering a grid lead on a prior tube or by placing a short circuit from grid to ground on this tube. Frequently the short will suffice although sometimes opening the circuit becomes necessary.

You are now ready to turn on the equipment and proceed with the alignment. Permit the set and the instruments to warm up for about 10 - 15 minutes to be sure that each has reached a stable operating condition. At the end of this time the oscilloscope should carry some indication of a response curve if the instruments and the circuit are operating normally. The output of the generator now should be turned down as far as possible and still provide a usable indication on the scope screen. Also, the vertical gain control

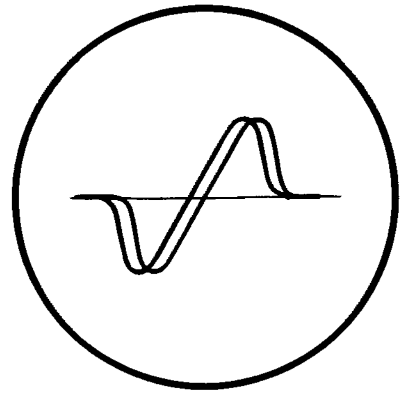


Figure 3. When You First Obtain a Response Pattern on the Screen, You Will Most Probably Have a Dual Trace.

on the oscilloscope should be adjusted until the pattern covers at least one half of the screen. Make certain the amplifiers in the oscilloscope are not being overloaded. A good test for overloading is to watch the pattern as the sweep generator output is alternately increased and decreased. If the height of the pattern on the screen varies in step with the generator output, no overloading is occurring. But if the pattern remains stationary through all or part of the generator output variation, then overloading is occurring. Another indication of overloading is an S curve possessing flat-topped ends.

At this point the pattern on the screen may or may not be the looked-for S response curve. If it is, then, of course, the work to follow will consist simply in determining whether it is on-frequency and making such minor adjustments as may be necessary to improve its linearity. The more natural assumption and the one more likely to occur is that while some sort of curve will be obtained on the screen, it will not have exactly the desired S shape. Let us see what can cause this and what steps can be taken to correct it.

Probably the first thing you will notice about any indications on the scope screen is the fact that there are two patterns. This stems from the phase difference between the 60-cycle driving voltage in the

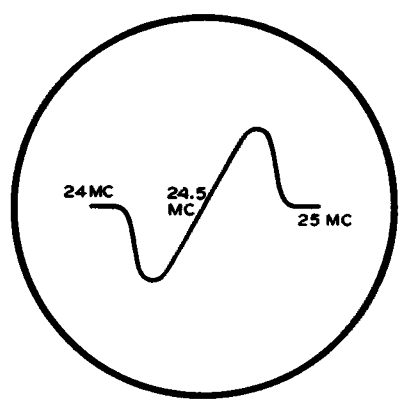



Figure 4. When the Phase Control has Been Properly Adjusted, the Two Patterns of Figure 3 Will Blend Together, as Shown.

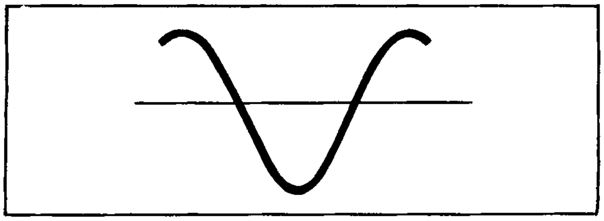


Figure 5. Response Distortion When the Discriminator Primary is Misadjusted.

sweep generator and the 60-cycle sweeping voltage which is driving the scanning beam in the oscilloscope. To bring the two patterns together, rotate the phase control.

The next step is to bring the response pattern to the desired S shape. See Figures 3 and 4. Deviations from this form may arise from two sources: Circuit misalignment or a generator that is not on frequency. Misalignment of the circuit as a cause of waveform distortion is well-known. Thus, when the primary of the discriminator transformer is misadjusted, the S curve takes on the appearance shown in Figure 5; when the secondary trimmer or slug is incorrectly positioned, the curve appears as shown in Figure 6.

With the appearance of an S curve, you are now ready to apply the marker signal for specific frequency identification. Take a good look at the S curve before the marker signal is applied; any appreciable change in curve shape thereafter will be due to excessive marker signal or to marker generator loading on the circuit. Neither of these conditions is desired and both must be carefully avoided.

MARKER SIGNAL INSERTION -

The method of inserting the marker signal depends upon the equipment used. Where the sweep generator contains its own marker generator (such as the units shown in Figures 24 and 26 of Section 3), insertion of the marker simply means turning the marker oscillator on, setting it to the frequency desired, and then slowly and gradually increasing its output until a marker pip appears on response curve on the scope screen.

Some sweep generators, while they do not generate their own marker signal, do contain provision

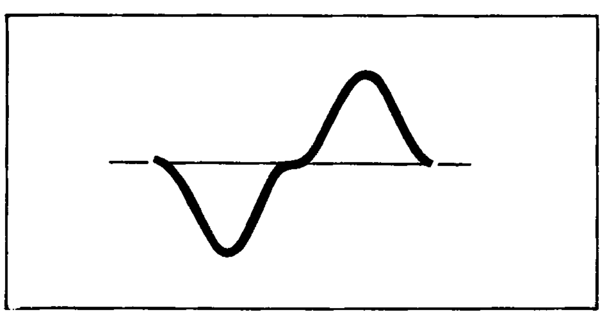


Figure 6. Response Distortion when the Secondary Slug is Misadjusted.

for receiving the marker signal and combining it with the sweep signal. (See Figure 19, Section 3.) The marker signal would be applied to the proper terminal (and ground) and then its amplitude increased until the pip became visible on the screen.

Finally, there are many sweep generators which do not have any provision for receiving the marker signal and when these units are employed, the marker signal must be introduced separately into the test circuit.

There are a number of ways of effecting marker signal insertion and the more common methods will be outlined here. Whatever the method, however, the precautions indicated above must be carefully observed, otherwise not only will the marker signal be useless, but worse still, it will distort the response curve and prevent the serviceman from properly aligning the circuit.

1. Probably the simplest method of marker insertion is to connect the marker ground lead to the receiver chassis and then clip the marker "hot" lead directly onto the sweep generator's "hot" lead. This places the outputs of both generators in parallel. Great care must be observed when using this method, however, because the shunting effect of the marker generator can readily affect the sweep generator output to such an extent that the response curve is swamped or distorted. If this is found to happen, the disturbing effect of the marker generator can frequently be reduced or eliminated by using an isolating resistor between the "hot" lead of the marker generator and the point where it connects to the sweep generator output clip. A resistance value of 25,000 - 75,000-ohms will usually be sufficient.*

2. The marker signal may be inserted at the grid of a tube located before or after the point where the sweep signal is applied. If the marker generator is connected between grid and ground of a stage which is located prior to the point where the sweep signal is applied, then the marker generator lead may be connected directly to the grid of this tube# without the use of an isolating resistor. However, if the marker generator is connected to the grid of a stage through which the sweep signal is passing, then an isolating resistor (25,000 - 75,000 ohms) should be employed as a precautionary measure.

Of course, where there is but one stage between sweep generator and oscilloscope, as in Figure 2, then the marker generator must be connected either at the same point as the sweep generator or at a prior stage.

An interesting fact with regard to marker insertion is that the marker signal need not necessarily

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*The reader is cautioned against using an excessive value of isolating resistor. This can cause marker displacement on the response curve and lead to a false conclusion concerning frequency indication of the steeper portions of the response curve.

#If a DC voltage (with respect to ground) is present on the grid, insert a .01 mfd isolating capacitor in series with the generator "hot" lead.

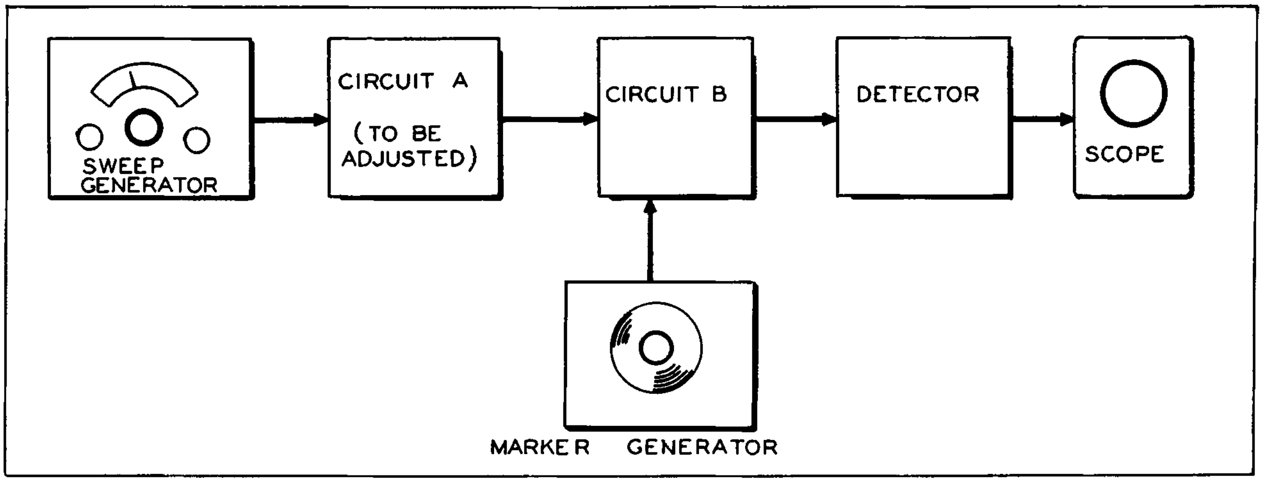


Figure 7. The Marker Signal Need Not Necessarily Pass Through the Circuit Being Aligned in Order to Serve its Purpose.

pass through the stage being aligned in order to serve its purpose as an identifying agent. However, the marker signal must pass through the detector with the signal from the test circuit. To illustrate this point, consider the adjustment of circuit A in Figure 7. The sweep generator is connected so that its signal will pass through circuit A. The marker generator, on the other hand, is not injected into the system until point B where it combines with the output of circuit A. Rectification of the signal then occurs at the detector, after which it is fed to the vertical input terminals of the oscilloscope. (In Section 5 special marker generators were described wherein it was not necessary to pass the marker signal through the test circuit or its detector at all. These units may be employed here in addition to the other methods described.)

3. The foregoing methods have dealt with direct insertion of the marker signal into the circuit. Usually just as effective and frequently less disturbing on the response curve is the indirect insertion of a marker

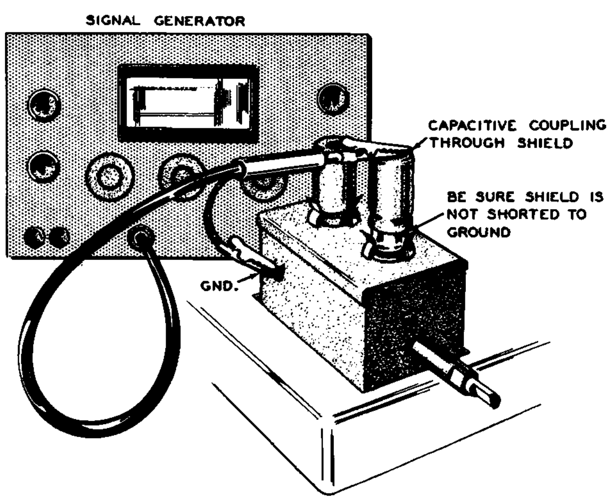


Figure 8. Signal Injection by Clipping "Hot" Lead From Generator Onto Tube Shield. Make Certain Tube is not Touching Chassis or Other Ground Points.

signal. This can assume such forms as merely positioning the hot lead of the marker generator near the circuit under test or clipping the lead onto the body of a capacitor or resistor in that circuit or system. Since the body is composed of some insulating material, direct electrical contact with the circuit is avoided. However, by radiation of the signal from the lead clip plus some extraneous capacitive coupling, the signal reaches the test circuit, combines with the sweep signal and appears on the oscilloscope screen.

Another effective method is applicable to those circuits where the tubes possess shields. Simply lift the shield up until it is no longer making contact with its grounding base and then tilt the shield sideways slightly until it rests on the glass of the tube. If this is done carefully, the shield will be supported by the tube envelope and not make contact with the chassis. Now clip the hot lead onto the tube shield and sufficient signal will radiate from the shield to the tube elements to serve as a marker signal injector. See Figure 8.

If you encounter trouble keeping the tube shield from sliding down and making contact with its grounding base, insert a small wad of paper between shield and tube.

An alternative method of marker injection, known as the "chassis" method,* is illustrated in Figure 9. The "hot" and ground leads of the marker generator are both connected directly to the receiver chassis, with the clips spaced approximately 6 to 8 inches apart. Position the clips on the chassis so that they straddle the sweep generator injection point. The lead signal voltages set up strong circulating ground currents in the receiver chassis which couples the marker signal into the circuit under test.

Irrespective of the method employed, always be on the alert against swamping the response curve by the marker signal. Never use more marker signal than is necessary.

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*Suggested by the engineers of Precision Apparatus Company, Elmhurst, Long Island, New York.

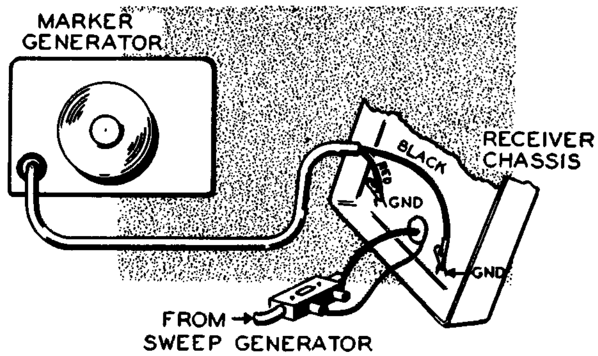


Figure 9. The "Chassis" Method of Injecting a Marker Signal. Courtesy Precision Apparatus Co., Inc.

When the equipment has all been set up and the circuit adjusted, the S curve and the marker pip should be visible on the screen. Some difficulty is sometimes encountered in locating the pip when it is moved along the steep linear section of the curve. One suggestion* for overcoming this is to reduce the sweep width control setting until only the center portion of the S curve (with its "pip") is visible on the screen. (The center frequency of the sweep generator may have to be readjusted as the sweep range is reduced in order to keep the center portion of the response curve on the screen.) When this is done, the expansion of the central portion of the discriminator curve produces a more pronounced "pip". The pip observed at the center of the "S" curve differs from the usual marker indication in that the actual center of the pip is represented by the straight line portion of the "wiggly" line. This is due to the fact that discriminator output voltage is zero at the exact center IF.

The double trace response curve, in which the two traces are brought together by means of the phasing control, is the type of curve that most servicemen will be working with. However, some sweep generators contain a blanking control and with it one curve may be eliminated and a base or zero reference line substituted in its place. See Figure 10. Where this facility is available, it should be employed be-

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*Precision Apparatus Company

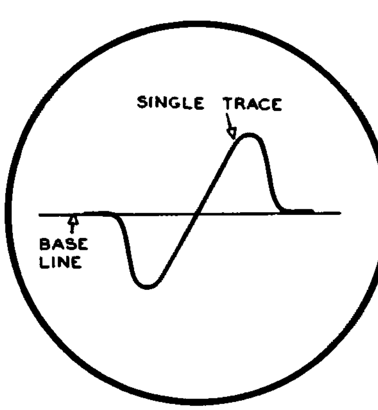


Figure 10. With a Blanking Control in the Sweep Generator, One of the Two Traces can be Converted into a Base or Reference Line.

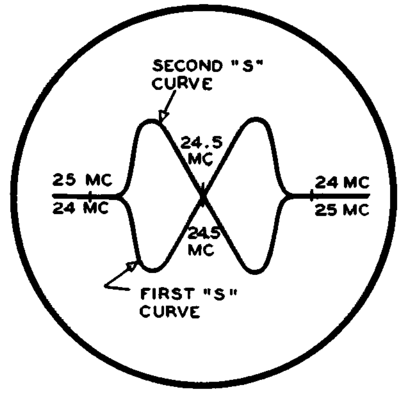


Figure 11. A Double "S" Curve Produced When the Scope Beam is Deflected by a 120 Cycle Saw-Tooth Voltage.

cause the reference line can be especially helpful in FM detector alignment.

A single trace (without any base line) can also be obtained when the oscilloscope contains provision for beam blanking during the retrace portion of the cycle.

ALTERNATE "S" CURVE -

There is still another method for presenting the "S" curve and this is shown in Figure 11. Here the oscilloscope is utilizing its internal saw-tooth deflection voltage operating at a frequency of 120 cycles per second. This means that during one-half of the sweep generator cycle, one S curve is traced out, then the scanning beam moves quickly back to the left-hand side of the scope screen and traces out the other S curve during the second half of the sweep generator cycle. Stabilization of the trace can be achieved either by setting the oscilloscope on line sync or by using the internal sync position. Some technicians prefer this method of discriminator alignment and many manufacturers recommend it. However, it does not insure any greater accuracy than the previous methods and so it becomes a matter of personal preference.

A precaution that must be observed when using the saw-tooth oscillator of the oscilloscope to move the beam across the screen is that its frequency is close to 120 cycles. If the rate is reduced to 60 cycles, then the pattern of Figure 12 will be obtained. Note that what you have here are two S curves back to

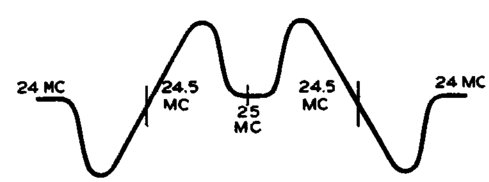


Figure 12. When a 60 Cycle Saw-Tooth Deflection Voltage is Used in the Oscilloscope, The Screen Presentation Will Appear as Shown.

back. Assumed identifying frequencies have been included to help illustrate how this sort of presentation is obtained. In one complete sweeping cycle in the sweep generator, the band of frequencies are swept across twice. In other words, if the band sweep is 1 mc and the frequency range covered extends from 24 to 25 mc, then the generator output will go from 24 mc to 25 mc and then from 25 mc back to 24 mc again. The beam in the oscilloscope is traveling forward throughout all this time, tracing out first the curve produced by the 24 to 25 mc sweep and then the curve resulting from the 25 to 24 mc sweep.

If the oscilloscope scanning frequency drops down to 30 cycles, four S curves strung out in a line will be seen.

When a variable frequency marker pip is employed with the presentation shown in Figure 11, its action will differ somewhat from that observed with an S curve obtained by using a 60-cycle sine wave deflection voltage. This, too, can be confusing unless the technician understands how the curves of Figure 11 are produced. In the curve of Figure 4, only one pip will be seen as the marker frequency is varied because every point on this curve represents a different frequency. But now consider the double trace in Figure 11. The frequencies represented by one curve are duplicated (in reverse position) on the other curve. When a marker signal is introduced into this arrangement, one pip will appear on each curve at its proper point. Thus, let us say that the marker signal frequency is set at 24 mc. Then one pip will appear at the 24 mc point on one curve and one pip will be seen at the 24 mc point on the other curve. If we raise the marker frequency gradually to 25 mc, the pip on the lower curve will move to the right (which is towards the 25 mc point on this curve) and the pip on the other curve will move toward the left (or towards its 25 mc point). The two travelling pips will meet at 24.5 mc and blend into one if the two S curves cross at this frequency.

ADDITIONAL CAUSES OF CURVE DISTORTION -

In dealing with response curves which are presented on an oscilloscope screen, there are certain variations that the serviceman will encounter which can cause him some unnecessary trouble unless he is

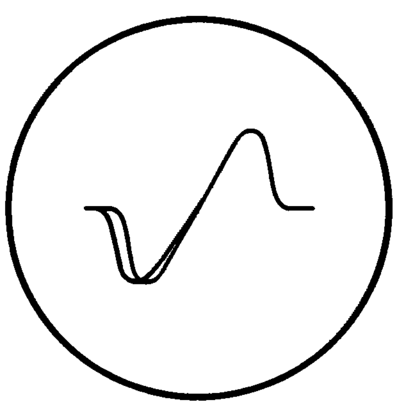

Figure 13. Sweep Generator Unbalance May Prevent Perfect Blending at all Points.

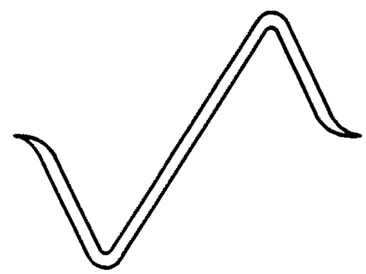

Figure 14. Two Curves Vertically Displaced From Each Other. See Text for Explanation.

familiar with their cause. Non-linearities in the sweep generator output can produce a pattern in which the two curves will not perfectly blend with each other at all points. If the phase control is set so that blending is achieved at the righthand side of the curve, then the curves may not superimpose at the left. See Figure 13. This slight unbalance will have no effect on the alignment and the serviceman can proceed as if he had only one curve. Note that over the section where the two curves do not blend, neither will the markers (when they reach this region).

Occasionally a condition will be found where the trace and retrace are essentially duplicates of each other but are more or less evenly displaced vertically. See Figure 14. This is due to hum in the detector, or hum picked up by the response curve cable* or isolating resistor. In general, this condition is not normal and the cause of it should be determined (heater-cathode leakage, insufficient filtering of the B+, poor grounding of generator or oscilloscope cable or receiver chassis, etc.). Placing your hand on the cable shield, on the test instruments, or on the receiver chassis should have no effect on the response pattern. If it does, poor grounding is indicated.

It sometimes happens that vertical jitter of the response pattern or multiple tracings is caused by the vertical circuits in the receiver itself. To determine whether this is so, simply remove the vertical oscillator or vertical output tubes.

Another source of confusion is an S curve on a screen which is 180° out-of phase with the curve shown in the manufacturer's manual. See Figure 15. If the oscilloscope has a phase reversal switch, then the situation can be "corrected". In the absence of such a switch, the alignment can be carried out with the reversed curve. As discussed previously, the polarity of the curve seen on the screen is primarily determined by the number of vertical amplifiers in the oscilloscope plus the position of the take-off point in the receiver. It has nothing to do with the alignment condition of the circuit under test.

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*Pick-up cables of the coaxial type (RG-59U or RG-11U) are recommended for the oscilloscope. Cable length should not exceed three or four feet to prevent the build up of input capacitance to excessive values.

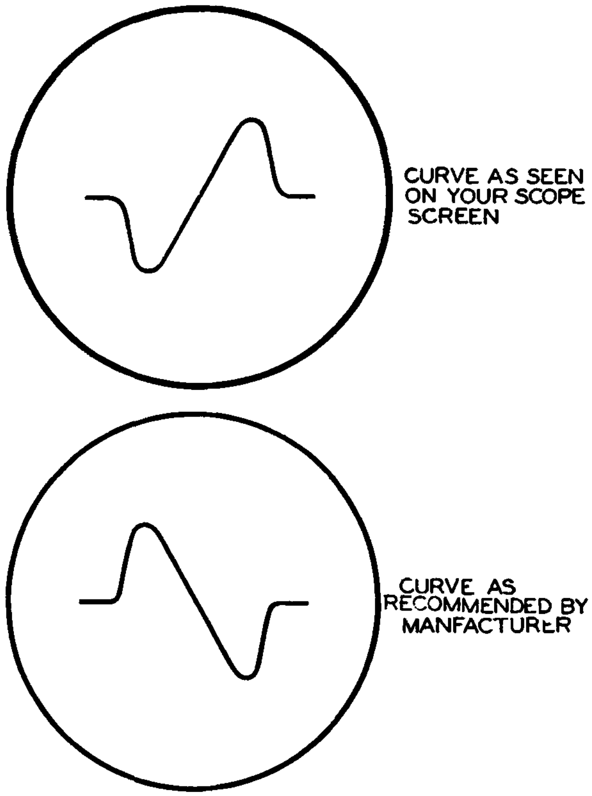


Figure 15. Two Curves $180^{\circ}$ Out of Phase With Each Other. This is Generally Caused by Number of Vertical System Amplifiers in Oscilloscope.

## ALTERNATE METHODS OF FM DETECTOR ALIGNMENT -

Alignment of Foster-Seeley discriminators and ratio detectors can be carried out by using an RF signal generator and a VTVM. The signal generator would be connected to the grid of the IF amplifier tube preceeding the detector. Where the VTVM would be connected depends upon the type of detector circuit employed. If we consider the Foster-Seeley circuit first, then the initial VTVM connection would be made between point B and chassis, as indicated in Figure 16. It might be advisable to insert a 10,000 ohm isolating resistor between the VTVM probe and point B.

