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101 WAYS to Use Your VOM and VTVM

by Robert G. Middleton

101 ways to use your

VOM and VTVM

by ROBERT G. MIDDLETON

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PREFACE

The VOM and VTVM are unquestionably the most popular and the most useful service instruments. Their ability to show circuit-action data is exceeded only by the oscilloscope. There is also an inherent functional appeal in their outward simplicity.

Technicians with any curiosity will find the applications picture is two-sided. It is usually thought that VOM and VTVM uses are limited. The other side of the story is an extensive field of tests far beyond simple measurement of DC voltage and resistance values.

This book describes the other side of the picture. The "yarn" unravels into 101 straight lines with no loose ends. Each line is the shortest distance between a service problem and its solution.

In this new edition, meter circuitry explanations are expanded to show the various means of protection against overload damage. Calibration is also detailed more extensively. Frequency-compensated multipliers in AC VTVM's are discussed and illustrated. Semiconductor testing has become of more importance to technicians, and this topic is given appropriate coverage. Decibel measurements are admittedly more difficult to make than are voltage or resistance measurements; additional explanation of this topic is provided in this new edition.

Although this is basically a working handbook for the practical technician, students and experimenters will find the text understandable. It provides valuable supplementary information for teaching personnel in technical institutes and junior colleges. Lab instructors will find this an indispensable reference source for planning experiments to accompany courses in electricity and electronics.

This handbook has the same general format as its companion volumes of the *101 Ways to Use Your Test Equipment* series. You will find just about every practical use for a VOM and VTVM categorized and referenced for quick location.

Robert G. Middleton

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INTRODUCTION

The VOM and VTVM are the basic test instruments in any shop. These instruments have very wide fields of use. Many of their important applications are not commonly recognized.

Experienced technicians use VOM's and VTVM's to adjust horizontal-drive and -linearity controls, to measure plate and screen dissipation, to check amplifier linearity, to measure the internal resistance of a circuit, to check receiver noise levels, to analyze regeneration and oscillation in IF amplifiers, to check receiver sensitivity, to measure DC millivolts, to check picture-tube rasters, to measure capacitance values, to measure extremely high and low resistance values, to make signal-tracing tests, to check for open screen and cathode capacitors, to measure audio gain or loss in decibels, to measure power consumption, to measure AC impedance, to measure power factors, to measure inductance and inductive reactance, and to make many other useful tests not generally recognized.

Beginners will be interested to learn that a VOM can be completely checked out and that tests can be made for indication accuracy on resistance, DC voltage, DC current, and AC voltage ranges with no other equipment than a battery and a few precision resistors. We show how to check function against function without using standard voltage or current sources.

The usability of VOM's and VTVM's is greatly extended by suitable probes. You will find in these pages explicit instructions concerning the use and constructional details of such probes.

It is true that some of the more common applications of VOM's and VTVM's, such as alignment procedures, can often be performed to better advantage with specialized equipment. However, not every shop can afford expensive sweep generators and oscilloscopes. Hence, the latter portion of this book discusses alignment methods using signal generators with a VOM or VTVM. Technicians interested in advanced alignment procedures are referred to the companion volume, *101 Ways to Use Your Sweep Generator*.

For troubleshooting TV receiver circuits, a VOM or VTVM can be made to do much of the work usually assigned to the scope. Peak-to-peak voltages can be measured. Horizontal components of waveform can be checked independently from vertical components, and vice versa. High-frequency signals can be traced through the IF amplifier, sync, and sound systems. However, technicians who desire to make more elaborate waveform tests are referred to the companion book, *101 Ways to Use Your Oscilloscope*.

You will observe that this is neither a theory book nor a textbook. Instead, it is a practical handbook for the professional technician. Each application is categorized and cross-referenced for quick location. The necessary practical information, showing how to connect instruments and equipment for the specific application, is given for each test. Typical test results are included to guide the user to correct conclusions.

VOM's and VTVM's are used to measure either DC or AC voltages. Beginners should note that all AC voltage measurements are based upon the characteristics of a sine wave. Fig. 1 shows the relations of rms (root-mean-square), peak, and peak-to-peak voltages in a sine wave. Most VOM's indicate the rms voltage of a sine wave. VTVM's may indicate rms, peak, or

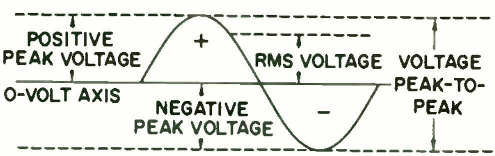
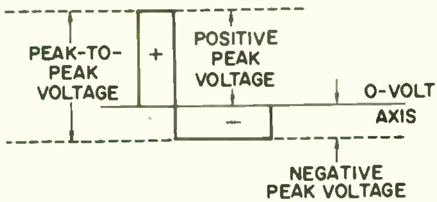


Fig. 1. A sine wave.

peak-to-peak voltages. Note in Fig. 1 that the positive-peak voltage and the negative-peak voltage of a sine wave are equal. On the other hand, this is not necessarily true of the peak voltages in other waveforms. For example, Fig. 2 shows the relations of the positive-peak and negative-peak voltages in a pulse.