The RF generator is now set to the sound IF value (say, 21.00 mc) and then the primary slug of the discriminator transformer, $T_1$, would be adjusted for maximum indication of the VTVM. The lowest DC voltmeter range of the meter should be used, reducing the output of the signal generator to keep the needle on scale.

The transformer primary is now in adjustment and the secondary winding is tackled next. For this, the VTVM probe is switched to point A. The secondary winding slug is now adjusted until the meter reading is zero. Rotating the slug in one direction from the zero point should produce a positive meter reading while rotating the slug in the opposite direction should produce a negative reading. The correct setting for the discriminator slug is at the zero point.

To facilitate the observation of this zero point, a number of vacuum-tube voltmeters have a center zero reading scale. See Section 1. With these instruments, the meter needle is in the center of the scale (at zero) when the discriminator secondary winding is adjusted correctly. Off resonance is indicated by the meter needle swinging to the right or left of this zero mark.

Where your VTVM does not possess a special center zero reading scale, one of two methods can be employed to determine when the discriminator secondary is in balance. In one method, you would carefully adjust the secondary slug until the meter read zero. Then the "Function" switch would be turned from +DC to -DC. If there is no voltage reaching the meter, the needle will remain at the zero mark. However, if there is some slight unbalance and a small negative voltage is present, the needle will deflect. If this happens, adjustment can again be made, bringing the needle back to zero. The process can be continued until a switch from one polarity to the other does not deflect the needle.

The second method is known as the "False Zero" method and consists initially in using the "Zero Adjust" knob of the VTVM to purposely swing the needle to some point on the meter scale (using the lowest DC scale). Let us say that the point chosen is 1 volt (on a 0-3 volt scale). 1 volt now becomes our new "Zero" point because we have disturbed the meter balance to this extent. (Any new "zero" point could have been chosen.)

Now, with the receiver in operation, and the VTVM connected between point A and ground, the secondary slug of $T_1$ is adjusted until the meter needle is at 1. Turning the slug in one direction should swing the needle above 1; turning it in the opposite direction should bring it below 1.

Note that we have established our own zero point at 1. The meter will read 1 when it is not receiving any external voltages. A positive applied voltage will cause the meter needle to swing above 1* and a negative applied voltage will force the meter needle below 1. Thus, when the discriminator secondary is balanced, no voltage should be present between point A and chassis and the meter needle should be at 1.

This "False Zero" method is just as effective as a center zero scale and may be used on all VTVM's not possessing the center zero scale.

The discriminator is now aligned and generally this is as far as most servicemen go. However, it might not be amiss to make one more check to determine whether the central portion of the S-curve is linear. This is carried out by swinging the RF generator frequency 50 to 75 kc above and below the center IF frequency and noting whether equal frequency shifts above and below the center frequency produce equal (but of opposite value) voltage readings on the VTVM. Linearity of the S-curve is as important to the faithful reproduction of a program as the adjustment of any of the receiver stages. Unfortunately,

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*provided the "Function" switch is in the +DC position.

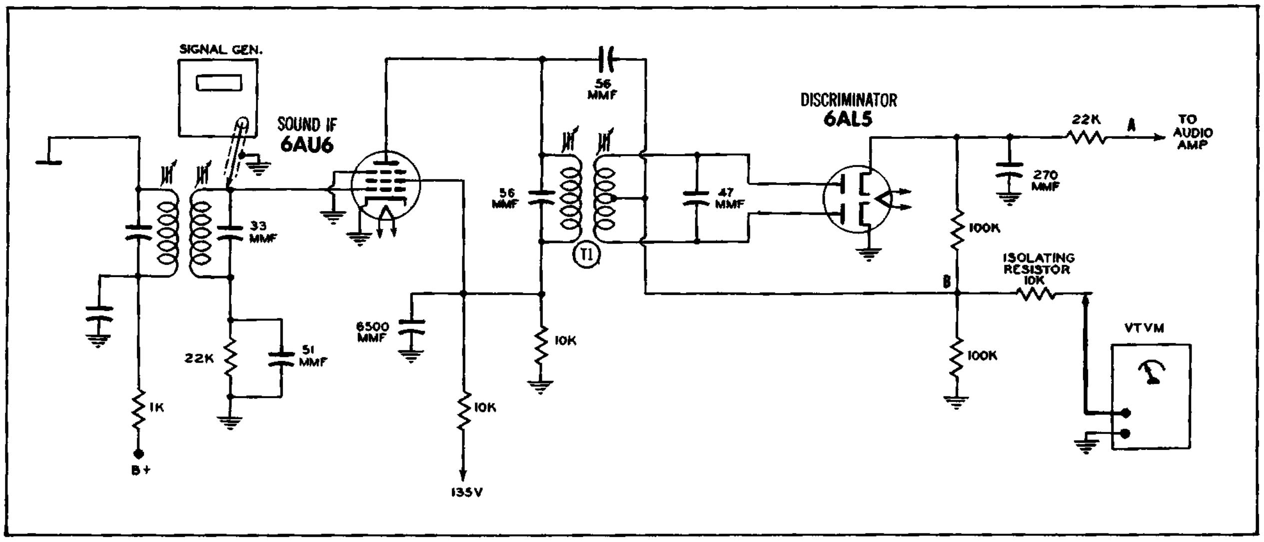


Figure 16. How to Connect a VTVM and Signal Generator for Discriminator Alignment.

many servicemen overlook this test when using a VTVM and an RF generator. They cannot ignore curve linearity when aligning the discriminator visually.

In aligning ratio detector circuits, the method of approach is altered somewhat. The RF signal generator is still connected to the grid of the IF amplifier tube preceeding the detector. However, because of circuit differences, the VTVM is initially connected between point B and chassis. See Figure 17. The primary slug of $T_1$ is then adjusted for maximum meter indication. This done, the VTVM probe is then switched to point A and the secondary slug of $T_1$ rotated for zero on the VTVM. As before, the zero point is located between positive values on one side and negative values on the other and any of the zeroing methods previously described can be employed here.

The Foster-Seeley discriminator and ratio detector circuits shown in Figures 16 and 17 are typical of their group. However, variations of these circuits exist and these may require some modification from the alignment procedure, as outlined. For those readers who wish additional information on circuit alignment or operation, reference should be made to "Television Simplified" or "Television and FM Receiver Servicing", both books by the same author.

## SWEEP ALIGNMENT OF SOUND IF STAGES

The sound IF systems of television receivers depend to a large extent upon the type of detector used and where the sound take-off point occurs. In the so-called conventional TV receiver, where the sound signal is separated from the video signal at some point prior to the video second detector, there will be found two or three sound IF stages. In the Intercarrier type of television receiver, where the sound and video signals remain together until some point beyond the video second detector, one and sometimes two sound IF amplifiers are employed. Usually, the greater number of stages will be found in sets using a Foster-Seeley discriminator since these circuits are preceded by a limiter stage. Ratio detectors are employed without a limiter although a few manufactur-

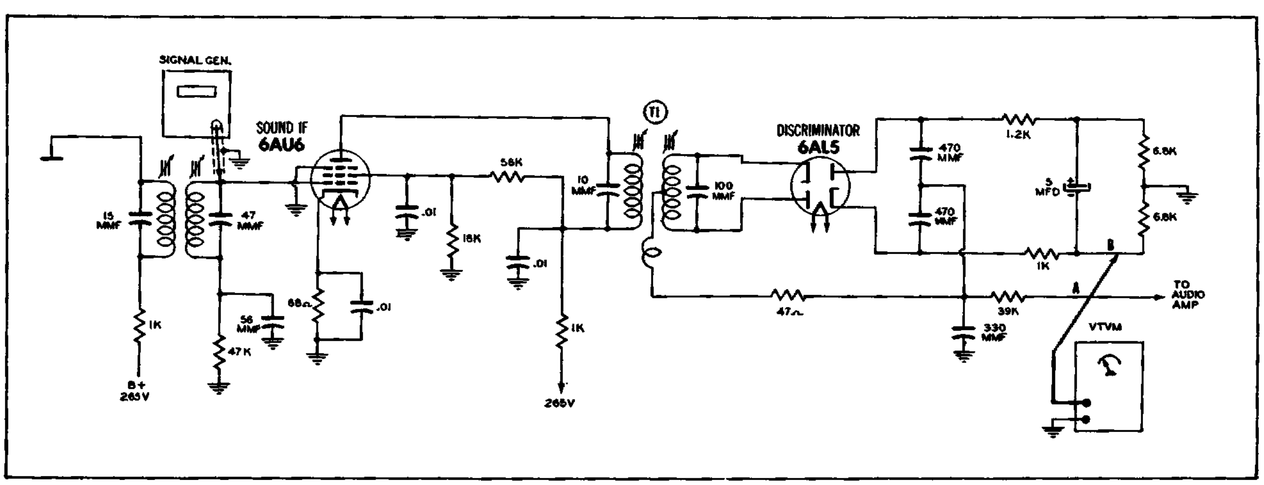


Figure 17. How to Connect a VTVM and Signal Generator for Ratio Detector Alignment.

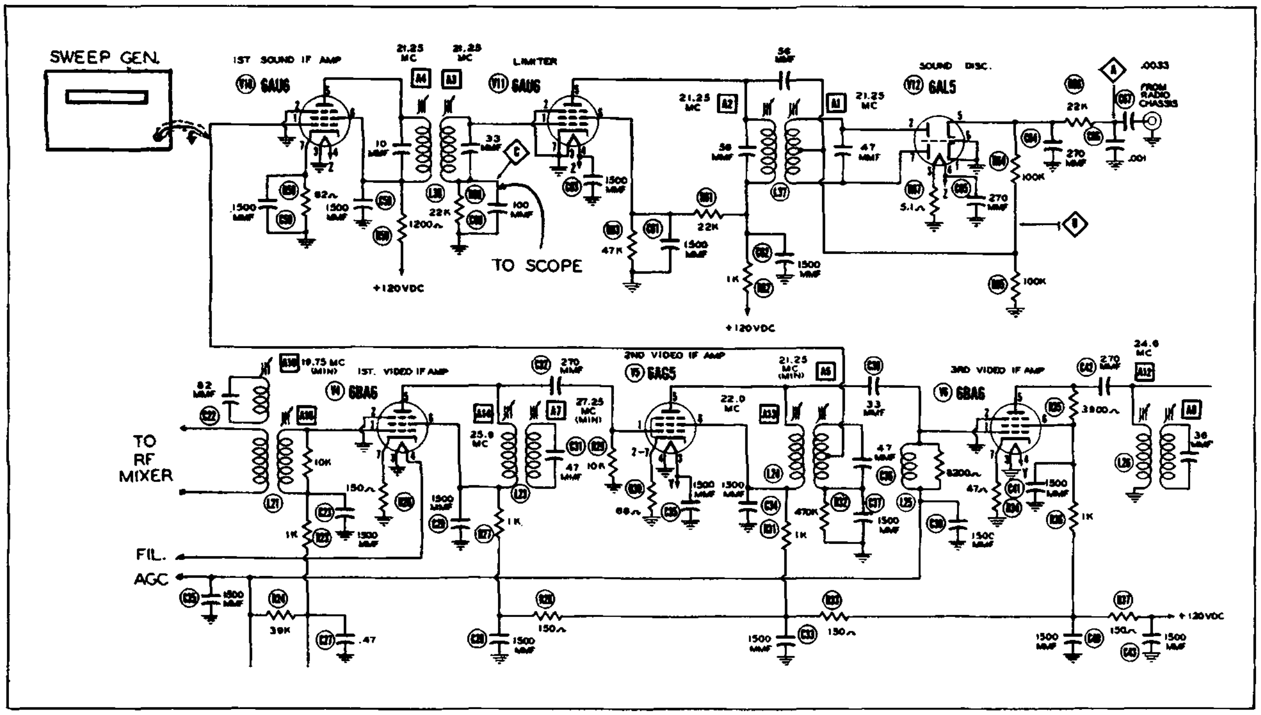


Figure 18. The Sound System in a Television Receiver Employing a Foster-Seeley Discriminator.

ers (like RCA) include a limiter with these circuits, too.

Visual alignment of the sound IF stage or stages is best considered by the type of detector used. Let us start first with the Foster-Seeley discriminator and then turn to the ratio detector.

FOSTER-SEELEY SYSTEMS -

The sound IF systems employed in an RCA receiver is shown in Figure 18. Sound take-off occurs in the plate circuit of the second video IF amplifier and consequently, this set must be considered as a conventional TV receiver. The sound IF carrier frequency is 21.25 mc and it is to this frequency that the discriminator and then the sound IF amplifiers are to be aligned.

The discriminator would be aligned, as described previously, by connecting the oscilloscope to point A and the sweep generator to the grid of the limiter.

To align the two sound IF amplifiers, the sweep generator would connect to the grid of the first sound IF amplifier and the vertical input terminals of the oscilloscope would be placed across R60. The second sound IF stage is designed to function as a limiter and in this type of circuit the voltage developed across the grid-leak resistor and capacitor (R60 and C60 in Figure 18) will vary with the amplitude of the incoming signal so long as the stage is not being overdriven. Therefore, if we apply a sweep signal to the grid of the previous stage, we will develop on the scope screen the response curve for the intervening transformer (L36).

With the sweep generator working over a range of 1 mc, the response curve of Figure 19 should appear on the oscilloscope screen. Then the top and bottom tuning slugs of L36 are adjusted for maximum gain and symmetry about 21.25 mc, the latter point being determined by a marker pip.

Everything that was said previously concerning the precautions which should be taken in connecting the equipment to the circuit should be observed here. In general, it is best to drive the scope scanning beam with a 60-cycle sine wave sweep (to get Figure 19) although the instrument's internal saw-tooth voltage operating at 60 cycles may be used. If this latter procedure is followed, the presentation of Figure 20 will be obtained. Again note that these curves are actually being placed, frequency-wise, back to back

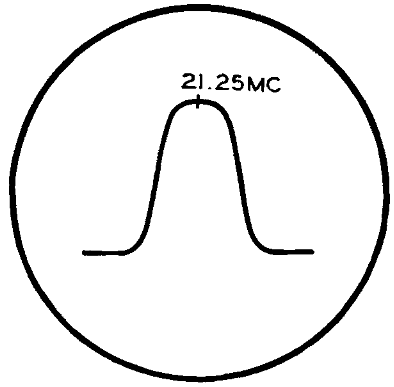


Figure 19. The Sound IF Response Curve of the Circuit in Figure 18 as Given by the Manufacturer.

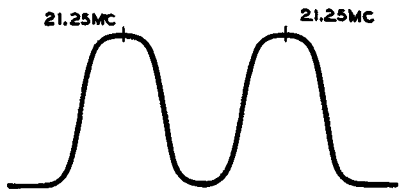


Figure 20. The Appearance of the Response Curve of Figure 19 When a 60 Cycle Saw-Tooth Deflection Voltage is Employed.

and each will contain its own marker pip. Whenever the frequency of the marker generator is varied, the two pip indications will move in opposite directions.

With a symmetrical curve, such as you generally obtain from the sound IF tuned circuits, both curves of Figure 20 can be superimposed over each other. This would be done by raising the linear sweep rate in the oscilloscope from 60 cycles to 120 cycles. At the 120-cycle rate, the beam first traces out the left-hand curve of Figure 20, then swings back sharply to the left and superimposes the right-hand curve of Figure 20 over the left-hand one. The two will superimpose perfectly if both halves of each curve are symmetrical. Note that on one curve traced out (say the first one), frequency increase is from left to right; on the second curve it is from right to left. If the circuit is misadjusted, the curves will no longer be symmetrical and will not blend into each other. Also remember that when a marker signal is introduced into the circuit, two marker pips will be seen on the scope screen because of the two curves. The pips will blend in the center (at the sound IF carrier frequency); at all other times two will be seen and when the marker frequency is varied, the pips will move in opposite directions. It frequently happens that when the test equipment is initially set up, the serviceman plans to drive the scope sweep with a 60-cycle sine wave voltage but forgets to do so. The presence of the two pips will notify him immediately of his oversight. When the deflection voltage is a 60-cycle sine wave voltage, only one pip will be seen when both curves have been blended into one.

Care should be taken to see that the sweep signal amplitude does not overdrive the limiter stage. In the circuit of Figure 18 this may not happen because only one stage (V10) is involved, but in more extensive IF systems this can be a very important consideration. Thus, in Figure 21, there are three sound IF stages. The oscilloscope would be connected to the point shown in Figure 21 and the sweep signal generator would start at the grid of V12 and then be moved progressively back as each intervening transformer is aligned. At the grid of V12, the sweep generator would be set up to give a fairly strong output in order to produce a useable indication on the oscilloscope screen. After L25 is adjusted, the generator output lead is shifted to the grid of V11 in order to permit L24 to be adjusted. This additional amplifier can cause the signal to become so powerful that V13 will overload producing an artificial flat-topped curve at point D. If a curve having this shape is sought--and sometimes it is--then the serviceman will be misled into believing that the circuit is completely adjusted, when in fact it may not be. If a flat-topped curve is not desired, then the serviceman may try to bring about a correction by adjusting the tuning slugs in L24 and/or L25. This, of course, will lead to misalignment. The only correct way of reducing the signal is with the output control of the sweep generator itself. Never use more signal than you need and always check for overloading by noting whether the response pattern amplitude varies in step with rotation of the sweep generator output control.

RATIO DETECTOR SYSTEMS -

The ratio detector is generally not preceded by a limiter and hence the method of aligning the associated sound IF system differs somewhat from the procedure given above.

In aligning the sound IF tuned circuits, we must place the oscilloscope at a point where the variations in signal amplitude produced by the circuits through which it passes can be developed. In a limiter stage such a point is found in the grid circuit because the grid-leak bias developed here does vary (within limits) with the amplitude of the incoming signal. With the elimination of the limiter in the ratio detector system, we also remove this vantage point.

The difficulty is overcome by going into the ratio detector itself and disconnecting one end of the stabilizing capacitor. This is C4 in Figure 22. By doing this and then connecting the vertical input terminal of the oscilloscope to point B and the oscilloscope ground to the set chassis, we will obtain the response pattern of the sound IF stages. In the cir-

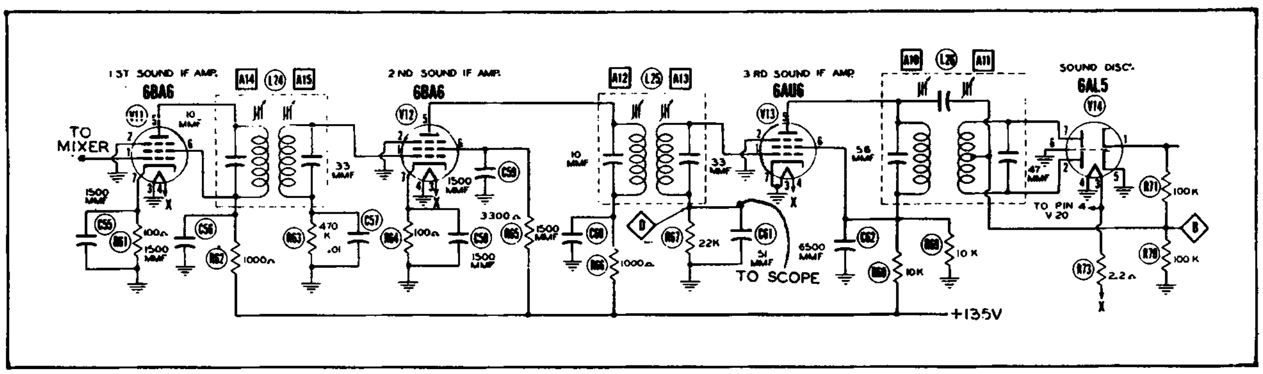


Figure 21. A More Extensive Sound IF System Than the Circuit Shown in Figure 18.

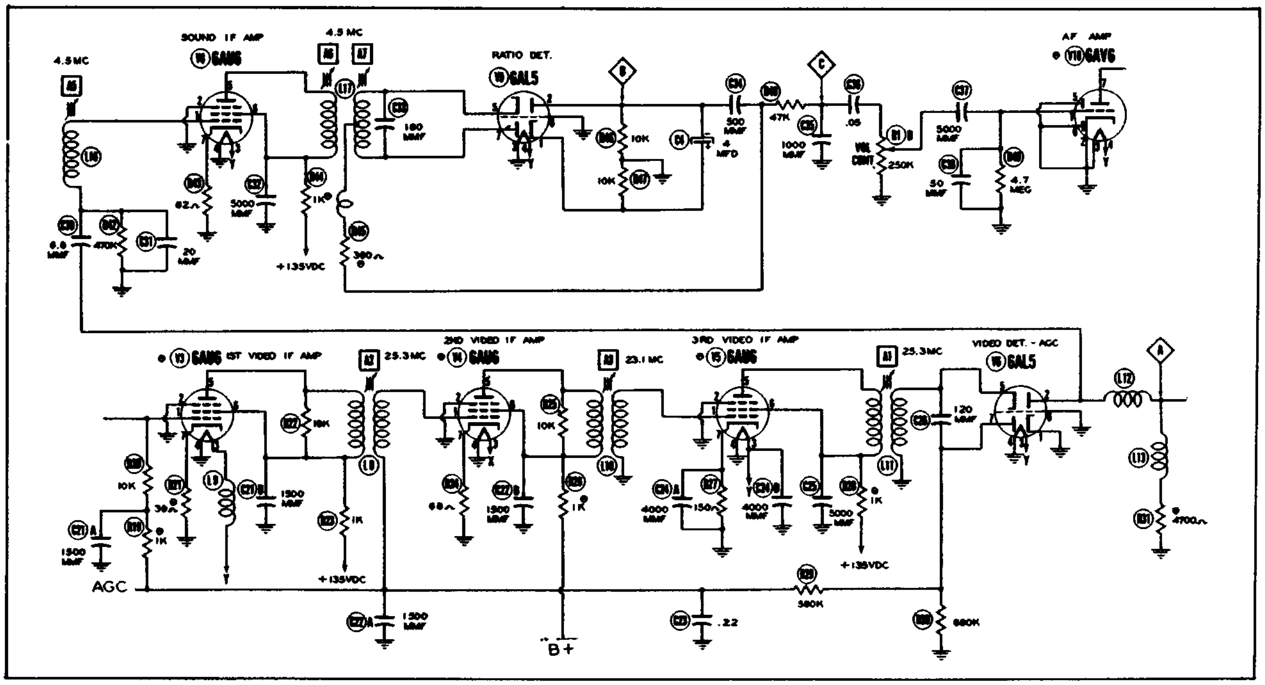


Figure 22. A Sound System of a Television Receiver Employing a Ratio Detector.

cuit shown, the sweep generator would be connected to point A (and ground) and set to the sound carrier IF value of 4.5 mc used here. Then L16 and the primary of L17 would be adjusted for the response curve. After that, C4 would be reconnected into the circuit, the scope moved to point C and, without changing the sweep generator setting or position, the secondary of L17 would be adjusted for a properly shaped S curve. The primary of L17 might require slight retouching because of the interaction between primary and secondary.

In a somewhat more extensive IF system, such as you would find in an FM receiver, there would be more tuned circuits to adjust, but all steps discussed above would be applicable. The mixer, IF stages, and ratio detector of an FM receiver are shown in Figure 23. The alignment procedure recommended by the manufacturer is to disconnect the stabilizing capacitor C2 in the ratio detector circuit and connect the vertical input terminal of the oscilloscope to point A. Scope ground goes to receiver chassis. The sweep generator is applied first to the grid of V4 and slugs A7, A8, and A9 are adjusted for maximum amplitude and symmetry of the response curve. Then the generator is transferred to the grid of the mixer tube, V2, and A10 and A11 are adjusted for maximum amplitude and symmetry of the response curve. This completes the adjustment of the IF stages and the ratio detector is taken next. The sweep generator is shifted back to the grid of V5, capacitor $C_2$ is reconnected and the oscilloscope is moved to point B. A12 (and possibly A7, too) would be adjusted for the proper S curve.

Where the ratio detector is preceded by a limiter, the alignment approach would be similar to that followed for the Foster-Seeley discriminator circuit and its limiter. The IF tuned circuits would be adjusted independently of the ratio detector with the oscilloscope connected into the limiter grid circuit and sweep generator to a prior point. The ratio detector alignment could precede or follow the IF system alignment, as desired. Note also that because of the presence of the limiter, there is no need to remove the stabilizing capacitor in the ratio detector.

The foregoing outline covers the application of sweep generators, marker generators, and oscilloscopes in aligning the sound section of a television receiver. Mentioned, too, are the IF and detector stages of an FM receiver, these differing in no way from similar stages in a television receiver. The frequencies employed may vary, from 10.7 mc for an FM receiver to as high as 41.25 mc for a television receiver, but aside from this, all else would be the same.

The relative narrowness of the sound IF bandpass and the fact that the response curves are usually symmetrical and peaked makes it possible to carry out the alignment using an RF signal generator and a VTVM. The signal generator would connect to the same points indicated for the sweep generator and the VTVM would go to the same places used by the oscilloscope. The generator would then be set to the sound IF frequency, say 21.00 mc, and each of the IF coils would be peaked for maximum reading of the VTVM. The signal would be unmodulated.

Use of an RF signal generator and a VTVM for sound system alignment is not as desirable as the visual method but it can be used and will provide satisfactory results. It is a simpler method and one which most servicemen find easier to perform. However, it presents a somewhat limited picture of circuit conditions which can sometimes be misleading. Once a serviceman becomes familiar with sweep signal

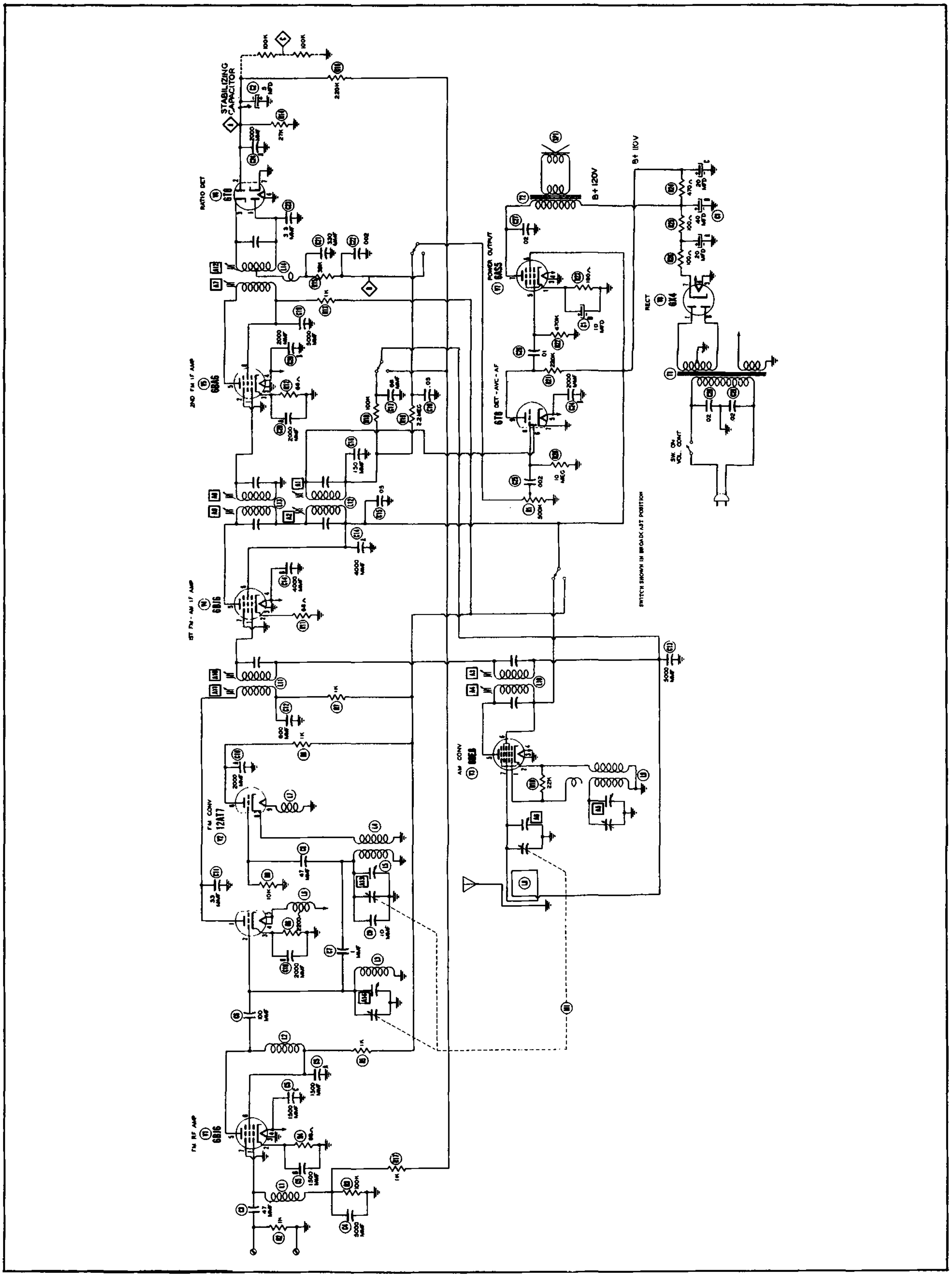

Figure 23. An AM-FM Broadcast Receiver.

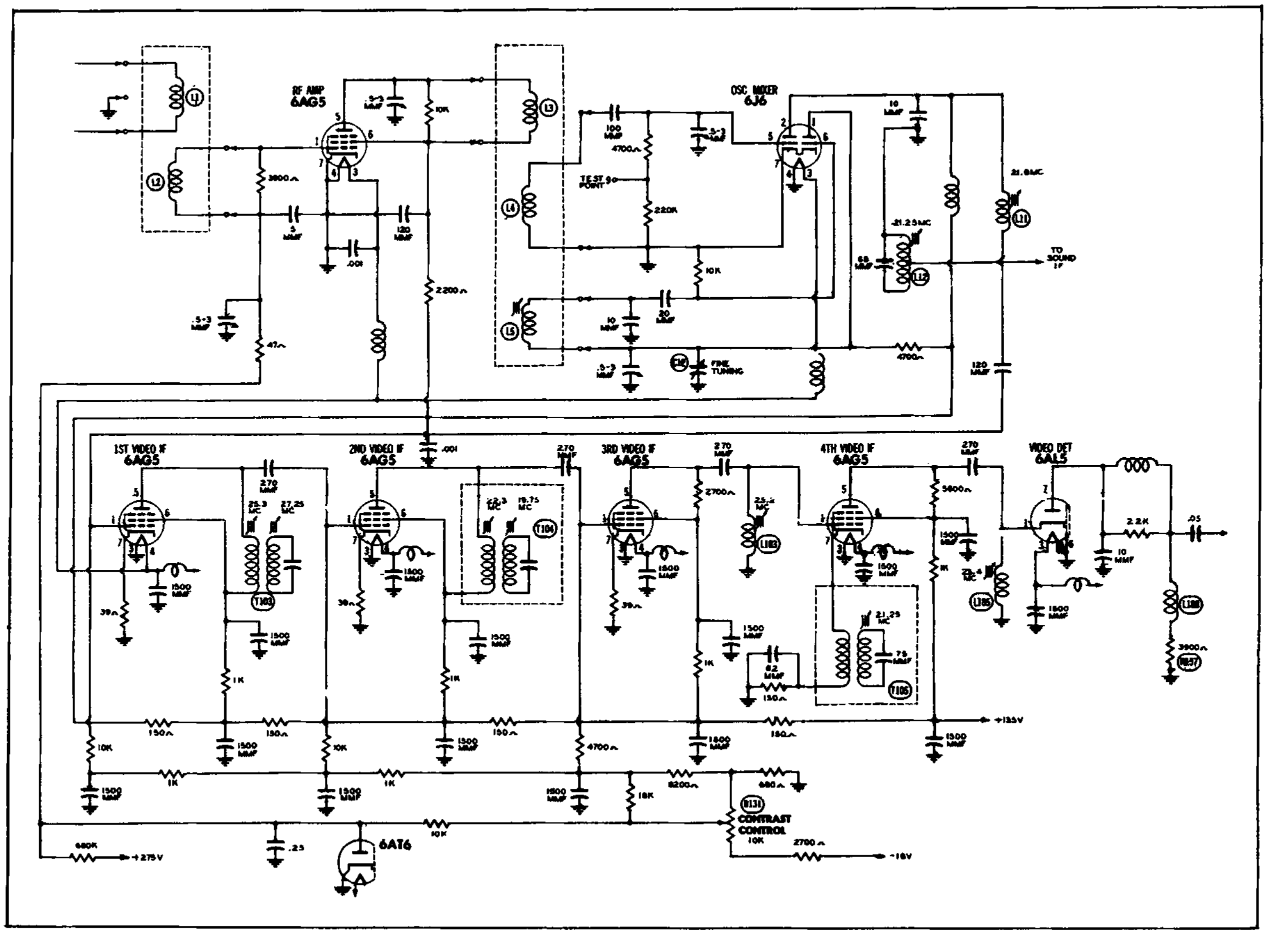

Figure 24. The RF and IF Sections of the Popular Model 630 Receiver. These Circuits are Widely Copied.

alignment, he seldom returns to the RF generator-VTVM method.

## VIDEO IF SYSTEM ALIGNMENT

The use of sweep signals as a method of alignment reaches its greatest effectiveness in the video IF section of a television receiver. Not only is the response curve here not symmetrical (except as noted later), but the bandpass is extremely wide (4 mc) and for proper operation, specific frequencies should occupy certain selected positions on this curve. While an approximation of this curve can be obtained using an AM signal generator and a VTVM, optimum results can only be achieved by actually sweeping out the response curve and inspecting it visually by eye and electrically with a marker signal.

A video IF system that is widely followed in conventional TV receivers is the circuit shown in Figure 24. The tuning circuits employed are all iron-core single peaked coils, each resonant to a different frequency. Coupled to several of the coils are absorption traps whose purpose it is to prevent certain signals from reaching the video detector. In the case of L12, the energy thus absorbed is transferred to the sound system; in all other instances the energy is dissipated in the trap.

The manufacturer of this receiver recommends a two-fold approach to its alignment. Since all of the coils and traps peak to specific frequencies, it is suggested that each unit be adjusted to its peak frequency first, using an AM signal generator and a VTVM. Then, a sweep generator and oscilloscope would be brought in to develop the overall response curve and to permit such correcting adjustments to be made as would be necessary. This might seem like double work but when the circuits are grossly out of adjustment, or the procedure is unfamiliar, it is really the quickest method. After we have examined the method, suggestions will be given which could help to shorten the time by proceeding directly with the sweep alignment.

To start as suggested, the AM signal generator is connected to test point 9 in the mixer grid circuit. The VTVM is placed across the video second detector load resistor, R137. The power in the receiver and in the instruments are turned on and the units are permitted to warm up. The bias on the first three video IF stages in Figure 24 is set to -3 volts, this being the normal value encountered in operation. Then the signal generator is set to each of the following frequencies, in turn, and the indicated slug rotated for minimum reading on the VTVM. In each instance the generator should be carefully set to insure that it is exactly on the frequency desired.

21.25 mc - L12 (In tuner)
21.25 mc - T105 (Top slug)
27.25 mc - T103 (Top slug)
19.75 mc - T104 (Top slug)

Each of these coils is an absorption trap, designed to remove the energy of the frequency to which it is resonant. That is the reason for the minimum meter indication. This done, the generator is next set, in turn, to each of the frequencies given below and the specified slug rotated for maximum reading on the VTVM. (Bias value remains at -3 volts.)

21.8 mc - L11 (In tuner)
25.3 mc - T103 (Bottom slug)
22.3 mc - T104 (Bottom slug)
25.2 mc - L183 (Top of chassis)
23.4 mc - L185 (Top of chassis)

These coils form the tuning circuits of the video IF system and hence they are set for maximum indication.

We are now ready to run a sweep test on the entire IF system. In place of the VTVM we would substitute an oscilloscope with the vertical input terminal connected to the junction of R137 and L188 through an isolating resistor of 10,000-ohms. The scope ground terminal goes to the receiver chassis. It is also desirable to connect a capacitor between 100 and 1000 mmf across the oscilloscope input terminals in order to sharpen the marker pips on the scope screen. Use the lowest value capacitor that gives the best results.

Injection of the sweep generator signal can be made at test point 9 (which, in the Standard Coil tuner is particularly easy to reach), or by direct connection to the mixer grid, or by attaching the signal lead to the mixer tube shield.* Be sure the tube shield is set away from the chassis. The sweep generator frequency for the circuit in Figure 24 would be set to approximately 23.5 mc and adjusted to sweep over a 6 mc range. The generator ground terminal attaches to the receiver chassis. Also the equipment should be set up, as outlined previously, for deflecting the oscilloscope tracing beam with a 60-cycle sine wave voltage. This voltage may be obtained either from the sweep generator or from the oscilloscope, if the latter has a phasing control to use with it. Marker injection (after the response curve has been obtained) may be accomplished by any of the methods outlined previously in the discriminator discussion.

We are almost set to go, but one more preparatory step still remains: The setting of the bias on those stages which are controlled. In the circuit in Figure 24, the grid bias on the first three video IF stages are manually controlled by the picture (contrast) control (R131). As this control is turned clockwise, the bias is reduced; as it is turned counter-clockwise, the bias is increased. It has been found that with a change in bias, the input impedance (here, notably the input capacitance) of a tube changes and this will alter the resonant frequency of the tuned circuit connected across the tube input. To derive the greatest benefit from an alignment, the grid bias of the controlled tubes should be set to the value it will possess under operating conditions. With signals of moderate strength, this value is -3 volts# and the picture control would be set for this value. If the receiver employs a.g.c., then a fixed 3 volts (from a battery) should be inserted into the a.g.c. line with the negative end connecting to the line and the positive terminal to the chassis.

(In fringe areas or wherever weak signals are encountered, the recommended bias is between 1 and 1.5 volts. However, under these conditions, you might not align the response curve to the same shape as you would for normal signals. This will be considered presently in more detail.)

A good precaution to observe before commencing the alignment is to disable the local oscillator in the receiver. This can frequently be done by pulling the oscillator tube out of its socket. If the oscillator and mixer tubes are in the same envelope, or if the filaments are series wired, tube removal is not feasible. In this case it may help to unsolder one of the oscillator connections or perhaps rotate the tuner to a non-interfering position. In the Standard Coil tuner the oscillator can be disabled by carefully rotating the tuner turret or drum until it is balanced on one of the ridges between each position where contact is made with the tuner circuits. If this precaution is not taken, spurious responses set up by the oscillator voltage beating against the sweep generator signal can interfere with the response curve, either distorting it or else swamping it altogether.

Now, if every step has been carefully observed, then some sort of indication should be observed on the scope screen. If there is no indication at all, check the oscilloscope first to see whether it contains any visible trace at all and if it does, then check the set and sweep generator. (In line with suggestions made previously, the marker generator should not be connected until a response pattern has been obtained on the scope screen.)

In the sweep generator, the following points should be examined:

1. Is the sweep generator putting out any signal at all?

    A fast way of determining this is to connect the sweep generator to the grid of one of the sound IF tubes in a receiver known to be in good condition. Set the generator frequency to the sound IF value (either 4.5 mc in Intercarrier sets, or between 20 and 42 mc in conventional sets) and turn up the volume control of the receiver. A 60-cycle rasping buzz indicative of the 60-cycle sweeping rate in the generator will be heard. The sound will disappear as the generator frequency is altered.

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*When the signal output of the generator is weak, it may be necessary to make direct connection to the mixer grid in order to obtain a usable indication on the VTVM. The other methods mentioned may not inject sufficient signal into the circuit.

#While -3 volts is a value widely used, it is not the only one. Some manufacturers recommend higher voltages than this.

2. Is the instrument set to the proper range?

   To sweep over a range of frequencies from 21.5 mc to 26.5 mc, the tuning indicator should be at some point between these frequencies, preferably at the midpoint.

3. Is the output control set at maximum (to start)?

4. Is the sweep width control set at from 6 to 10 mc?

In the absence of any response pattern on the scope screen, try rotating the sweep generator frequency dial from about 15 mc to 30 mc (assuming a video IF of 25 mc or so). It is not uncommon to find that the dial calibration is off. When the error is small, it is of little consequence as long as the sweep generator is operating properly in all other respects. The precise frequency of every point on the response curve is determined by accurate markers anyway.

Where the dial calibration of the sweep generator is considerably off and the serviceman would either like to recalibrate it or reset it (if there is provision for this), the following method is very useful.

Take the sweep generator and reduce the sweep width to zero, converting the instrument effectively into a simple RF generator. Then connect its output into the input terminals of the germanium detector network shown in Figure 40 of this section. Across the same two input terminals feed the signal from a carefully calibrated marker generator covering the same frequency range. The other end of this detector connects to the vertical input terminals of an oscilloscope. The frequency at every setting of the sweep generator dial can now be checked against the marker generator by zero beating both signals.

This calibration can be carried out in short order and will reveal, with an accuracy equal to that of the marker generator, how far the sweep generator's dial readings are off.

With the instruments and the receiver in operation, some type of curve will appear on the oscilloscope screen. In spite of all the warnings that have been given concerning feeding in of too much signal, or of disabling the oscillator, or of carefully bringing in the marker signal after a response curve has been obtained, certain errors will be made which will distort an otherwise normal response curve. Given below are a group of typically distorted or incorrect curves such as the serviceman is likely to encounter when he has committed some error in his preparation for the alignment. The analysis of each curve is designed to help the technician avoid making these mistakes or, at least, if a mistake is made, to realize what has caused it.

Figure 25A shows a typical desired response. Specific frequency values are included to identify various points on the curves, such information being determined with a marker generator, one point at a time.

Figures 25B, 25C, and 25D show the effect of too little bias on the stages to be aligned. The correct bias should be -3 volts. At -2.5 volts the curve is not appreciably affected although there is a definite change in the contour of the curve along the top. The overall amplitude of the curve has increased, including that of the two smaller side peaks. The greater amplitude, of course, is a direct consequence of the bias reduction. With -2 volts bias, the curve has become distorted due to a certain amount of overdriving or saturation in the video IF amplifiers. This condition becomes progressively worse as the bias is reduced

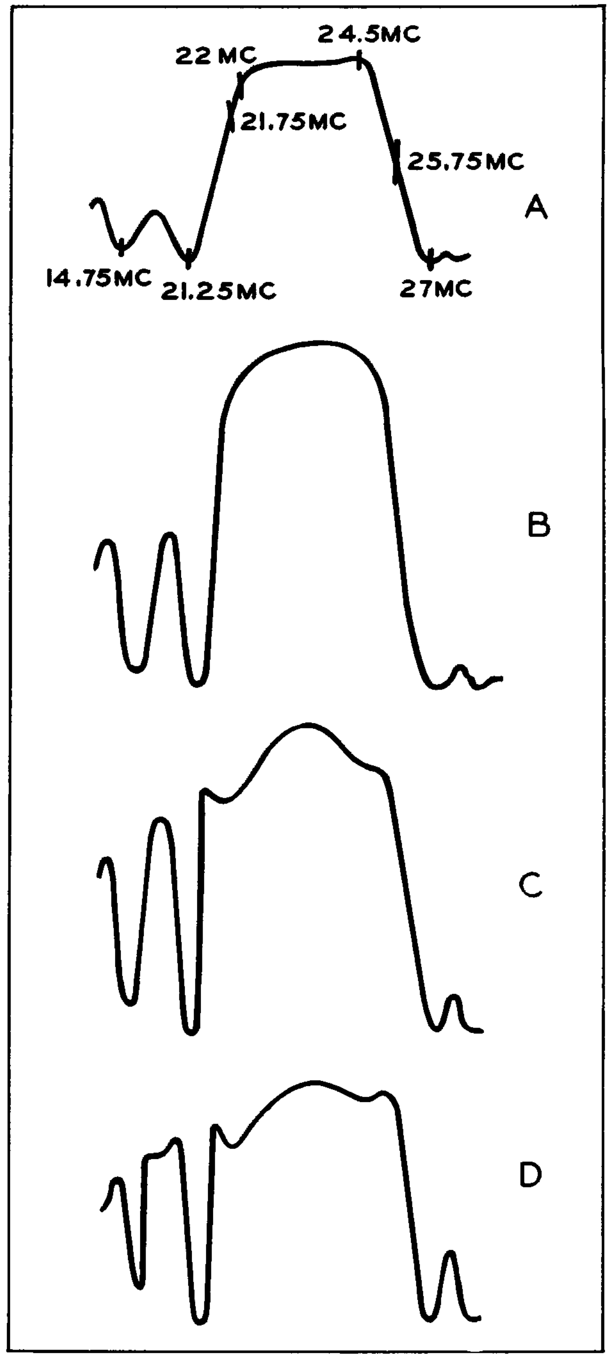


Figure 25. (A) Ideal Response Curve. (B) Bias at -2.5 Volts. (C) Bias at -2.0 Volts. (D) Bias at -1.5 Volts.

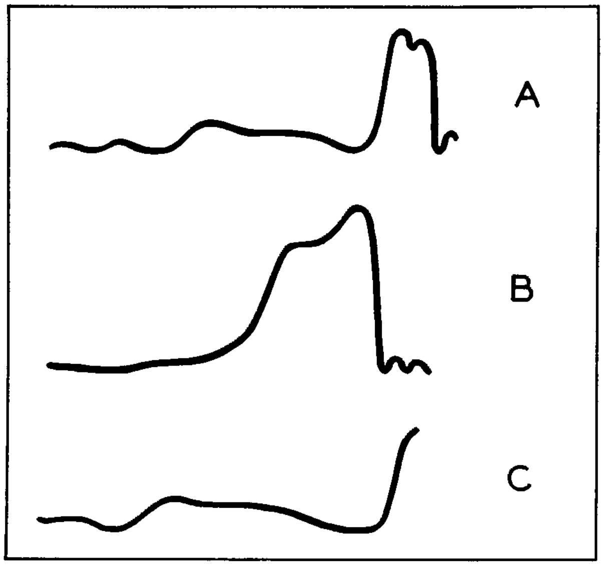


Figure 26. Curves Obtained by Tuning the Set to Various Channels.

still further, (as in Figure 25D) and now the artificial flattening of both the main curve and its secondary side peaks is quite pronounced.

The next set of related curves are Figures 26A, 26B, and 26C and they show what can happen when the set oscillator is permitted to function during the alignment operation. Each of these curves was obtained by tuning the set to a different channel. Within any one channel, rotation of the fine-tuning control will cause the pattern shape to change.

Some injurious effects which can be caused by the marker generator are shown in Figures 27A, 27B, and 27C. In Figure 27A the marker generator is connected directly to the grid of the first video IF amplifier and the output of this generator has been turned up high. Result is a complete swamping of the response curve.

In Figure 27B the marker generator is still connected to the grid of the first video IF amplifier but its signal output has been considerably reduced. Now, some semblance of the video IF response curve can be seen, although the marker generator loading is still quite evident. The loading is due to the very low input impedance of the marker generator. In this respect it is important to keep in mind that if the marker generator is connected into the circuit at a point which is closer to the video second detector than the sweep generator, the impedance the marker generator shunts across the circuit will have a direct effect on the sweep generator signal passing through the system.

On the other hand, if the marker generator is placed ahead of the sweep generator (nearer to, or in, the mixer stage), its impedance will have no effect on any response curve seen on the scope screen. This would happen, for example, if we connected the sweep generator to the grid of the first video IF amplifier tube and the marker generator to the mixer grid.

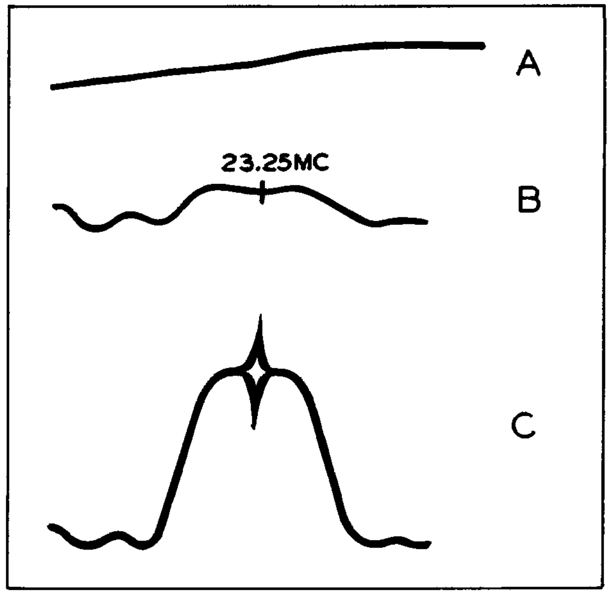


Figure 27. (A) Marker Generator Connected Directly to Grid of the First Video IF Amplifier. Strong Signal Output. (B) Marker Generator Connected Same as "A" but With Weak Signal Output. (C) Marker Generator Coupled to Grid of First Video IF Amplifier Through 75,000 Ohm Isolating Resistor. Strong Signal Output.

Now, the only way the marker can affect the response curve is by injecting too strong a signal.

In Figure 27C the marker generator is coupled to the grid of the first video IF amplifier through a 75,000-ohm resistor, thereby effectively isolating its low internal impedance from the video circuit. The big pip in the center of the response curve is now due to a strong output. If the marker generator output is reduced, the pip will attain its proper perspective and the response curve will be unaffected. All connecting leads should be kept as short as possible to minimize the effect of the inevitable shunting capacitance.

In Figure 28 the shape of the response curve is correct but due to an improperly adjusted phase control (on the sweep generator), two curves are seen. The control should be adjusted until the two curves blend into one. In Figure 29 we have the same

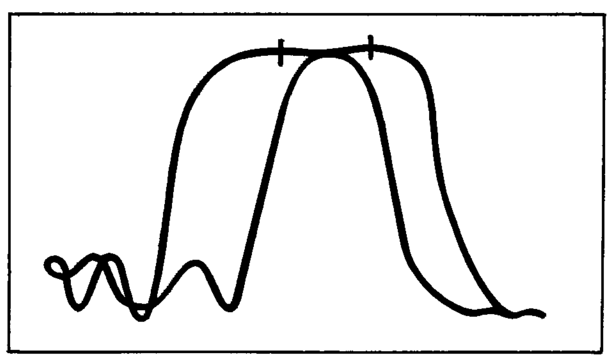

Figure 28. Sweep Generator Phasing Control not Properly Adjusted.

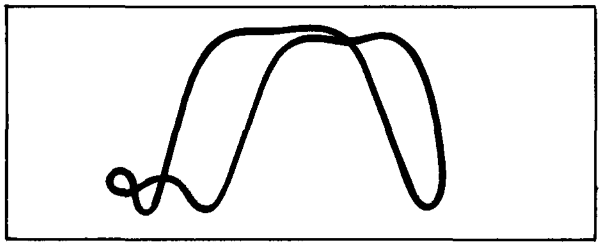

Figure 29. Insufficient Sweep Width for Phasing.

situation except that it is not possible to produce one curve at any setting of the phase control. Reason: The sweep width or sweeping range is too small. Increase the sweep width (to at least 6 mc) and then a position on the phase control will be found where the curves will blend.

Incidentally, it should be noted that perfect blending is not always achievable. At some points the two curves will discernible. This can be disregarded, being due to an unbalance in the generator circuit.

As the sweeping range is increased, the area that the response curve occupies on the screen becomes progressively less. See Figure 30. A curve which is too narrow is difficult to work with. 6 to 8 mc sweeping range for a 4 mc bandpass is sufficient. There is no need to go beyond this.

In some instruments, however, it is not unusual to find that a 6 to 8 mc sweeping range is obtained only when the range indicator is turned to its extreme clockwise position.

When the sweep generator is being set up, its dial should be turned to the center frequency of the band being swept over. Thus, if the bandpass from 22 to 27 mc is to be observed, the generator should be set at (or near) 24.5 mc. If the center of sweep

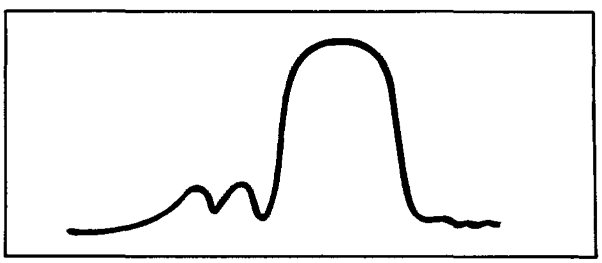

Figure 30. Curve Caused by too Great a Sweep Range.

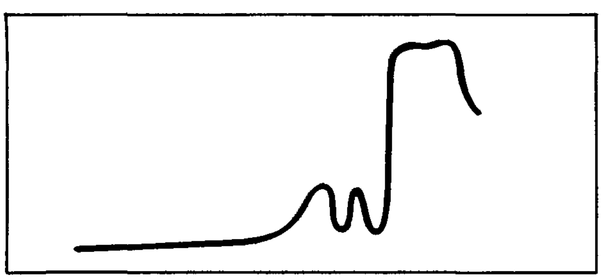

Figure 31. Improper Centering of Sweep Range (Too Low).

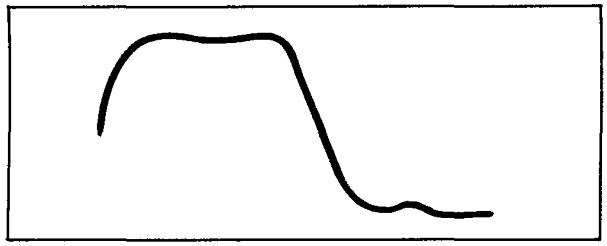

Figure 32. Improper Centering of Sweep Range (Too High).

frequency is too low, Figure 31 will result. If the center of the sweep frequency is too high, Figure 32 will be obtained. Whenever both ends of a response curve are not at the base or lowest point on the observed pattern, you can be sure that the full band is not being swept over.

A common error made by many servicemen results in the pattern shown in Figure 33. Everything has been properly connected here, except that the oscilloscope is still using its saw-tooth deflection voltage to sweep the beam across the face of the screen. To obtain the proper beam motion correctly synchronized to the sweep of the frequencies across the band, the internal sweep of the scope should be turned off and 60-cycle sweep voltage obtained from the generator itself.

The foregoing patterns are representative of those most frequently encountered by servicemen in their failure to obtain the proper response curve. If you study each one carefully and learn why it occurred, your chances of making the same error will be materially lessened.

The ideal video IF response curve is the one shown in Figure 25A. This curve has the proper slope on the video carrier side, has a full 4.0 mc bandwidth, and decreases to the proper level at the trap frequencies. There are a number of sets on the market from which such response curves will be obtainable. But the longer you work with television receivers, the more you come to find that there are also many sets from which you will not be able to obtain this shape curve. Thus one manufacturer shows the overall response curve of Figure 34 from mixer to video second detector. Note that the bandpass here is 3.5 mc (which is not bad at all), and the curve is quite symmetrical.* Another manufacturer indicates in his

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*It is not uncommon to find a symmetrical response curve when the video IF system does not contain any trap circuits.

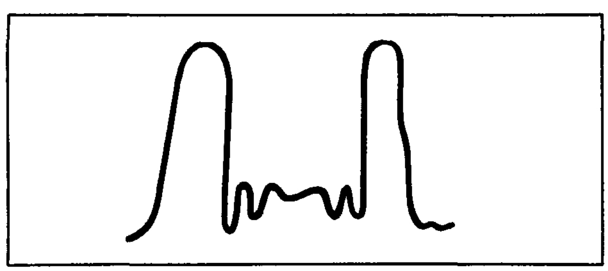


Figure 33. Curve with Incorrect Scope Deflection.

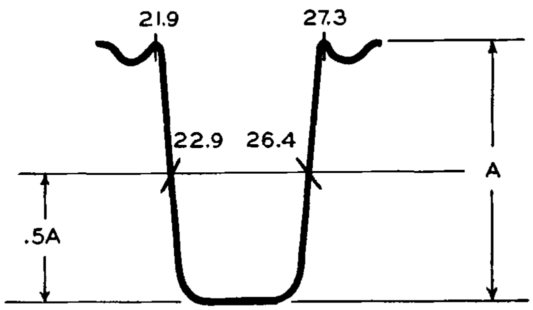



Figure 34. Overall Video IF Response Curve Recommended by a Large Manufacturer for his Sets.

service manual that the video IF response has a pronounced dip in the center of the curve. (See Figure 35). He recommends that this dip should not extend more than 30 per cent of the overall height of the curve. Other manufacturers state that the dip should not exceed 10 per cent.

Here you have but a few of the variations that you will find among different sets when checking their IF response. For their particular circuits, under the policies of their design, these curves are "normal" and there is little the serviceman can do to change them--even if he should be so inclined. Try to strike the best compromise between amplification and bandwidth, emphasizing amplification in weak signal areas and bandwidth in strong signal areas.

As indicated on the video IF response curve, the placement of the video carrier and the trap frequencies are most important and should be carefully checked. This is done by setting the marker generator to each of the frequencies to be checked and noting where the pip falls on the response curve. Checking the video IF carrier and all other frequencies which fall fairly high on the response curve is readily carried out because no difficulty is encountered ir seeing the marker pip. Within the trap hollows, however, the pip disappears and so you can never be completely sure whether the trap circuit is being aligned precisely on frequency.

One way to overcome this is to gradually reduce the sweeping range of the generator while the marker

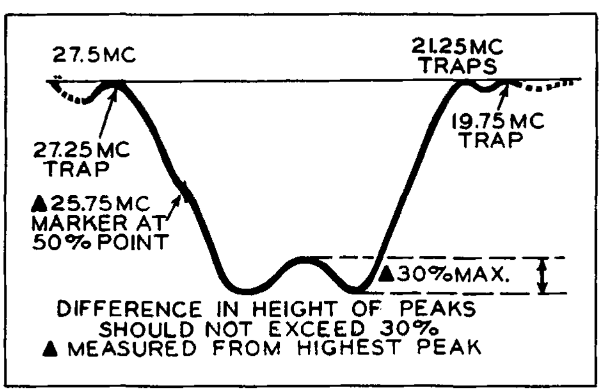



Figure 35. The Overall Video IF Response Curve Recommended by Another Manufacturer. Note Dip in Center of Curve.

generator is kept at the frequency of the trap. Eventually, the marker pip will become visible in the trap and then the trap circuit can be adjusted for minimum height of the pip. The center frequency of the sweep generator may have to be readjusted as the sweep range is reduced in order to keep the marker pip and the trap it is in visible on the screen.

## MODIFIED VIDEO IF ALIGNMENT -

Most recommended procedures for aligning the video IF system specify first the individual peaking of the various video coils and traps, followed by an overall sweep alignment. Where it is desired to run a check on a receiver and there is no reason to believe that the system is grossly misaligned, it is often possible to omit the preliminary coil peaking steps and proceed directly with the sweep alignment. In order to carry this out properly and in minimum time, the various slugs must never be haphazardly rotated. After the curve has been produced on the screen, use the marker generator to check its bandwidth and the placement of the various key frequencies such as the sound and video carriers. With this information, you are then in a position to make such corrections as are needed. For example, if you find that the video carrier is located too far up or down on the side of the response curve, then you would tune the slugs of those video IF coils whose resonant frequency was close to that of the video carrier. In the circuit of Figure 24, these would be T103 and L183 since their frequencies are, respectively, 25.3 mc and 25.2 mc and rotating their slugs would affect the side of the response curve containing the video carrier (frequency of 25.75 mc). Also effective here is the 27.25 mc trap (in T103) and it, too, could be adjusted.

At the other end of the curve (where the IF values are lower but which govern the higher picture frequencies), L11, T105, and T104 would have the greatest effect in altering the shape of the curve. Finally, for the flat-top center portion of the curve, we would turn to L185 (23.4 mc). Note that these adjustments are all interdependent to some extent and while their effect will be greatest on the section of the curve containing their frequencies, they will also influence, to some extent, all other portions. This may require a certain amount of compromising between adjustments but if you proceed carefully, not too much difficulty will be encountered--certainly no where near as much as you would fall heir to if you turned slugs haphazardly. This modified procedure is not recommended for the beginner, but the experienced serviceman employs it frequently.

Often overlooked in alignment is the effect that the traps have in establishing the steepness of the sides. As you move the trap in toward the main body of the response curve, the side facing the trap tends to become steeper. If the slug is rotated too far, however, the trap will enter the response curve itself and tear a hole in it.

## CURVE ALIGNMENT FOR FRINGE AREA OPERATION

Many television receivers are located in areas where the amount of signal available to the receiver is extremely small, possibly on the order of 50

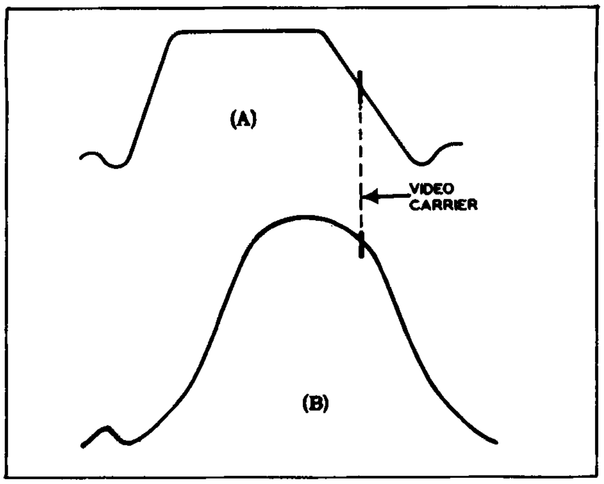



Figure 36. (A) Normal Video IF Response Curve. (B) Modified Response for Fringe Operation.

microvolts or less. Under these conditions, it has been found desirable to modify the video IF response curve from its normal configuration to the shape shown in Figure 36. The response to the higher video frequencies has been sacrificed in order to raise the amplification accorded the carrier and the adjacent low video frequencies. The sound carrier still receives its normal amount of amplification.

One precaution should be observed when making this modification. Manufacturers usually indicate that video alignments should be performed at a certain bias value. The figure generally given is -3 volts. Under weak signal conditions, the bias will be considerably under this value, possibly less than -1 volt. Since the set will operate with this type of signal, it is suggested that the bias value be determined with the set operating in the home and then aligned at the shop with this bias value.

The narrowing of the video IF response reduces the overall receiver bandwidth to approximately 2.5 mc in place of the customary 3.5 to 4.0 mc. Because of this it is not necessary that the video frequency amplifiers following the detector possess any wider response. Advantage can be taken of this to increase set gain by raising the value of the load resistors in the video detector and the following video frequency amplifiers.

An increase of 75 to 100 per cent is recommended. Thus, if the load resistor value is 2200 ohms, a 100 per cent increase will mean a resistor of 4400 ohms. Since resistors of this value are not common, any value close to it (as 3900 ohms or 4700 ohms) will do as well.

INTERCARRIER RECEIVERS -

Intercarrier television receivers differ from the conventional receiver principally in the fact that the sound and video carriers remain together at least up to and frequently beyond the video second detector. However, despite the fact that the sound signal is permitted to reach the video second detector, it does so with very little amplitude and consequently it re-

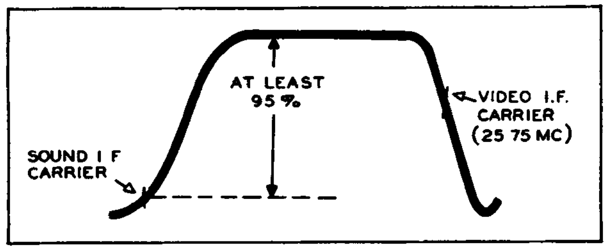



Figure 37. In an Intercarrier Receiver, The Sound Carrier Should Receive no More Than 5% of the Total Amplification Available in the Video IF System.

mains at approximately the same level on the response curve as it does in the conventional circuit. It may be moved slightly up on the curve, perhaps to a point where it receives about 5 per cent of the maximum amplification, but care should be taken to see that it goes no higher. See Figure 37.

The video IF system of a typical television Intercarrier receiver is shown in Figure 38. There are three stages using four tuned circuits. Three of the circuits are bifilar coils, each containing closely wound primary and secondary windings tuned by a single movable slug. Two of the bifilar coils are resonant to 25.3 mc while the third peaks at 23.1 mc.

The recommended alignment procedure for the entire video IF system follows closely that outlined for conventional systems. First, each of the tuned circuits are peaked to their respective frequencies, with the AM signal generator connected either to test point D or to a loosely held mixer shield (that is not grounded). The VTVM indicator is connected across the video second detector load resistor or point A, whichever is most convenient. Since there are no traps in this system, each coil would be peaked for maximum meter indication.

After this has been done, a sweep generator replaces the AM generator and an oscilloscope is substituted in place of the VTVM. A 10,000-ohm isolating resistor is placed in series with the vertical input lead of the oscilloscope. After a response pattern has been produced on the scope screen, a marker signal is injected by one of the methods previously described. The various adjustments are then touched up as needed.

In this circuit, as in the previous circuit, a negative 3 volt bias would be applied to the a.g.c. line, with the positive side of the battery attaching to the chassis. Also, to prevent spurious responses, the oscillator should be disabled.

Throughout the alignment, particular attention should be given to the placement of the sound IF carrier. It must be positioned at least 95 per cent of the way down the curve. It may be placed somewhat lower than this but it should not go any higher.

It is not the purpose of this section (or this book) to investigate each of the different types of video IF circuits that are in use but rather to note how test instruments can be employed to align such circuits. In all instances it is recommended that the manu-

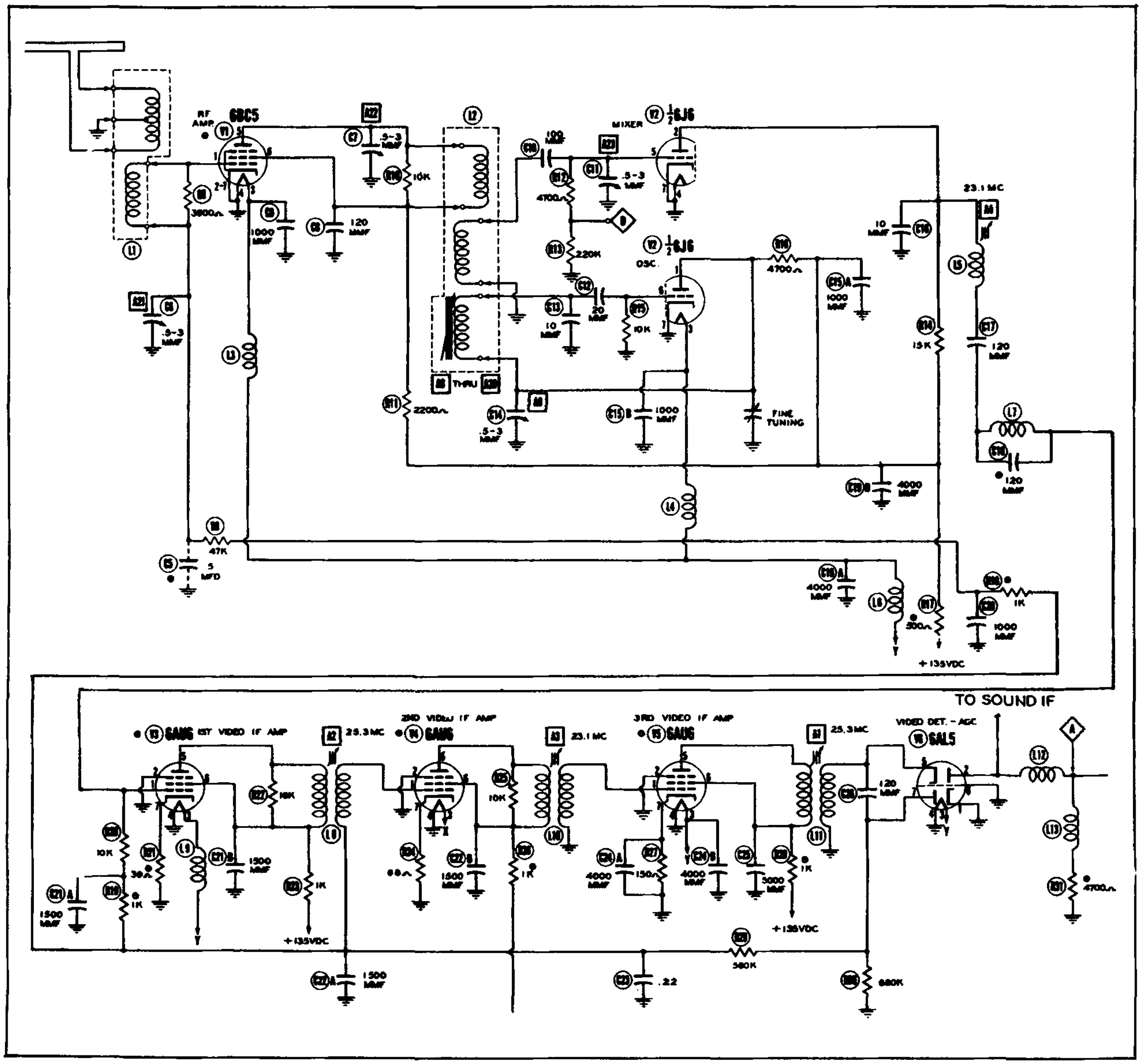



Figure 38. The RF and IF Stages of an Intercarrier Receiver.

facturer's instructions be followed as closely as possible because while the general procedure outlined above will be sufficient in most instances, there appear, from time to time, certain variations that should be followed for best results. RCA, in their Model KCS66 Intercarrier receiver, stipulate that 330-ohm composition resistors be placed across certain portions of the video IF system. Emerson, in their Model 709A receiver, suggest that the response curve of the first or input IF transformer be checked separately by the use of a special detector network (which we will discuss presently). The important thing is to know what you are looking for and how the equipment should be connected.

From time to time in your service or alignment work you will come across IF systems whose response cannot be brought in line with what is recommended or what it should be. The curve may be too narrow or you may find that while one section of the curve possesses the proper form, the other side does not. Common causes of these conditions might be a defective tuning coil or slug, a shunting resistor which has radically increased or decreased in value, or even a defective tube. Whenever the tuning slug of a coil or transformer is varied, it should produce a very definite effect on the indicator (VTVM or oscilloscope). If it does not, check the coil and any shunting resistor. If the shunting resistor has appreciably increased in value, it will narrow the response curve; if the resistor has decreased in value sufficiently, it will load down the coil to such an extent that slug rotation will have no effect. Utilization of this fact is made by RCA in many of their service manuals. They recognize that at times it may be desirable to observe an individual IF stage response pattern (perhaps when the proper overall response curve cannot be obtained). To do this, it is suggested that all other IF tuned

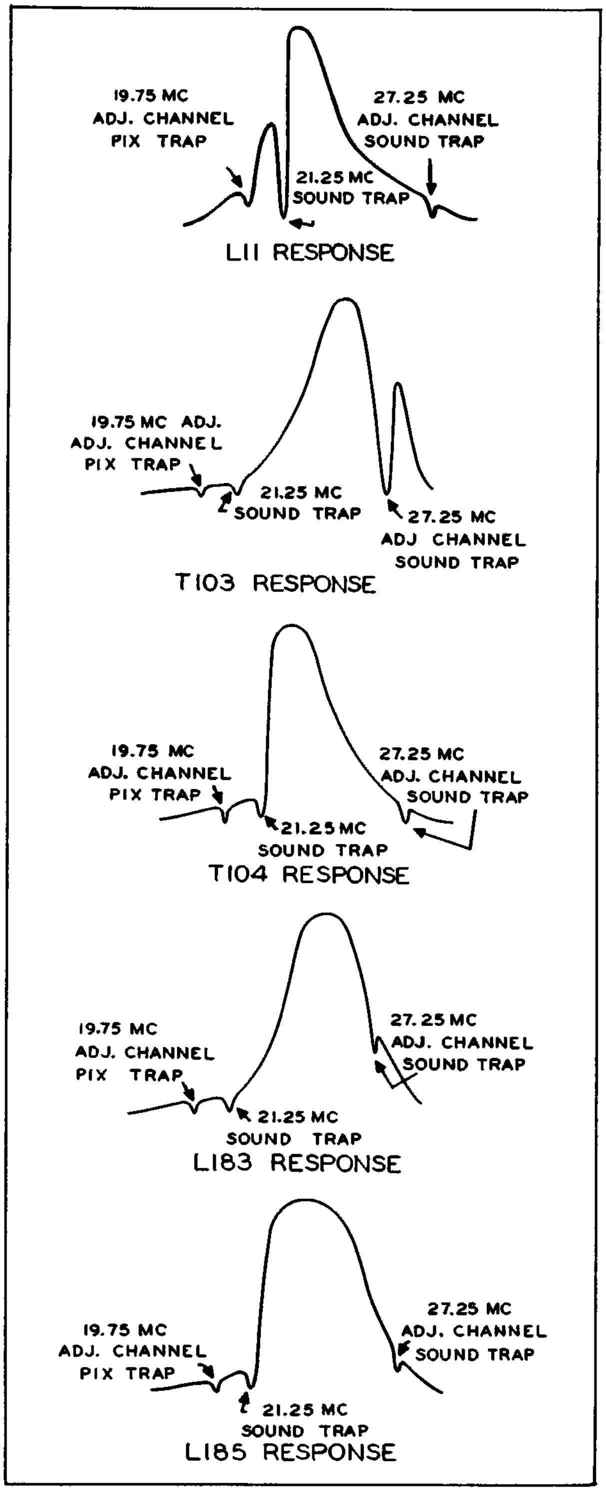



Figure 39. Representative Response Curves for Each of the Tuned Circuits (Except Traps) in Figure 24.

circuits (except the trap circuits) be shunted with 330-ohm carbon resistors. The sweep generator would feed its output into the mixer tube (via its shield) while the oscilloscope would be connected across the video detector load resistor. With this set-up, the response pattern obtained will be essentially that of the unshunted stage. The effects of the various traps will also be visible. Representative response curves for each of the tuned circuits of Figure 24 are reproduced in Figure 39, together with that of the overall response curve. (These curves were obtained from the manufacturer's service manual.)

## ALIGNING OTHER VIDEO IF SYSTEMS

Over 95 per cent of the television receivers on the market can be aligned by the methods outlined above. About 5 per cent of the sets employ transformer or complex coupling and for these circuits the manufacturer frequently recommends a stage-by-stage alignment which differs in many respects from the foregoing procedure. The best way to illustrate this type of alignment is to follow through a step-by-step adjustment of a representative circuit. In the material to follow, the circuitry from a Du Mont receiver is used.

The equipment required consists of a sweep generator, a marker generator, an oscilloscope and an RF probe. Everything but the probe has been employed before and the reason for the probe is quite simple. If you want to observe the signal at the plate of any IF amplifier, it first must be rectified or detected before it can be applied to the vertical input terminals of the oscilloscope. In all previously described alignments the video second detector served to perform this function. However, when you wish to observe the response of a single IF stage, you must obtain the signal at the plate of the video IF stage; you cannot wait until the signal has passed through the remaining IF stages and the second detector before applying it to the scope.

The additional probe indicated above serves to take the signal at any point in the video IF system, detect it, and apply the rectified voltage to the vertical input terminals of the scope.

Figure 40 shows the circuit of a probe detector recommended by the manufacturer. (There are many variations of this circuit, all functioning in the same manner.) Detection is accomplished with the 1N34. When constructing this unit, make it as compact as possible in order that its input capacitance will have as little disturbing effect on the IF circuit as possible. In using this detector, the output would be fed to the vertical input terminals of the oscilloscope. The input terminal (or probe end) would touch that point in the circuit where we wished to observe the signal. The ground terminal would go to the receiver chassis.

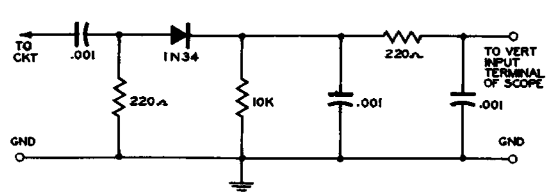



Figure 40. A Probe Detector Recommended by Du-Mont for Use in Their Video Circuits. There are Many Variations of This Circuit.

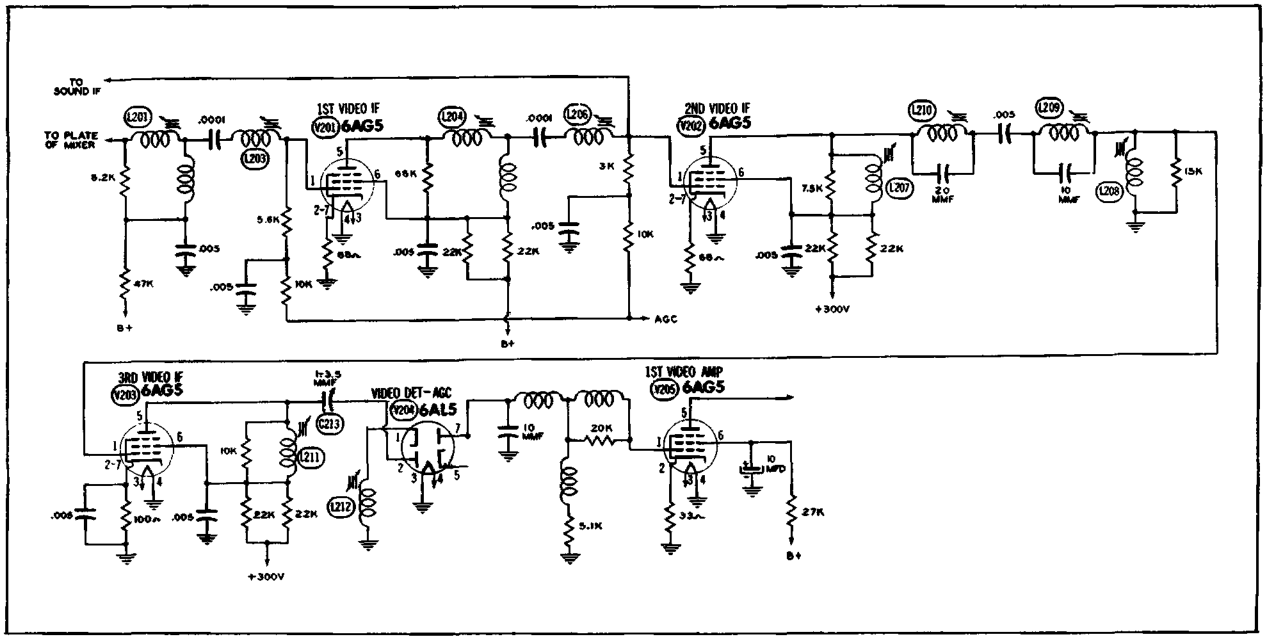



Figure 41. Video IF System of a DuMont Model RA-105 Television Receiver.

The video IF alignment of the Du Mont video IF system (shown in Figure 41) would be carried in the sequence of steps given in Table 1. Wherever a response curve is to be obtained, an illustration of that curve is given. This enables you to compare what you obtain with an average curve recommended by the manufacturer.

The alignment table commences with the adjustment of the tuning circuits contained between the plate of the final video IF tube (V203) and the video second detector (V204). Since the oscilloscope is placed beyond the detector, no special probe is needed.

The next step is the setting of the a.g.c. bias to -3.2 volts for the first two video IF amplifiers. The third video IF amplifier is not controlled and so it can be adjusted before the bias was set.

Steps 3 and 4 of Table 1 concern the adjustment of the sound trap (21.9 mc) and the adjacent channel sound trap (27.9 mc). Both are set, by means of an AM signal generator, for minimum output. To use the scope as an indicator, simply amplitude modulate the carrier with a 400-cycle audio note. After demodulation of the signal in the video second detector, the 400 cycle note would appear on the scope screen. The traps would be adjusted for minimum amplitude of the 400-cycle wave in each instance.

In step 5 the sweep and marker generators are moved to the grid of V202, the second video IF amplifier while the oscilloscope remains beyond the video detector. L207 and L208 are now adjusted to give the curve shown in Figure 42B. This curve represents the response of the video IF system from the grid of V202 to the video detector. In essence, then, it covers two video IF stages.

The first use of the special probe detector comes in step 6 where it is desired to view the response of the tuning network located between the plate of V201 and the grid of V202. The sweep and marker signal generators go to the grid of V201 while the probe touches the plate of V202. The probe output then connects to the oscilloscope. The recommended response pattern for the network between V201 and V202 is shown in Figure 42C. Any deviations that might be observed should be correctable by adjusting L204 and L206.

In step 7, an overall check is run on the video IF system from the grid of V201 to the video detector. This means that the sweep and marker signal generators remain at the grid of V201 while the scope is moved back beyond the video detector. The response curve for this section of the IF system is shown in Figure 42D.

In step 8 we return to the alignment and viewing of a single stage (between the plate of the mixer and the grid of V201) and again the probe detector is required. For the final step, the overall IF response is viewed.

The alignment of a complex coupled system is a rather lengthy procedure, as the foregoing description indicates. However, unless the effect of adjusting each of the tuned circuits on the overall response is known, it would be a difficult matter--if not an impossible one--for someone to attempt an overall alignment rather than the stage-by-stage procedure given. There are too many interlocking adjustments to be made.

## SWEEP ALIGNMENT OF THE RF STAGES

The front end section of a television receiver possesses a greater overall bandpass (6 mc) than either the video or sound IF stages that follow it. To attain this bandpass, the tuning circuits are heavily loaded by a combination of shunting resistors and the

| Step No. | To Adjust | Type of Input Signal Required | Connect Generator Leads Across | Connect Output Leads Across | Feed Output leads directly into Scope or into Scope via Probe Detector | Adjust to Conform to response Curve Shown In | Remarks |
|---|---|---|---|---|---|---|---|
| 1 | C213<br>L211<br>L212 | Wobb and unmodulated RF signal. | Pin 1 (grid) V203 and chassis | Pin 1 (grid) V205 and chassis | Direct | Figure 42A | C213 adjusts curve for double peak. L211 and L212 adjusts markers. L209 should be shorted to ground. |
| 2 | R251 AGC | | | | | | Set for 3.2V. |
| 3 | L210 | Mod. signal at 21.9 mc. | Pin 1 (grid) V201 and chassis | Pin 1 (grid) V205 and chassis | Direct | None | Adjust both for minimum output. |
| 4 | L209 | Mod. signal at 27.9 mc. | Pin 1 (grid) V201 and chassis | Pin 1 (grid) V205 and chassis | Direct | None | Adjust for minimum output. |
| 5 | L207<br>L208 | Wobb and unmodulated RF signal. | Pin 1 (grid) V202 and chassis | Pin 1 (grid) V205 and chassis | Direct | Fig. 42B | |
| 6 | L204<br>L206 | Wobb and unmodulated RF signal. | Pin 1 (grid) V201 and chassis | Pin 5 (plate) V202 and chassis | Probe Detector | Fig.42C | |
| 7 | To check 1st, 2nd and 3rd Video IF | Wobb and unmodulated RF signal. | Pin 1 (grid) V201 and chassis | Pin 1 (grid) V205 and chassis | Direct | Fig. 42D | If necessary readjust L204 and L206 |
| 8 | L201<br>L203 | Wobb and unmodulated RF signal. | Pin 1 (grid) of Mixer and chassis | Pin 5 (plate) V201 and chassis | Probe Detector | Fig. 42E | Grid of V202 should be grounded. |
| 9 | Check overall Video IF stages | Wobb and unmodulated RF signal | Pin 1 (grid) of Mixer and chassis | Pin 1 (grid) V205 and chassis | Direct | Fig. 42F | If necessary readjust L206 and L204 |

Table 1
A Video IF Alignment Chart for the Circuit Shown in Figure 41. (The Word Wobb Refers to a Wobbulator Which is Another Name for Sweep Generator.

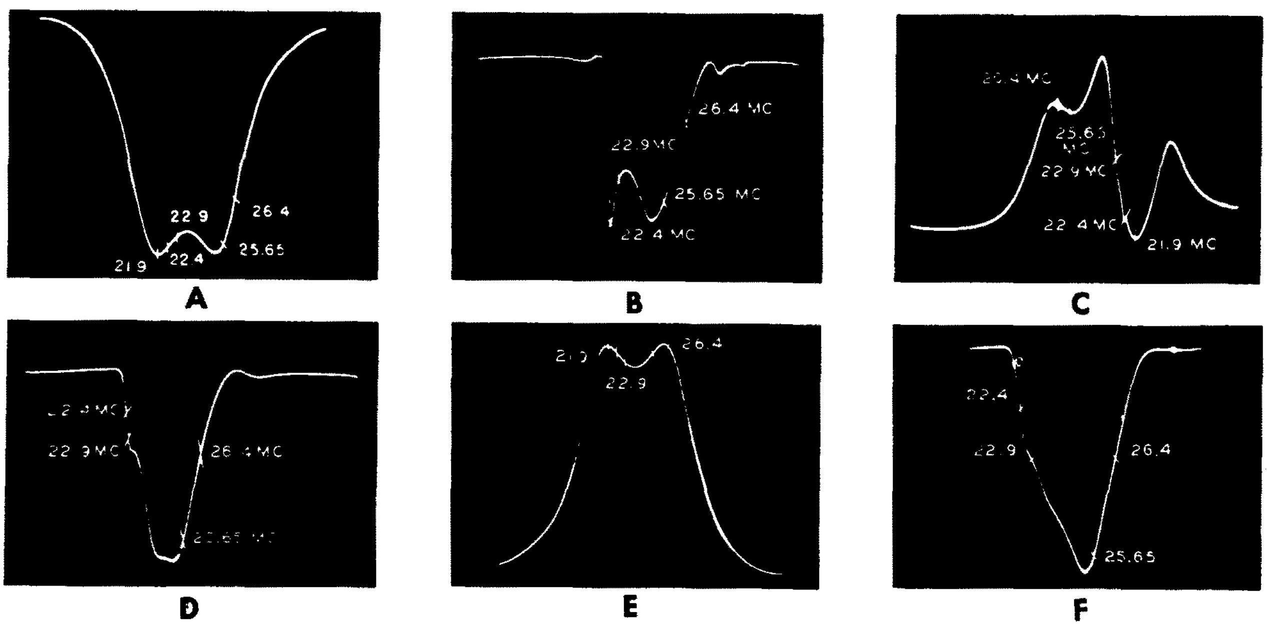



Figure 42. The Response Characteristics of the Tuned Circuits in the IF System of Figure 41.

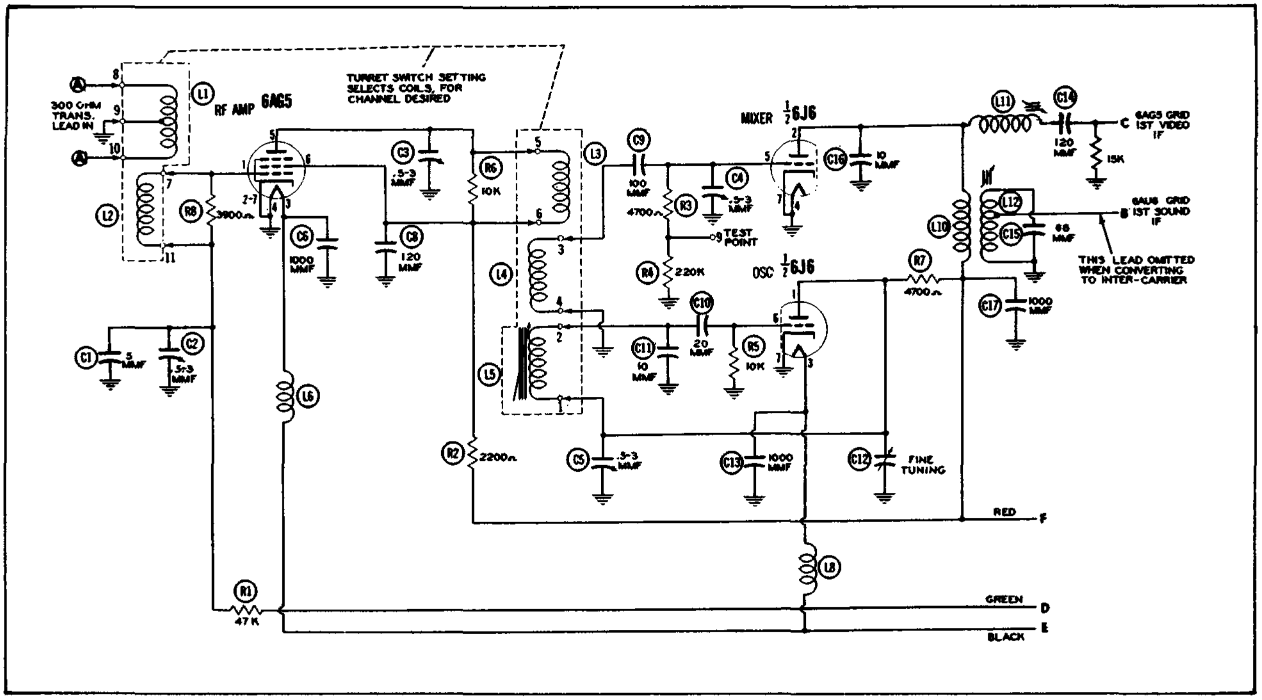


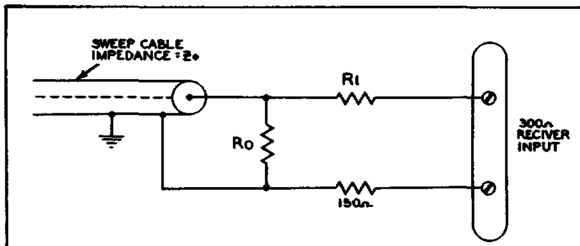

Figure 43. Circuit Diagram of the Standard Coil Tuner.

relatively low input impedance of vacuum tubes at high frequencies. There are a number of front-end tuners in use of which the most popular is the Standard Coil tuner shown in Figure 43. This is a turret type of tuner containing separate removable RF and oscillator coils for each of the twelve VHF television channels. There are only three adjustments for the RF coils on all channels (C2, C3, and C4 in Figure 43) and these are set so that the most uniform response is obtained on all local channels. The oscillator coils have a tuning slug for each channel, this being required since the oscillator generates a single frequency per channel and it is relatively easy for this frequency to drift too far to one side or the other.

Alignment of the RF stages carries with it a number of precautions that must be observed if the job is to be properly carried out. First, there is the matter of matching the sweep signal generator to the receiver input terminals. Most sweep generators have an unbalanced output with impedances between 50 ohms and 100 ohms. On the other hand, television receivers possess either a 75-ohm unbalanced input or a 300-ohm balanced input. The 75-ohm unbalanced receiver input can usually be connected directly to a generator whose output is similarly unbalanced and whose impedance lies between 50 to 100 ohms without causing appreciable mismatching. However, when you attempt to connect such a sweep generator directly to the input terminals of a 300-ohm balanced receiver, the response pattern will be sufficiently affected to result in misadjustment of the circuit trimmers. (The input tuning circuits of a television receiver contribute to the shape of the overall RF response curve and when the proper matching is not employed between instrument and receiver, the tuning curve of this input circuit is affected. This, in turn, alters the overall pattern.)

To match an unbalanced sweep generator to a 300-ohm balanced television receiver, an arrangement such as shown in Figure 44 would be employed. One series resistor has a fixed value of 150 ohms. The other series resistor has a value which depends upon the impedance of the sweep generator output; this is true also of the shunt resistor, Ro. The resistors should be of the non-inductive variety, preferably carbon or of composition construction. If the attenuation introduced by the resistors reduces the signal too much, a matching network using sections of a 150-ohm twin lead line may be formed. See Figure 45.

It is never good practice to align a strange tuner without having the manufacturer's alignment instructions on hand (unless this cannot be helped).




| $Z_0$ | $R_0$ | $R_1$ |
|---|---|---|
| 50Ω | 56Ω | 120Ω |
| 72Ω | 82Ω | 110Ω |
| 92Ω | 110Ω | 100Ω |

Figure 44. Resistive Network to Match Sweep Cable Impedance to Receiver Input.

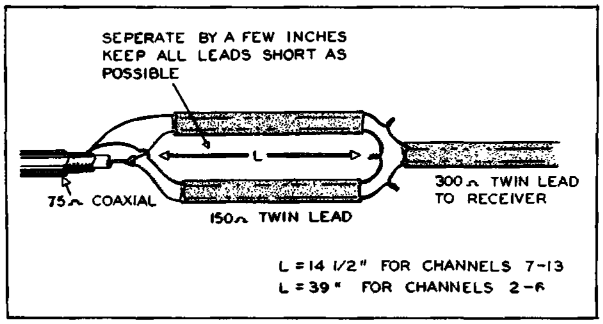



Figure 45. How to Match an Unbalanced 75 Ohm Coaxial Cable to a Balanced 300 Ohm Impedance. Courtesy of Sylvania Electric.

Some tuners, for example, must be removed from the receiver for the alignment. This is usually necessitated because only by removal can certain necessary adjustments be made. For other tuners, special jigs are required. Finally, the sequence in which the adjustments are made is frequently of great importance and this information, again, is available only from the manufacturer. Other factors which should be checked carefully in RF alignment is the value of bias recommended for the RF amplifier, whether or not the local receiver oscillator is to be cut-off, and whether the mixer plate tuning circuit is to be shorted out or otherwise modified to prevent it from affecting the RF response. RCA, in their Model KCS67-68 receiver, states that the tuner is to be aligned using zero a.g.c. bias and the output co-ax cable which connects the mixer plate to its tuned circuit is to be disconnected from this transformer and terminated by a 39-ohm resistor. Philco, in some models, uses -1.5 volts bias and shunts a 330-ohm resistor across the first IF coil to eliminate the absorption effect of this coil on the response curve. Pay particular attention to these pointers or you will not obtain the response curve indicated in the service manual.

Since the RF tuner in Figure 43 is used quite extensively, it may be instructive to examine its alignment procedure. The sweep generator is connected to the receiver input terminals through an appropriate matching network. The oscilloscope vertical input terminal connects to test point 9 through a 10,000-ohm resistor and the oscilloscope ground attaches to the receiver chassis.* The scope beam should be driven by a 60-cycle sine wave voltage obtained either from the sweep generator or from the oscilloscope if the latter contains a phase control. The marker signal, when it is needed after a response curve has been obtained, would be loosely coupled to the sweep generator, either by connection through a small (5-10 mmfd) condenser, or by laying the marker generator output cable across the resistive matching network.

The negative terminal of a 1.5-volt battery is clipped onto the a.g.c. wire (D in Figure 43) and the

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*The mixer, being essentially a detector, provides the oscilloscope with a demodulated voltage. Should the response pattern of the RF amplifier stage itself be desired, then an RF probe would be required.

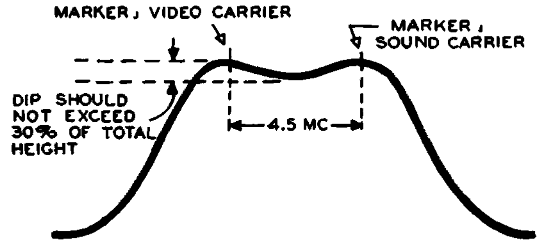


Figure 46. RF Response Curve.

positive terminal goes to the chassis. If it is found difficult to obtain a curve of sufficient amplitude, the battery can be removed and wire D simply grounded to the receiver chassis.

With the equipment in operation after an appropriate warm-up interval of 10 to 15 minutes, the receiver is tuned to channel 12. The response curve sought for this channel is shown in Figure 46. If the curve observed does not possess this form, adjust C2, C3, and C4. Adjusting C3 will generally shift the center of the response curve in relation to the video and sound carrier markers. C2 and C4 should be alternately adjusted for best gain with flat top appearance consistent with proper band width and correct marker location. Do not overly broaden the curves as this will result in a loss of sensitivity.

After the curve for channel 12 has been obtained, each of the other channels should be checked in turn. In each instance, the marker generator frequency would be changed to the corresponding video carrier frequency and sound carrier frequency for the particular channel being tested. None of the RF coils possess individual adjustments and ordinarily the C2, C3, and C4 settings established for channel 12 will provide satisfactory response curves on all channels. However, if reasonable alignment is not obtained on a particular channel, (a) check to see that coils have not been intermixed, or (b) try replacing the pair of coils for that particular channel, or (c) repeat the C2, C3, and C4 adjustments for the weak channel as a compromise adjustment to favor this particular channel. If a compromise adjustment is made, other channels operating in the locality should be checked to make certain that they have not been appreciably affected.

The foregoing outline represents the alignment procedure for one type of tuner and other units have other methods of approach. In all RF alignments, follow the manufacturer's instructions closely.

### HF OSCILLATOR ADJUSTMENT

In every television receiver, the high frequency oscillator operates, on any given channel, at one particular frequency. If the oscillator frequency should drift, the sound and video IF frequencies which are produced by beating the HF oscillator against the incoming signal will also change. With sufficient drifting, the set may be detuned to an extent which will produce a fuzzy picture and distorted (or no) sound.

To provide the viewer with some means of overcoming oscillator drift, nearly all television receivers possess a fine tuning control. When aligning the oscillator on each of the channels, this control is set (and left) at mid-position. This is done to insure that sufficient correction is available to the viewer should the oscillator drift in either direction.

There are a number of methods by which the oscillator can be accurately set on frequency for the channel or channels on which the set is used. Probably the simplest method, the one most widely practiced by servicemen, and, in a sense, the most accurate method, is the alignment of the oscillator using a received television signal. The set is left in the cabinet, but the dial plate (or whatever other obstruction is in the way) is removed in order that the oscillator tuning slug may be reached. The antenna is connected to the receiver and a local station is tuned in. The fine tuning control is set to mid-position. Then the alignment screwdriver (non-metallic, preferably) is inserted into the oscillator slug and the slug position adjusted for best picture and/or loudest sound depending upon the receiver. In Intercarrier sets, the slug adjustment is made with an eye on the picture rather than the sound because it will normally be found that where the sound is loudest does not necessarily represent the optimum operating point so far as the picture is concerned.

On the other hand, in conventionally operated receivers, the oscillator slug is adjusted for loudest sound and, if the set is operating normally, the picture will be best here, too. It is important that this difference between systems be kept in mind.

With the TV signal method, the set is adjusted on each channel where a signal can be received. The unused channels are disregarded.

A second method of alignment can be employed in those receivers where the correct HF oscillator frequency for each channel is known. This information may be obtained directly from the manufacturer's service notes or the serviceman can compute the proper value by adding the video IF carrier frequency to the channel's video RF carrier frequency. Thus, for channel 2, the video carrier RF value is 55.25 mc and the video IF value is 25.75 mc. Added together, we obtain the oscillator frequency of 81.00 mc. This procedure can be followed on all low band channels (2-6) because all TV receivers have the HF oscillator working above the signal frequency in this portion of the TV spectrum.

For channels 7-13, the HF oscillator usually is placed above the incoming signal, but it need not be and some manufacturers place it below the signal frequency. Where the oscillator frequency is below, we would subtract the video IF value from the video RF figure, rather than add the two.

Once the oscillator frequency for each channel is known, we would proceed as follows: A carefully calibrated AM signal generator is connected to the input terminals of the receiver (matching network not required) and set to the oscillator frequency for the channel to which the set is tuned. Let us say this is 81 mc for channel 2. A wire is then connected from the mixer, point 9 in Figure 43, to grid of the first audio amplifier. The FM detector tube is removed to prevent any other signal from reaching the audio system. The oscillator fine tuning control is set to mid-position and then the tuning slug of the oscillator coil is carefully adjusted until a zero beat whistle is heard in the receiver speaker. This indicates that the oscillator signal beats with the generator signal in the mixer and the resultant difference frequency is transferred to the audio system where it can be heard. At zero beat, both frequencies are equal. If desired, an oscilloscope could be connected to point 9 and the zero beat observed visually.

A third method of oscillator adjustment is to set the AM signal generator to the sound RF frequency itself (59.75 mc for channel 2, for example) rather than to the HF oscillator frequency as in the previous method. A zero center VTVM is then connected to the FM detector; for the ratio detector, it would be point A (and ground), Figure 2 and for a Foster-Seeley discriminator, it would be point A (and ground), Figure 1. Then, with the set and equipment in operation, the oscillator slug would be adjusted for zero reading on the VTVM. Slight rotation of the slug in one direction will produce a negative reading; slight rotation in the opposite direction will produce a positive reading.

Be careful that the oscillator slug is not rotated too far in any one direction because it is possible to obtain a false zero reading. In the correct position, the action just described will occur. In a false zero position, you will not be able to go from one polarity to the other, with zero in between.

A fourth method of oscillator alignment which is sometimes recommended by manufacturers consists in connecting a sweep generator to the input terminals of the receiver through an appropriate matching network. The output of a marker generator is then loosely coupled to the matching network as previously described. An oscilloscope is connected through a 10,000-ohm isolating resistor to the video second detector load resistor. Bias for the a.g.c. network would be set at -3 volts unless otherwise recommended by the manufacturer.

With the set and test equipment in operation, an overall RF and IF response curve, such as shown in Figure 47, should be obtained. Note that this response curve is actually the same as the response curve of the video IF system alone. Now, with a non-metallic screwdriver, adjust the oscillator slug (of the channel to which the receiver is tuned) until the sound marker pip falls into the hollow provided for it, as shown in Figure 47. In order to see the marker clearly, it may be necessary to advance the vertical gain control on the oscilloscope in order to blow up the sound trap portion of the response curve.

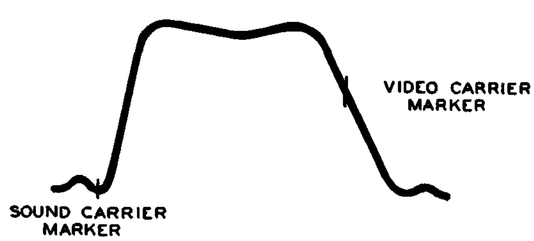


Figure 47. Overall RF and IF Response Curve of a Television Receiver Such as the One Shown in Figure 24.

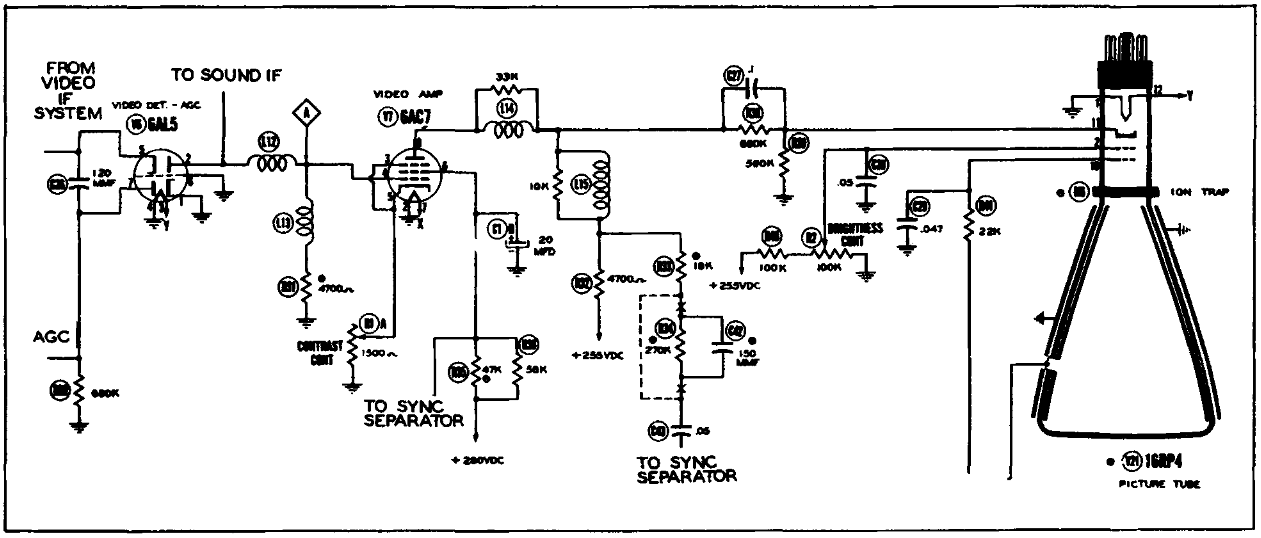


Figure 48. A One-Stage Video Amplifier System.

After the sound marker has been properly positioned, change the marker generator frequency to the video RF carrier value for that channel and note whether the marker pip appears on the response curve in its proper place. (This is also indicated in Figure 47.)

A similar procedure can be followed for each channel. In each instance the sweep generator frequency and marker signal frequencies would be changed to suit the channel.

A similar procedure using the output of the FM detector (i.e., an S-curve) instead of the video IF system could be followed. The sound marker pip now would appear at the zero or center point of the S curve when the oscillator frequency is properly set. The reader will recognize that we are now doing visually exactly what was done previously using an AM generator and a VTVM.

Aside from alignment of the oscillator, this last method reveals that whenever an overall response test is run, the shape of the curve seen on the screen will be that of the last system through which the signal has passed.* If the scope is placed at the video second detector (with the sweep generator at the receiver input terminals), then the curve viewed on the scope screen will be that of the video IF system. If the scope is placed at the sound FM detector, then an S curve will be seen.

In employing this fourth method care must be taken to see that the sound and video IF systems are correctly aligned before any oscillator adjustments are made. Also see that the oscillator tube shield plus all tuner shields are in place. Because of the high frequencies dealt with, any slight circuit disturbance, in the form of stray capacity or inductance, will alter the oscillator frequency. Another item of importance is the dial calibration of the marker generator. This must be accurate, otherwise the oscillator will be set incorrectly.

## RESPONSE CHECKING OF VIDEO AMPLIFIERS

Most servicemen know that the tuned circuits in the RF and IF stages of a television receiver lend themselves readily to sweep signal alignment. Not so well known is the fact that the overall response of the video amplifiers can also be developed on a scope screen. The video amplifiers (as distinguished from the video IF amplifiers) are those stages which follow the video second detector. There may be one stage, as in Figure 48, or two, as in Figure 49. There is never less than one and, in commercial sets, seldom more than two. The response of this stage (or stages) ordinarily extends from 30 cycles up to 3 or 4 mc. The low frequency response is upheld by special compensating networks, such as of C4B and R51 in Figure 49. The extent of the high-frequency response is determined by the values of the load resistors (R50 and R55 of Figure 49) and the series and shunt peaking coils. Should any of these components change value or otherwise become defective, the effect on the response would make itself evident in the quality of the pictures produced on the screen. The entire video signal must pass through the video amplifier stages before it reaches the picture tube and quality degradation in this section of the receiver is just as effective as poor alignment in any of the IF or RF stages.

The wide bandpass of the video amplifiers precludes point-to-point frequency checking just as it did in the IF and RF stages. To perform a sweep alignment, using equipment that might ordinarily be found in the average TV service shop, we would take an IF sweep generator and connect its output across the input to the video second detector. This is shown in Figure 50. A 220-ohm resistor would have to be shunted across L16 in order that all frequencies produced by the sweep generator affect the video detector uniformly. The sweep generator would be set to swing over the IF frequency range of this receiver (21.25 to 25.75 mc, here).

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*There are some reservations to this statement which do not apply to normally operating TV receivers.

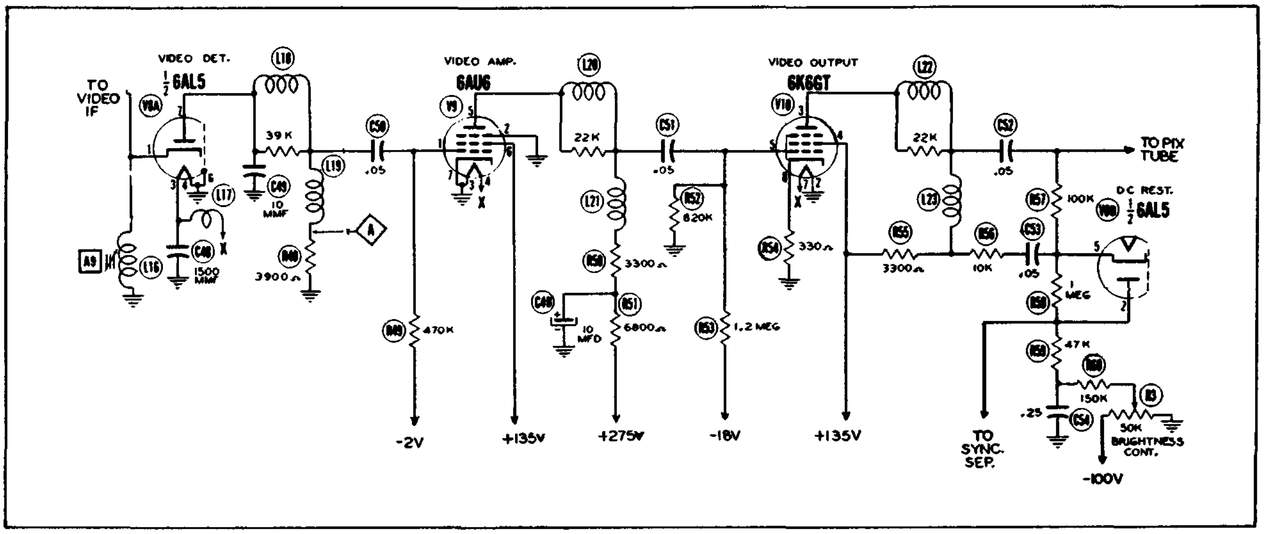


Figure 49. A Two-Stage Video Amplifier System.

The next step would be to connect a marker signal generator to the same point as the sweep generator, possibly through a 100 mmf capacitor. The marker generator would be set at exactly the video IF carrier value, in this instance 25.75 mc. Now, with both these signals feeding into the detector, here is what happens. When the sweep generator is at 25.75 mc, the zero beat between it and the marker generator produces no output (actually only a DC voltage). As the sweep generator frequency swings away from 25.75 mc, the beating with the marker signal continues and so difference (and sum) frequencies will continue

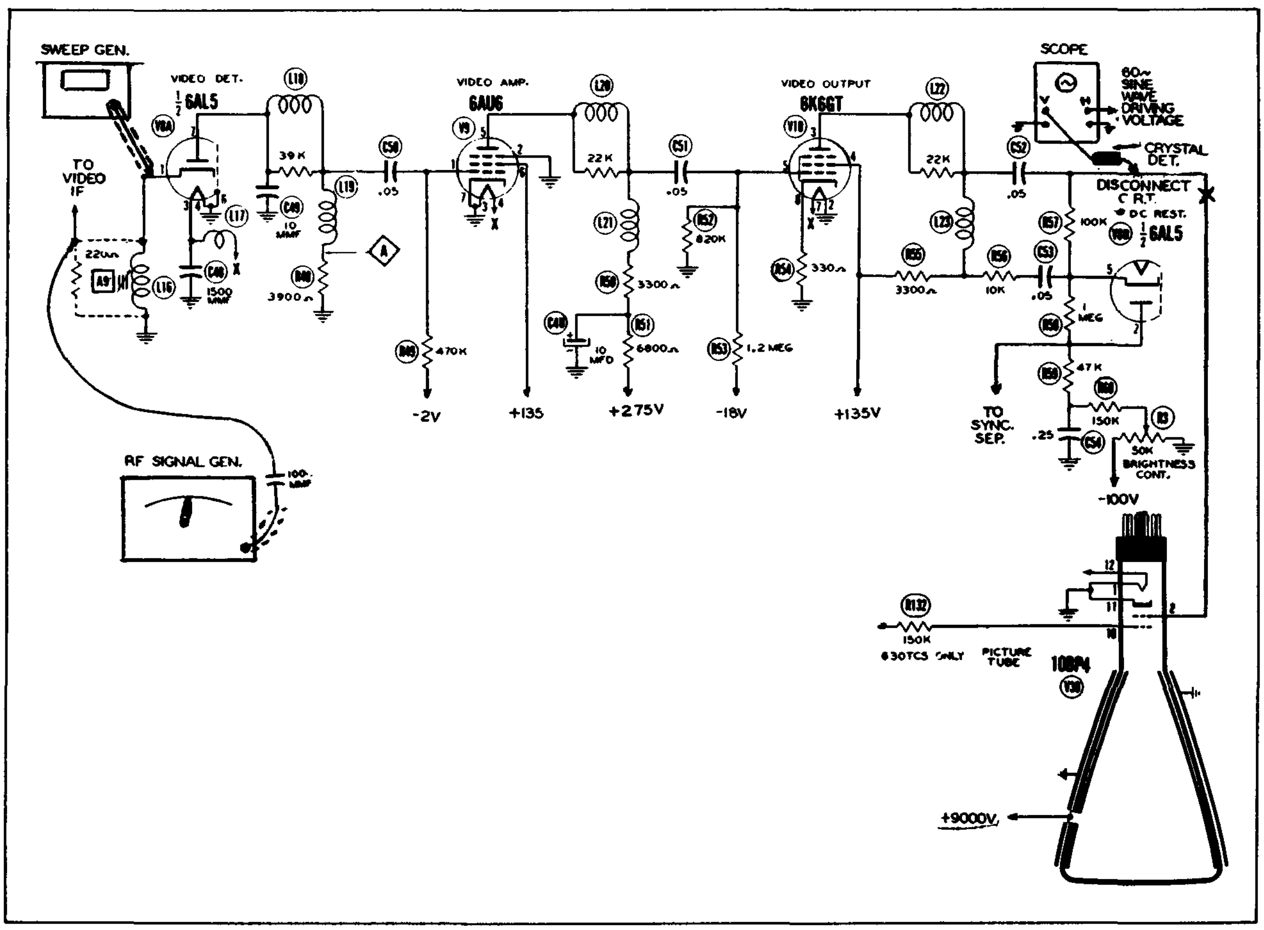


Figure 50. How the Equipment is Set Up to Obtain Video Amplifier Response Curve.

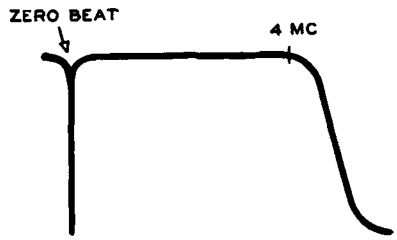


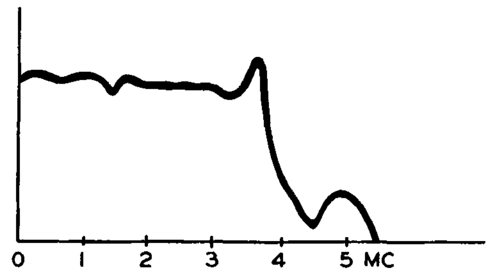

Figure 51. An Ideal 4 mc Video Amplifier Response Pattern.

to be generated in the video detector. At 24.75 mc, the difference frequency is 1 mc; at 23.75 mc, it is 2 mc, etc. With an overall 5 mc sweep (say from 20.75 mc to 25.75 mc), a continuously sweeping difference frequency signal from 0 to 5 mc would appear at the output of the video detector and proceed through the video amplifier stages. At the picture tube some of these frequencies would be stronger than others because they received more amplification. If we now take a crystal detector and rectify this amplitude varying (or modulated) signal and feed the amplitude variations to an oscilloscope, we will develop the response characteristic of the video system between 0 and 5 mc.

In order not to shunt too much capacitance across the output of the video amplifier system, the lead to the picture tube would be removed. Also, the scanning beam in the oscilloscope would be driven by the 60-cycle sine wave voltage obtained from the sweep generator. (If the oscilloscope has its own provision for supplying this voltage, this may be used instead.)

With the equipment set up and operating, and the phase control properly set for a single trace, you may possibly obtain a pattern such as shown in Figure 51. The zero beat point (representing zero frequency) is indicated by the marker pip hash. This pip may be in the center of the pattern or off to one side. When it is in the center, it signifies that the frequency in the sweep generator is swinging above and below the marker frequency which, for our present illustration, is 25.75 mc. To move the zero beat indication over to the left, lower the sweep generator frequency. If this is done carefully and the sweep width is set to cover a range of 5 mc, the zero frequency marker pip will be stationed at the extreme left-hand side of the screen and the shape of the pattern from this point to the right will represent the response characteristic of the video amplifier from 0 to 5 mc.

Just what type of curve will be obtained will depend upon how well the video system was designed. In very few instances will it look like the curve shown in Figure 51, which is an ideal curve and employed here mainly for comparative and instructional purposes. More likely the curve you obtain will look like one of those shown in Figure 52. These were taken from various commercial receivers.



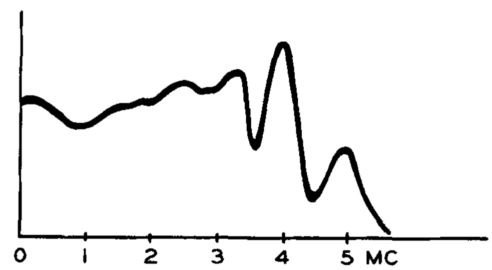
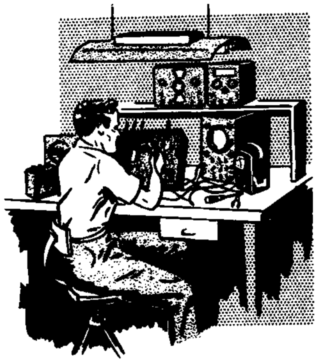




Figure 52. The Video Amplifier Response Patterns of Several Commercial Receivers.

Once the curve is obtained, your next step is to check it at various points in order to determine at what frequencies the curve rises and where it starts to fall off. For this a variable marker pip is required and such a pip can be obtained from any AM signal generator operating between 500 kc and 5 mc. Couple the output of this generator very lightly into the video amplifier circuit (by one of the methods outlined previously) so that the response curve is not disturbed. Then by changing the frequency of the marker pip, we can inspect the entire response curve, noting at what point it rises and where it dips.

By means of the video amplifier response curve, the serviceman can study the effect that various components have on it. Thus, for example, by increasing the plate load resistor (R50 and R55 in Figure 49), the curves amplitude will be found to increase but, at the same time, the frequency bandpass will become narrower. A sharp rise in the curve near the high frequency end can frequently be traced to an open resistor shunting one of the peaking coils. Removal of the low frequency compensating networks will adversely affect the low frequency response, etc. A serviceman can gain a liberal education in television receiver operation by systematically changing the value of different components in a system and noting the effect on the response curve. While this may be somewhat beyond the province of everyday service work, it will provide the technician with a deeper and clearer insight into receiver circuit behavior and this knowledge can be of great value in television receiver servicing, especially when the cause of a certain defect appears obscure.



# section seven

## Use of Test Instruments in TV Servicing

USE OF TEST INSTRUMENTS IN TV SERVICING

The successful servicing of a television receiver can be summed up in a single phrase: The proper interpretation of what the receiver and your instruments tell you. Learn to use your instruments properly and you have won half the battle; the other half depends upon how familiar you are with the circuit operation of the TV receiver you are working on.

The general approach to the localization of a defect starts first with an examination of the symptoms exhibited by the receiver on its screen. You look at the screen and try to determine in what section of the receiver the trouble exists. You should also try the various operating controls to see what they can tell you; you might visually inspect the chassis, both top and bottom, for any obvious defects such as smoking, charred components, unlit (or cold) tubes, etc.

Up to this point you have not used an instrument; you are simply trying to learn as much as you can about the location of the receiver's trouble from the receiver itself. These preliminary steps should be considered carefully because the conclusions which they lead to will govern the trend of your servicing procedure on this particular receiver. If you start off on the wrong track, you may not discover the error for many valuable hours.

From this preliminary examination your next step is to concentrate on the particular section of the receiver where you believe the trouble exists and to try to narrow the field down still more. As a start, tubes should be checked, either by direct test in a tube checker or by substitution. If these prove O.K., the next step would generally be to check either the waveforms or to make voltage and resistance measurements in that circuit (or section). Thus, normally, it is not until this third step that any equipment is brought to bear upon the problem.

Let us suppose that you wish to inspect circuit waveforms. The instrument to use would be an oscilloscope. The scope power is turned on and the various controls adjusted until a straight line becomes visible across the screen. This procedure was outlined in Section 4. For waveform checking, the oscilloscope uses its own saw-tooth deflection voltage to drive the beam across the screen. The saw-tooth frequency that is chosen will depend upon the circuit in which the instrument is used. In the horizontal sweep system, the frequency of the alternating voltages is 15,750 cycles and the oscilloscope deflection frequency could be set at this value. The result, on the scope screen, would be one cycle of the wave. A more convenient approach is to adjust the scope sweep rate to one half the frequency of the wave to be observed. For the horizontal system, this would mean 7875 cycles. With this rate, two cycles of the wave will appear on the screen, insuring that every section of one complete cycle is observable.

In the vertical sweep system, the basic rate is 60 cycles per second and an oscilloscope sweeping rate of 30 cycles is recommended. In the sync separator stages, both types of pulses are present and the oscilloscope sweeping rate will depend upon which type of pulse is to be viewed. In the video amplifiers the same situation prevails.

With the oscilloscope in operation, its ground terminal is connected to the chassis of the television receiver. The lead or prod from the vertical input terminal then acts as a probe. In the horizontal sweep system of Figure 1, we might start at the control grid of the 6BG6-G horizontal output amplifier and if the circuit is working properly up to this point, the waveform shown in Figure 2 would be obtained. In the cathode circuit, pin 3, the wave should appear as shown in Figure 3.

The preliminary step in waveform checking is a comparison of the shape of the wave you obtain with that shown by the manufacturer. Do the two correspond? If they do, then it is customary to move forward into the following circuit and determine if the proper wave is being produced here. If the correct wave shape is not obtained in the first check, then additional checking in prior circuits would be indicated. In the circuit of Figure 1, this would mean checking the waveforms at the plate and grid of the 6SN7 horizontal oscillator.

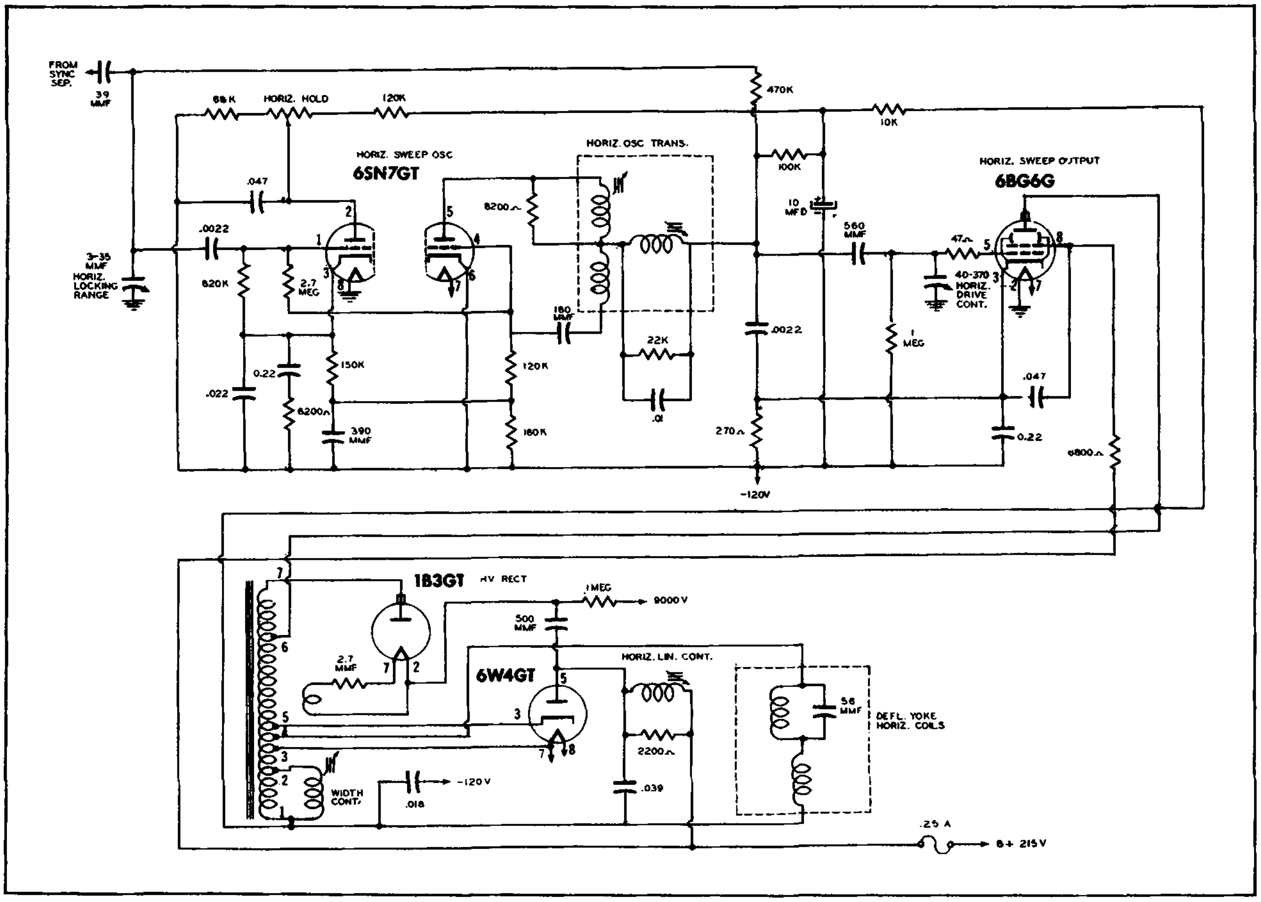



Figure 1. Horizontal Sweep System.

The second aspect of the wave which is important is its peak-to-peak amplitude. This information can be obtained either from the manufacturer's service manual or from another receiver of the same model which is in good operating condition. In addition, similar sweep systems are employed in a number of different sets and in the absence of specific information, the data obtained from one make set may be used to judge the results in another, similar set. This will do when all other sources of information fail, but specific data on the particular model being worked on should be sought first.

The problem of when to measure the peak-to-peak amplitude of a wave is one that often plagues the beginner. In the vertical or horizontal sweep system, it is generally not necessary to check the wave amplitude except at the grid of the respective output tube. At all other points the serviceman will find that checking wave shape is enough to determine whether

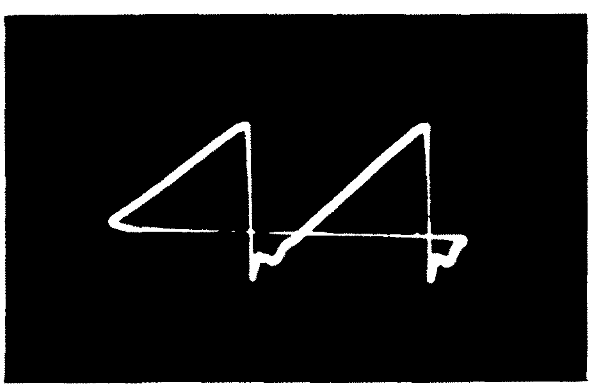


Figure 2. The Waveform Normally Present at the Grid of the Horizontal Output Amplifier in Figure 1.

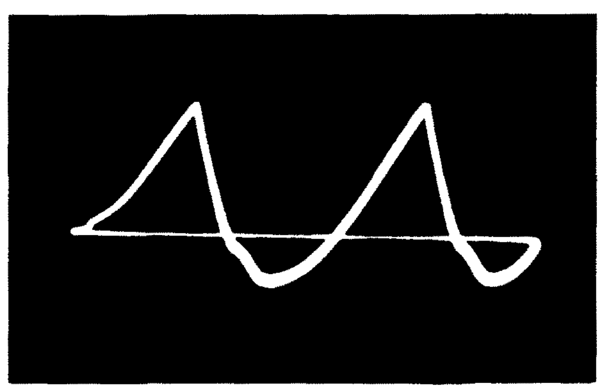


Figure 3. The Cathode Waveform of the Horizontal Output Amplifier in Figure 1.

or not a circuit is operating correctly. Of course, there are exceptions to this rule, but they will not occur often enough to warrant the peak-to-peak measurement in all instances.

One of the functions of the horizontal sweep system in most television receivers is to produce the high accelerating voltage required by the cathode-ray tube. These voltages are developed during the beam retrace interval when the forward driving voltage is suddenly cut-off. The full high voltage surge appears across the primary of the horizontal output transformer; specifically, in the system shown in Figure 1, the high voltage pulse would be obtained at terminal No. 7 of the output transformer (terminal No. 1 could be considered as the low or ground end of this winding). Since the voltage surge attains a value of 9,000 volts or more, connecting the scope probe to this point would undoubtedly result in damage to the vertical input stage as well as possible injury to the person holding the probe. It is also important that the probe be kept away from the plate of the 6BG6-G output tube since the pulse here is of the order of 6,000 volts or more and this is too high to be taken directly by the oscilloscope.

It is usually not necessary to check the waveforms at either of these two points but should this be desired, it could be accomplished by constructing the capacity voltage divider shown in Figure 4, placing it between the plate of the 6BG6-G and the chassis, and then connecting the oscilloscope probe to point B. Each of the capacitors should be capable of withstanding at least 5,000 volts. The ratio of the capacitances is 100 to 1 and the voltages that appear across each unit will be inversely proportional to its capacitance. That means that $C_1$ will get 100 times as much voltage as $C_2$; or, in other words, what appears across $C_2$ will be 1/100 that across $C_1$ and 1/101 of the total voltage.

In moving the oscilloscope about from one circuit to another, careful attention should be given to its vertical gain control. If the gain setting is high and the applied voltage strong, overloading in the vertical amplifier system will result in a distorted wave appearing on the scope screen. On the other

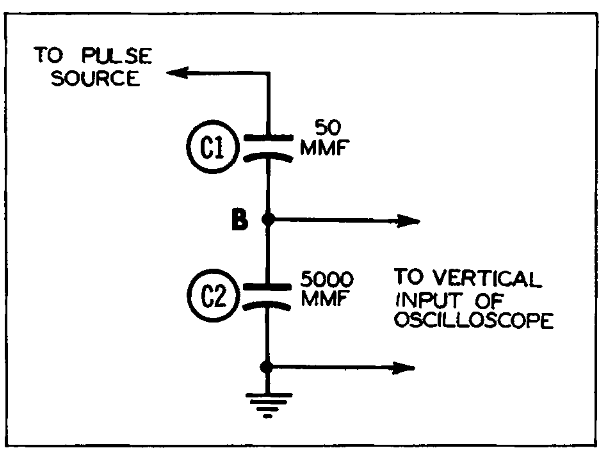



Figure 4. A Capacity Voltage Divider which Can Be Used to Observe the Pulse Voltages at the Plate of the Horizontal Output Amplifier.

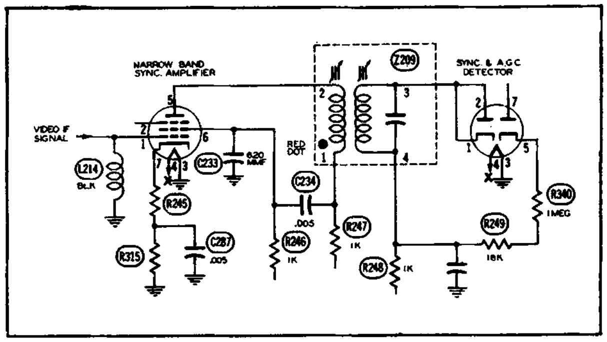


Figure 5. The Narrow-Band Sync Amplifier Used in many DuMont Receivers.

hand, if the gain control setting is too low and the applied voltage is weak, you may get so little deflection as to arrive at the erroneous conclusion that there is no signal present at all.

Another factor that may cause wave distortion is spurious signal pickup by unshielded leads. This is especially bothersome in the vertical sweep system where the 60-cycle frequency of the vertical deflection waves is the same as that of the power supplied to the tube filaments.

Reduction or elimination of spurious signal pickup can be achieved by the use of a shielded cable such as RG-59U coax. The center lead is used for probing and the outer conductor connects, at one end, to the ground terminal of the oscilloscope, and, at the other end, to the receiver chassis, The latter connection should be made as close as possible to the point where the probe makes contact with the receiver circuitry.

The one disadvantage to the use of a shielded lead is the additional capacitance it introduces. In resonant circuits or in low capacity circuits, the addition of this capacity can alter circuit operation sufficiently to produce a wave which does not possess the same shape as the wave you are seeking. If you are not aware of what is happening, you can readily conclude that the circuit is not operating properly when, in fact, it is.

There is one example which illustrates this point rather effectively. Many Du Mont television receivers employ a special narrow-band sync amplifier. This circuit, shown in part in Figure 5, receives a portion of the video IF signal, amplifies it, and then passes it on to a separate detector where it is rectified. The transformer (Z209) in this stage is sharply tuned to the video IF carrier, 26.4 mc and the frequencies immediately surrounding it. The purpose of this arrangement is to pass only those frequencies necessary to reproduce the sync pulses, but to exclude all the higher video frequencies as well as the noise pulses. In this way, better noise-free synchronization is sought.

For the circuit to function properly, transformer Z209 must be correctly tuned, otherwise the set loses sync. Circuit adjustment is determined by using a crystal detector probe to pick-up the signal present

Figure 6. Normal Video Waveform Seen in Narrow-Band Circuit. Courtesy DuMont Laboratories, Inc.

at the transformer. The waveform which should be observed on the scope screen is shown in Figure 6. What it becomes when the crystal probe loads down the circuit too much is clearly evident in Figure 7. A lot of valuable servicing time could be lost looking for a non-existent trouble.

The oscilloscope will be one of your most valuable TV receiver servicing tools provided (1) that you know how to operate the instrument and (2) that you are capable of interpreting the patterns you see on its screen. The previous sections of this book

Figure 7. Waveform at Narrow-Band Sync Transformer when Distorted by Probe Loading. Courtesy DuMont Laboratories, Inc.

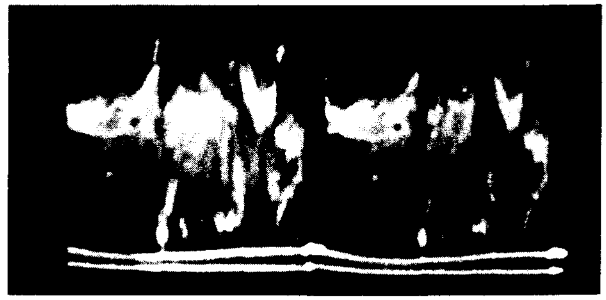


Figure 8. A Composite Video Signal Exhibiting Sync Pulse Compression.

were designed to help you master oscilloscope operation. To successfully interpret patterns would require a book on television servicing and those readers who have not had this training might refer to the author's "Television and FM Receiver Servicing." A few representative examples will be given here but these will do no more than scratch the surface of this subject.

A receiver was recently brought into the shop for repair with the complaint that the picture lost vertical sync easily. The picture held in horizontally although the horizontal hold control was found to possess less hold-in range than it normally did.

From these symptoms it was decided to check first the sync separator stages and then the video amplifiers to determine what was happening to the sync pulses. Following this procedure, it was found that the signal at the plate of the first video amplifier appeared as shown in Figure 8. Note that the sync pulses are compressed (they should occupy about 25% of the total signal amplitude), indicating that at some prior point a tube was either being overloaded or one or more of the operating voltages were incorrect. In the present instance it was found that the first video amplifier bias was too high.

Note that all the oscilloscope can do is give you a picture of the conditions existing at that point in the circuit; it can do no more than this. It is your job to interpret what the pattern means.

Another illustration is the one shown in Figure 9. Here the signal has mixed in with it a large amount

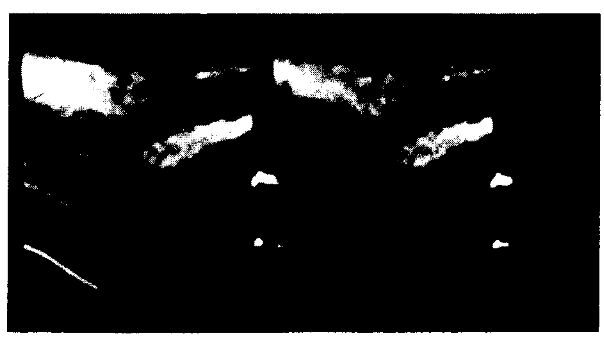


Figure 9. A Video Signal Containing 60-Cycle AC.

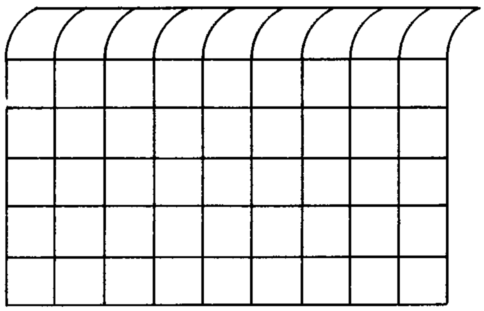


Figure 10. Horizontal Pull at Top of Picture.

of 60-cycle hum. This voltage, if it is not caused by stray pickup, usually arises from a filament to cathode leakage in one of the RF, IF or video amplifier tubes. To find the faulty tube, substitution on a one-at-a-time basis is the accepted procedure. Occasionally 60-cycle voltage somehow gets into the a.g.c. network and this, too, can produce the pattern of Figure 9.

While the primary application of the oscilloscope in television servicing is in waveform checking, there are other valuable uses to which this instrument can be put.

Thus, for example, the following excerpt* from a trade publication indicates how an oscilloscope can be employed to service a TV set with pull at top of the picture.

The set is brought into the shop with the complaint that the upper portion of the picture is pulled to the right. Most of the picture is good but very little pull at the top of a picture is annoying and will always create a customer for the service technician.

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*"Servicing a TV Set with Pull at Top of Picture" by H. Allen White, December, 1951 issue of Sylvania News.

In order to have the condition shown in Figure 10, the horizontal deflecting voltage which is scanning the top line must be off by 5 microseconds, the second line is off by a little less than 5 microseconds, and finally, after about 60 horizontal lines have been scanned, the horizontal oscillator is functioning properly and all horizontal lines in the rest of the picture are on time. Assume the scope is connected to the grid of the sweep amplifier, point "B" in Figure 11. One could expect to see a waveform similar to that shown. Usually, the scope is used with internal synchronization, so that the signal seen on the screen is the one which triggers the sweep oscillator inside the scope and gives a single trace on the screen. Now, if the signal at "B" is varying in time the scope will tend to keep in step with it and a single trace is still seen on the screen. The pattern would look like Figure 12. If the sweep frequency of the scope would be made constant with no variation, then the sweep signal causing the top line to trace from left to right would be 5 microseconds off compared with those farther down which are in step, and the pattern would appear as shown in Figure 13. The second line would be just a little less than 5 microseconds off, and the sweep signal on the scope would be just a little to the right of that shown as "top line". Lines 1 through 60 would cause the entire area designated "lines 1 to 60" in Figure 13 to be solidly filled in, giving the appearance of a broadened scope trace.

It should prove interesting to use a scope this way, and actually, it is easy to do. It is merely necessary to make the scope trigger every time the station sends a horizontal sync pulse, keeping in step with the transmitting station--not in step with the signal being fed to the vertical deflection plates of the scope. Most scopes have an "External Sync Input" which is exactly what is needed here. A signal is available, referring to Figure 11, at point "A". Here the horizontal sync pulses have been amplified, clipped and sharpened, and they are exactly in step with the transmitting station. By connecting a lead from point "A" to the EXT SYNC IN connection of the scope and

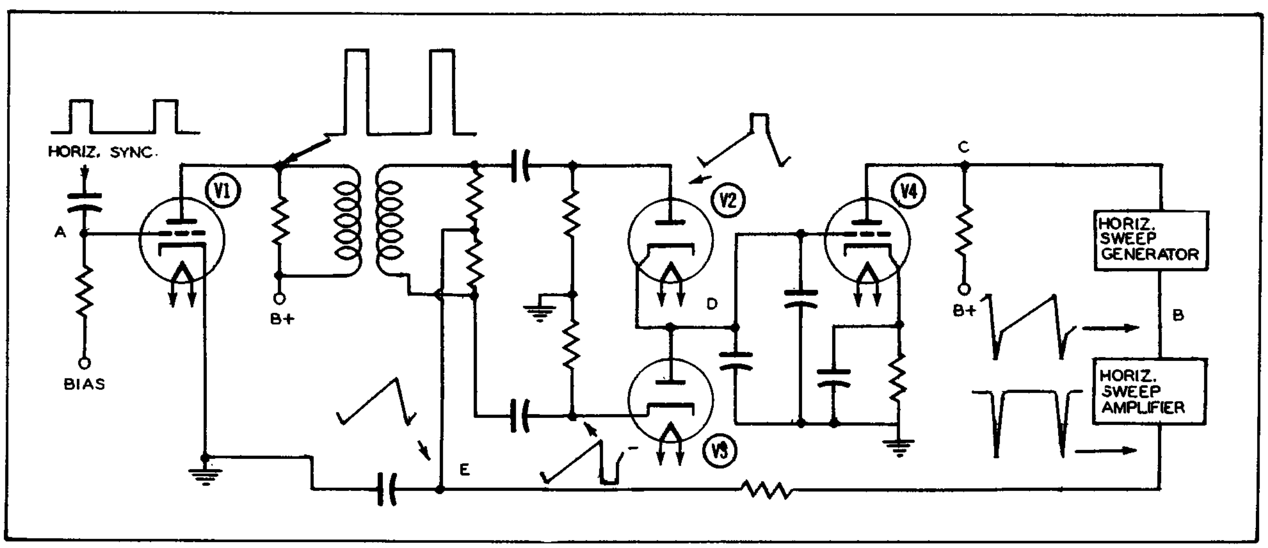


Figure 11.

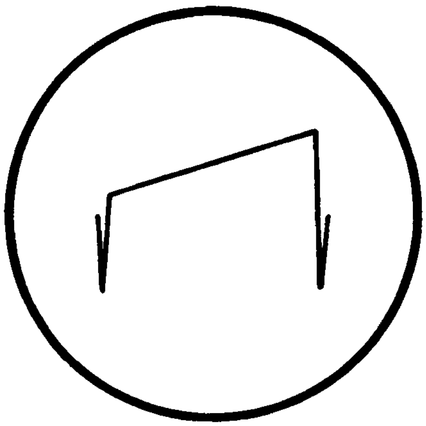

Figure 12. Pulled Pattern Using Int. Sync.

switching the sync function switch to EXT SYNC, then the sweep of the scope will be controlled by the pulses at "A". This means, the trace on the scope will start at the correct time as determined by the transmitted signal, and not 5 microseconds off as determined by the signal applied to the vertical amplifier in the scope. This application of the scope is interesting, but more important, it can be very useful.

Our basic trouble is the fact that the horizontal sweep at the top of the picture is 5 microseconds out of step with the sync pulses, and, by using external synchronization, we are able to see this. The trouble may be that the signal on the grid of the sweep amplifier is also out of step. If so, it will appear as shown in Figure 13. This pull may be seen in turn on the grids and plates of the multivibrator sweep generator. If so, the trace here too would be broadened 5 microseconds. Finally, at point "C", there should be no AC signal of any kind, but DC only. Likewise, at point "D", there should be no AC, but DC only. Hence, the scope may be used to trace the source of any AC which could be causing trouble. The discriminator circuit shown (V2, V3) is balanced to ground for both AC and DC. The scope connected to "D" would show any AC which could be causing trouble, and a voltmeter would indicate DC. Presence of AC could be caused by unbalance in the resistor divider networks across the diodes, and this unbalance would also cause some DC bias at point "D". The pulled picture must be caused by some 60-cycle AC since the trouble appears at the top of the picture every 1/60th of a second. The signal is not coming from the power line frequency, or the pulled portion would occasionally appear in other parts of the picture.

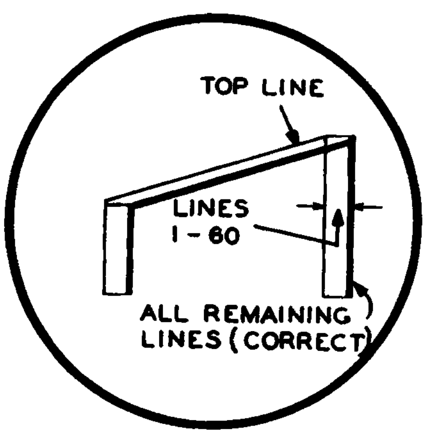


Figure 13. Pulled Pattern Using Ext. Sync.

In order for the horizontal oscillator to get out of step at the top of the picture, there are two possibilities to consider:

(1) The vertical scanning generator with its heavy current surges could drain the power supply sufficiently to cause voltage to change on the DC amplifier plate, or on the plates of the multivibrator oscillator; or,

(2) Some of the vertical sync pulse is appearing on the grid of the DC amplifier at point "D".

The following procedure is suggested to determine which of these two faults is causing the pulled picture.

First, turn down the brightness and disable the vertical scanning amplifier. Check with the scope at point "B", still using external sync as described above, and if the pulling has disappeared, then there is feedback from vertical to horizontal by way of the yoke or through the power supply. The discriminator circuit is working properly if the pull has disappeared. Reactivate the vertical scanning output circuit. Using the scope, look at the signal at point "E". A clean trace should be seen here. A trace varying in amplitude indicates that some vertical is feeding into the horizontal by way of the deflection yoke windings. This should still cause no trouble at "D" if all components of the discriminator circuit are balanced. Next, check with the scope for vertical signals in the B+ supplying the DC amplifier and the horizontal sweep generator. Trouble here would indicate deterioration of some power supply electrolytic capacitors as a most likely source of trouble.

In still another servicing job it was found that the picture appeared very weak and it was difficult to hold it in sync. At the input to the first video amplifier the video signal, as viewed on a scope screen, appeared entirely normal. At the plate, the signal was still evident but with greatly reduced amplitude. Since the output of an amplifier should be stronger than the input, the trouble existed in this stage. A subsequent resistance check revealed that the plate load resistor had decreased from a value of 2200 ohms to about 600 ohms.

The application of an oscilloscope to measure stage gain is one that is frequently overlooked. In the case history just given, a previous voltage check at the plate of the first video amplifier had revealed a slight increase in voltage but because of the low value of the plate load resistor originally, this change was not considered significant. It was only when the oscilloscope revealed the decrease in output voltage over input voltage, that the reduction in load resistor value was brought to light. You will find, as a general rule, that in low impedance circuits, voltage changes arising from resistance increases or decreases are not as marked as they are in high impedance circuits and hence can be readily overlooked.

## VTVM APPLICATIONS

The vacuum-tube voltmeter is employed in television receiver servicing principally for voltage and resistance measurements. As pointed out previously there are other measurements that the VTVM can make but voltage (AC, DC, and RF by means of a probe) and resistance measurements represent, by far, the bulk of the uses to which this instrument is put.

In obtaining voltage readings at various points in a television receiver and comparing them with the values specified by the manufacturer, several facts should be known.

1. Are the voltages being taken with respect to the point indicated by the manufacturer?

2. Are you using the same general type of instrument as that used in obtaining the voltages indicated on the schematic diagram?

3. Does the AC line voltage have a value close to that specified?

4. Finally, are the controls set in the same position as they were when the manufacturer measured the indicated voltages?

Voltages are not absolute but comparative values. When you say that the plate of a tube has on it a voltage of 210 volts, you mean it is 210 volts positive with respect to some other point. Generally this other point is the chassis but it need not be so. General Electric, in nearly all of their television receivers, specify that voltages given are with respect to B-. They do this because their television sets (currently, at least) do not use power transformers and the B- line is the reference or return line for all circuits.

In Capehart sets, on the other hand, the statement is made that all voltages are measured from the chassis unless otherwise indicated. The alternate indication are voltages marked with an (x) and these must be taken with respect to the -90 volt line in this receiver. Failure to observe this precaution will give you readings which are 90 volts too low.

The type of voltmeter used to make the measurements will also have a very decided influence on the values which are obtained. A 1000-ohm-per-volt meter, for example, possesses such a low internal impedance on the low voltage ranges that it will provide reliable indications only in similar low resistance networks. In all other instances the voltages indicated will frequently be too low to prove of value.

The best instruments to use for all-around service measurements are the 20,000 ohm-per-volt meter and the VTVM. Some set manufacturers specify the use of one meter, some the other. In general, the readings obtained with either instrument will correspond sufficiently close so that, for all practical purposes, they may be used interchangeably. In most instances higher readings will be obtained on the VTVM by virtue of its usually higher input impedance. (However, on high voltage ranges it is not unusual for the impedance of 20,000 ohm-per-volt meters to exceed that of some VTVM's.)

The source of all the power utilized by the television receiver stems from the AC power line. And since this is true, any line voltage variations will have a direct effect on the voltages which you find in the receiver. Now, most of us have a deep rooted respect for the prodigious job which is accomplished daily by the local power company and frequently we let this respect carry over into our everyday servicing with the result that we come to believe that when a manufacturer specifies that this set is to be operated from 117 volts, 60 cycles and we plug that set into the nearest outlet, that it is automatically receiving 117 volts. It would be nice if this were true, but unfortunately it is not. While the 60-cycle figure may remain fairly constant, the accompaning voltage value does not and it is not unusual to find line voltages dropping to as low as 100 volts or rising as high as 125 volts. And this variation will immediately be reflected in corresponding lower or higher DC voltages within the receiver.

Always make a point of checking the incoming line voltage before commencing service work on any piece of equipment. An excellent arrangement, in this respect, is a Variac placed between the line and the set. With a voltmeter permanently installed across the Variac output, you will know at a glance how much voltage is being applied to the receiver. If any correction is necessary, it can be made simply and quickly with the Variac control.

A further precaution to observe when checking receiver voltages concern the settings of the various operating controls. This precaution is necessary because many of the voltages will vary with the control setting and if you make your measurement with the control in one position and the manufacturer obtained his voltage value with the control set in a totally different position, the two readings can be far enough apart to lead you to believe that the circuit is not functioning properly.

The controls whose settings are most frequently specified include the focus, contrast, brightness, hold, size, and linearity controls. The settings, however, will vary from one manufacturer to the next. Thus, Admiral states that the contrast (picture) control should be turned fully clockwise while all the other front panel controls should be set at approximately half rotation. Vertical linearity and height are also set at mid-position. General Electric wants all the controls to be set fully clockwise, while Capehart merely specifies that the controls should be set for a normal picture. Finally, the Philco manual indicates the range of variation for those voltages that vary with control setting. There is no uniformity and each set must be treated differently. The important thing, however, is to be aware of the fact that certain voltages will vary with control settings and to consider this fact when voltage readings are taken.

The more information that is placed in the service manual or on the schematic diagram, the easier it is for the technician to determine whether the values he obtains are correct or not. Unfortunately, however, the serviceman will, in the course of his work, come across many diagrams or manuals that do not contain any specific voltage values. What do you do in these cases?

There are several approaches to this situation. The most obvious one is to rely on your background and past experience. You know, for example, that in a conventional amplifier, the plate is more positive than the cathode or grid while the grid is more negative than the cathode. You also know that when current flows through a plate load resistor, the plate end of the resistor should be less positive than the other end of the resistor. And probably most important of all, you know that the output signal of an amplifier should be larger than the input signal. With an oscilloscope you can determine whether this is actually occurring.

These few facts are merely given to emphasize how much the technician can rely on and should. The fundamental basis of operation of all television receivers is the same and if you know what to expect, from each section of a TV receiver then you are not incapable of servicing a television receiver even without a schematic diagram. But the basic information must be known in the first place.

Other approaches to the problem of servicing a television receiver, without knowing definitely what its normal voltage values are, include:

1. Referring to somewhat earlier models by the same manufacturer about which information may be available.

2. Comparison between the indications (waveforms, voltages) of the faulty receiver and the instruction booklets of other sets (of different make) using similar circuits. This is frequently helpful because of the great similarity between many of today's television circuits. In this respect it is important to note that while the voltages found in different sets usually differ, the voltage differences between the same sections of similar circuits frequently correspond. Check the plate-to-cathode voltage and grid-to-cathode voltage of your set against the corresponding voltage difference in the known receiver and see whether they fall within the same range.

As an illustration, consider the two horizontal oscillator circuits shown in Figure 14. The one in Figure 14A is taken from an Emerson receiver, Model 676B; the other is from a Majestic set, Model 17DA. Both circuits, it will be seen, are closely similar in design, yet the voltages which are applied to the various elements differ considerably. Thus, in Figure 14A, the cathode, pin 6, of V18 is returned to -175 volts; in Figure 14B, the same element in the same tube connects directly to ground. From this casual examination, one might easily come to believe that the voltages existing in one circuit would be of little value in helping the serviceman determine whether the voltages he finds in the other circuit are normal or not.

However, let us disregard the absolute voltage values given and consider, instead, the voltage differences. Between pin 4 and pin 6 of V18 in Figure 14A, the voltage present is -60 volts. In Figure 14B it is -55 volts. Back in Figure 14A again, the difference in voltage between pin 5 and pin 6 is +175 volts; in Figure 14B the same two pins yield a difference of +165 volts.

Could the voltages in this circuit in one set be used as a guide for the other set? The answer is a very definite yes.

In all fairness, of course, it should be mentioned that this procedure is valid only when similar circuits are being compared. But with the current trend in television receiver design, this is far from being an important handicap.

In the vertical and horizontal sweep systems, another valuable guide to the operating condition of the circuit are the peak-to-peak voltages. From these you will learn not so much whether the exact peak-to-peak value is being attained, but rather whether the voltage has a value which is somewhere within the range it should be.

The foregoing are some of the more useful methods of attack that have been successfully employed. It is true that they fall short of supplying all the data desired, but they do offer a basis for comparison and this, at least, is a significant foothold.

## AM SIGNAL GENERATORS IN TV SERVICING

Signal tracing, as a means of servicing a receiver, developed in the early nineteen-thirties and once the service industry grasped the significance of this powerful servicing tool, it was adopted wholeheartedly. Signal tracing, as its name implies, consists in tracing or following the signal as it travels through the receiver. Failure of the signal to get through any tube or connecting circuit immediately pin points the seat of the trouble and subsequent voltage and/or resistance measurements usually bring the defective component to light.

The signal which is followed through the receiver may be obtained from a local broadcasting station or it may be artificially derived from an AM signal generator. The latter approach is generally the more practical one because not only does it provide a stronger signal, but it also provides one which is controllable and thus more easily adaptable to a wide range of applications.

The manner in which a signal generator is utilized for signal tracing in a television receiver can best be understood if we examine each section of a TV receiver separately. In the video amplifier stages

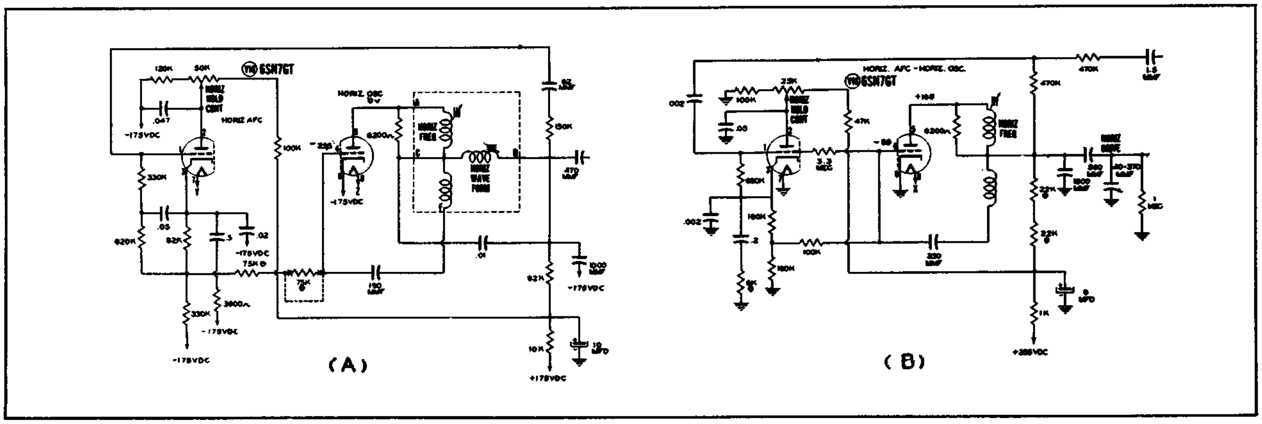


Figure 14. Two Different Television Receivers Employing Similar Horizontal Sweep Oscillators. See Text for Explanation of Voltages. (A) Emerson Model 676B, (B) Majestic Model Model 17DA.

which follow the video second detector, the frequency band-pass extends from about 20 or 30 cycles up to 3.0 mc or beyond. To determine if a signal can pass through these amplifiers, connect a signal generator to the grid of the first video amplifier (and chassis, of course) and set its dial to some frequency between 30 cycles and 3.0 mc. An audio generator could furnish frequencies between 30 cycles and 20,000 cycles, while an RF generator would be needed for all higher frequencies (say 100 kc and up). When the RF generator is employed, do not turn on the 400 cycle modulation. The RF signal, whatever its frequency, is used unmodulated.

In conjunction with the generator some form of indicator is required. If the frequency of the test signal is low enough, say 15,000 cycles or less, then a VTVM, operating on its AC range, may be applied directly. The VTVM is placed at the output of the video amplifier system--perhaps just before the picture tube--and set to the appropriate AC scale. The signal generator could then be moved back, stage by stage, until the video second detector is reached and in each instance the VTVM would reveal whether the signal was passing through the intervening stages. If the signal path was broken at any point, moving the generator beyond that point would automatically prevent the signal from reaching the meter.

The same arrangement could also be used to indicate roughly the amplification of a video amplifier. A resistive voltage divider, as shown in Figure 15, is placed across the output of the signal generator and the VTVM is then connected between points A and B. With the signal generator output turned to maximum position, note the VTVM reading. Return the VTVM to the output of the video amplifier system. Then, without changing the generator output level, move this instrument and its voltage divider to the input of the last video stage and apply the signal from point C of the resistive network to the tube grid. This signal is .1 of the value previously indicated by the VTVM. Note what the VTVM reading is now. Then, divide the present meter reading by .1 of the original VTVM reading and the answer will be the stage amplification. If there are two video amplifier stages, the signal from point C could be injected at the grid of the first stage and the VTVM reading noted. Again, the ratio of these two figures would give you the overall gain.

To illustrate: Suppose the VTVM indicates .9 of a volt when it is connected between points A and B of the voltage divider. This means that between C and B, there is .09 volts. Now, when the generator feeds a signal (from point C) to the grid of a video stage, the VTVM at the output might record a value of 1.1 volts. Stage amplification is then

$$\frac{1.1}{.09}$$

or, approximately 12 times.

Since the serviceman is primarily interested in determining whether a stage is amplifying or not, the choice of the testing frequency is not too important. A 1000-cycle note might be as convenient as any to use.

To employ the VTVM as is, without any additional components, requires that the test signal have a relatively low frequency. This has already been noted. If for some reason, it is desired to employ a high frequency probing signal, an RF probe will have to be attached to the VTVM and the probe end used to receive the signal. This arrangement would enable the VTVM to serve as an indicator up to several hundred megacycles and this would be useful for checking signals in the RF and IF stages, as we shall see presently.

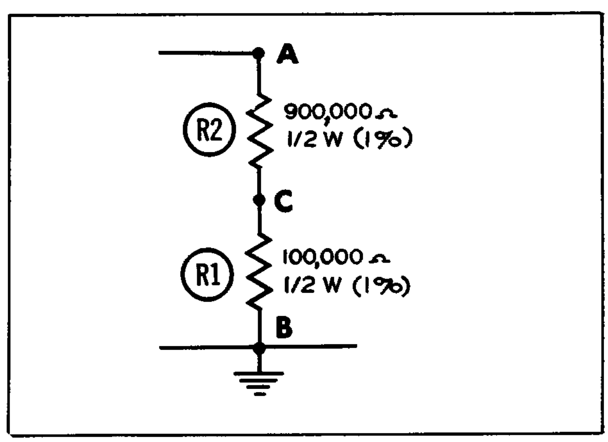


Figure 15.

Before we leave the video amplifiers, note should be made of another indicator that can be used to reveal whether the signal is passing through the video amplifier stages or not. This is the picture tube itself. Whenever a sine wave signal is applied to any point in the video amplifiers, a series of black and white lines will appear on the screen. The number of lines observed will depend upon the signal frequency. Actually, the number of lines is of little consequence. What is important is the indication that the signal is reaching the picture tube.

An AM generator, in conjunction with the VTVM can be employed to trace the signal through all of the RF and IF stages. In the RF system, the signal generator is set to the video carrier frequency of the channel to which the set is tuned and this signal is then applied to the antenna input terminals of the receiver. With the RF probe, we can look for this signal at the plate of the RF amplifier, at the mixer, and in the grid and plate circuits of each of the video IF amplifiers. At each point, as we progress farther and farther into the set, the signal amplitude should increase. A decrease or complete loss of signal at any point immediately warns us of trouble.

The signal can be followed to the video second detector. At the detector, the RF carrier signal is rectified and a DC voltage appears across the detector load resistor. If we wish to trace the signal right up to the picture tube, then the generator output should be audio modulated when the second detector is reached. This will provide an audio signal at the detector output and the VTVM can follow this signal through the video amplifier stages to the picture tube.

There are several ways in which the generator-VTVM combination can be worked through the RF and IF stages. The method just given is one approach. Or, if desired, the DC prod of the VTVM can be placed across the video detector load resistor and the readings noted as the signal generator is moved back (toward the front end) of the IF and then the RF stages. As the separation between the generator and VTVM increases, the DC voltage recorded by the meter should increase likewise.

It is, of course, possible to dispense with the VTVM entirely and use the picture tube as the indicator. All we have to do is start at the final video IF amplifier and gradually work our way back to the receiver front end. As long as we remain in the video IF system, the signal frequency will be that of the video carrier IF; when the RF end is reached, we switch to the video carrier RF. In both instances, however, amplitude modulation of the signal is required in order that after it is detected, an alternating voltage remains which can pass through the video amplifier stages and reach the picture tube.

The audio system can be handled in a somewhat similar manner despite the fact that the sound detector is designed to handle frequency-modulated signals. Thus, if you apply an AM signal to any of the sound IF amplifiers (at the sound IF frequency) you will hear a 400 cycle audio note from the speaker if the signal is able to pass through the intervening stages. An FM detector ideally would suppress all amplitude modulation in a signal but practically this has never been achieved and some detection of AM signals occurs. Of course, a sweep generator, in which the signal is frequency modulated, would perhaps be somewhat better suited for this task. In this case the 60 cycle sweeping voltage would produce a 60-cycle speaker output.

It should be understood by the reader that each of the foregoing suggested applications of the AM signal generator is designed to indicate to the serviceman whether or not a signal can get through the various stages through which it is passed. The tests are admittedly rough ones, since they will not reveal whether the stage is properly aligned or whether the signal suffers distortion as it passes through. It will merely indicate whether or not a signal can pass through and from this information the assumption can be made that a similar video or audio signal will do likewise. Whether distortion is introduced remains to be seen when the proper signal is re-applied to the set.

## MEASURING RECEIVER SENSITIVITY

The sensitivity of a television receiver is an important consideration, especially when the set is to be used in weak signal areas. A set may be properly aligned and yet due to the poor operating characteristics of one or more tubes, may be far below its normal sensitivity. Moderate strength signals, which should provide clear, noise-free reception will instead produce weak snowy pictures, leading to customer dissatisfaction with eventual loss of business to the serviceman. Sensitivity data of a receiver can also be employed by the serviceman to determine whether a set is operating normally or whether some defect, not readily apparent or revealed by the usual servicing tests, exists in the receiver.

Sensitivity and band pass are the two operating criteria by which all television receivers can be compared and it behooves the serviceman to be able to determine each. Band pass can be checked by one of the methods outlined in Section 6 or by carefully examining a received test pattern.* Receiver sensitivity measurement requires an AM signal generator and either a VTVM or an oscilloscope and it is performed by one of the following methods.

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*See the author's "Servicing TV In The Customer's Home" published by Howard W. Sams & Co., Inc.

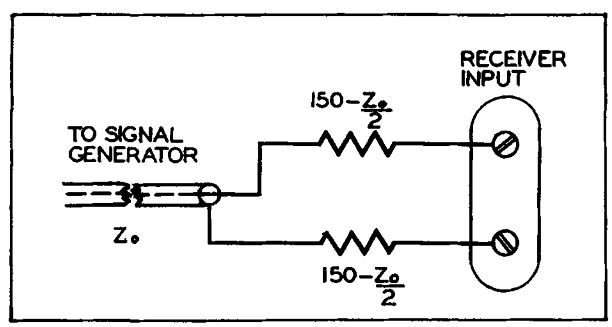


Figure 16. Dummy Antenna Connection for a Signal Generator.

(A) Connect an AM signal generator to the antenna input terminals of the receiver, matching the generator to the receiver with a resistor network. See Figure 16. The value of each series resistor, $R_1$ and $R_2$, is equal to 150 ohms less one-half of the generator's output impedance. Thus, if the generator impedance is given as 50 ohms, $R_1$ and $R_2$ would each be 150-25 ohms or 125 ohms. The value of $R_1$ and $R_2$ plus the 50 ohms output impedance of the generator equals the 300 ohms input impedance of the receiver. Hence, the system is matched.

The next step is to connect an oscilloscope across the signal line going to the picture tube (either grid or cathode, as the case may be). Short out the a.g.c. line to the chassis and turn the contrast control for maximum sensitivity (fully clockwise). Then set the signal generator for 30% modulation at 400 cycles, tune it to the mid frequency of the channel being checked, and rotate the fine tuning control for maximum output.

Adjust the generator output to produce a 20-volt peak-to-peak sine wave on the scope screen. When this has been done, note the microvolt output from the generator. For a sensitive receiver this will be less than 50 microvolts on the low channels and somewhat greater on the high channels.

(B) An alternate procedure which is frequently employed is to leave the AM generator set up as indicated (with no modulation) but to substitute a VTVM for the oscilloscope. The VTVM is not connected to the output of the video system, but across the video detector load resistor. The unmodulated signal generator output is then adjusted until the VTVM indicates a 1-volt DC reading.

In this second method, the a.g.c. line is also grounded to the chassis and the contrast control run wide open.

It is possible to determine the sensitivity of the video IF system separately, should this be desired. Connect the AM signal generator to the grid of the mixer tube through a 1000 mmfd capacitor. The generator frequency is set to a mid IF frequency. Thus, if the video IF range is from 21.75 to 25.75 mc, the generator setting would be at 23.75 mc. The signal is unmodulated.

Again the a.g.c. network is disabled by grounding and the contrast control (if it is in the video IF system) is turned to maximum clockwise position. A VTVM is connected across the video detector load resistor. Then, the AM generator output is adjusted until 1 volt is indicated on the VTVM. Typical signals required from the generator range between 200 to 300 microvolts.

## SIGNAL GENERATOR CALIBRATION

While the foregoing sensitivity measurement procedure is straightforward, there is only one drawback so far as the ordinary service shop is concerned. No signal generator having a calibrated output attenuator is available. This being the case, how can receiver sensitivity be measured?

There are two approaches to this problem. If you are fortunate enough to know someone who has a calibrated AM generator, then you can calibrate your instrument against his. The procedure is quite simple. Set up the calibrated generator according to one of the sensitivity procedures just outlined and note how much signal is required from the generator to produce a 1-volt reading on the VTVM at the video second detector. (If desired, the scope positioned at the output of the video system could be employed instead. In this case, a 20-volt peak-to-peak reading is required and the signal should be modulated.)

The calibrated generator is then removed and your unit substituted instead. Adjust its output until the same meter indication is obtained. Record the setting of the attenuator controls of your instrument on a chart because at this point the circuit is receiving as much signal as it did from the calibrated generator.

Similar calibration can be carried out over a range of attenuator control settings and at various frequencies.

When you have no access to a calibrated generator, you cannot determine the exact sensitivity of a receiver. But you can obtain its relative sensitivity. Every time you get a receiver in your shop, measure its sensitivity by noting at what position of your attenuator control 1 volt is produced on a VTVM connected across the video detector load resistor. Keep a record of your results, and after you have performed this test on a dozen receivers, you will be able to judge with a fair degree of accuracy whether or not a set is sensitive. You will know, for example, that when 1 volt is produced by attenuator setting below a certain value, that the set will operate with weak signals. But when the attenuator must be turned up to produce the same reading, that the set requires a much larger input signal to develop a good picture. If you classify your information by sets, you will not only come to know what to expect of any given model, but also to recognize when this set is operating below its customary sensitivity. Information such as this can be of invaluable assistance.

## IN CONCLUSION -

The application of test instruments to television and FM receiver servicing has been covered in part in this section and in part in each of the previous sections. Undoubtedly there are many additional ways in which these instruments can be used, but the ones chosen were those which have been found to have the greatest usefulness in every day servicing.

Illustrations of current test instruments were used freely throughout this book to acquaint the reader with those instruments which he is most likely to meet in every day work. The author is indebted to the various manufacturers for their generous assistance in supplying photographs and operating manuals and to their engineering staffs who provided additional data on instrument characteristics and applications. The author would also like to express his thanks to his associate, Donald F. Blood, for proofreading portions of the manuscript and making many worthwhile suggestions, to Central Television Service of Chicago and their men, and to the Howard W. Sams organization for their enthusiastic endorsement of the entire project. Without this encouragement, it is doubtful whether this book would have appeared at this time.