Fig. 2. A pulse waveform.



Observe that the peak-to-peak voltage of a pulse is equal to the sum of its positive-peak and negative-peak voltages. It is not practical to measure the rms voltage of a pulse or other nonsinusoidal waveform with service-type VOM's and VTVM's. Therefore, to measure pulse voltages in electronic equipment, use a VTVM that has peak-to-peak indication. In general, the peak-to-peak voltage of a nonsinusoidal waveform is more important than the peak voltage. Peak-to-peak voltage values are specified in receiver service data.

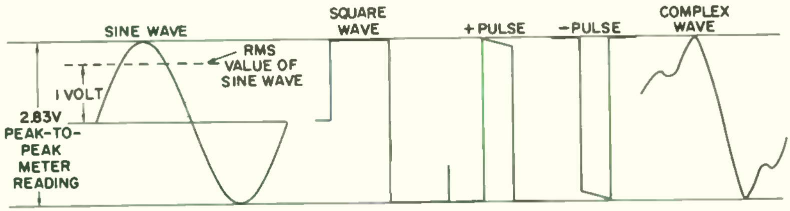
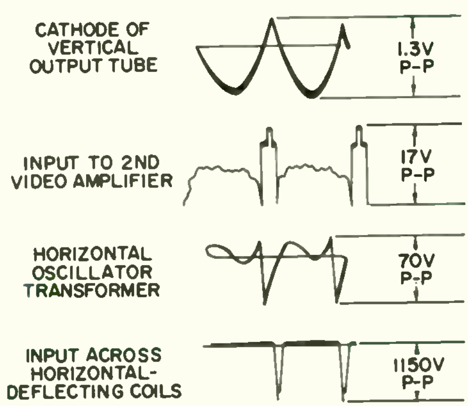


Fig. 3. Typical voltage waveforms.

Fig. 3 depicts five different types of waveforms that have the same peak-to-peak voltage. A peak-to-peak voltage is equivalent to the same value of DC voltage. For example, if we switch a 1.5-volt battery on and off, we generate a square wave or a pulse

Fig. 4. Typical television waveforms.



with a peak voltage of 1.5 volts. Many types of nonsinusoidal waveforms are encountered in TV receiver circuits. Fig. 4 shows some typical waveforms, with their normal peak-to-peak voltages.

In vacuum-tube and transistor amplifier circuits, we commonly work with pulsating DC waveforms. A pulsating DC waveform is a mixture of alternating and direct current components, as depicted in Fig. 5. Strictly speaking, pulsating DC is defined as

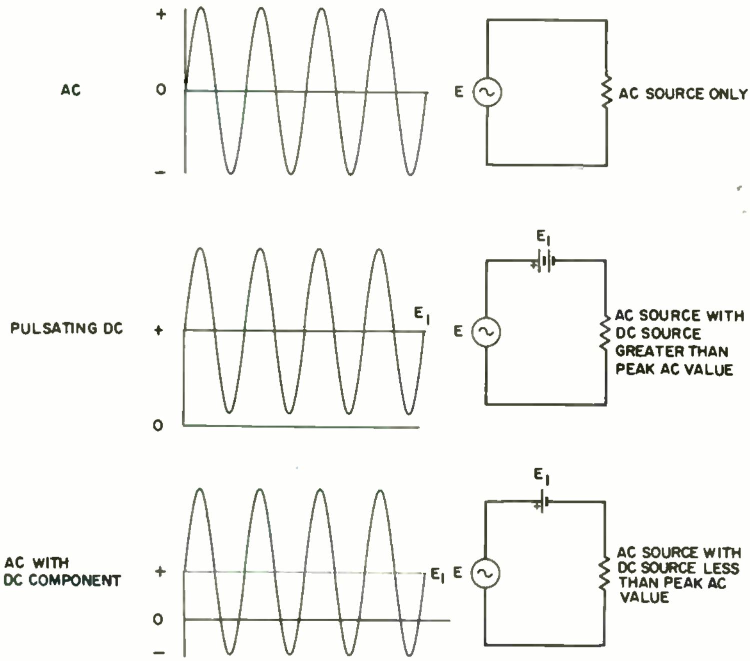


Fig. 5. Three basic classes of current.

a mixture of AC and DC in which the waveform does not cross the zero-volt level. If the waveform crosses the zero-volt level, it is called AC with a DC component. Suppose that in Fig. 5 E_1 has a value of 10 volts and E has a value of 3 volts rms. If a VOM is connected across the resistor and operated on its DC-voltage function, the meter will read 10 volts. On the other hand, if the VOM is operated on its "output" function, the meter will read 3 volts. Details of such tests are subsequently explained in detail.

Ohm's law is often used when making measurements with the VOM and VTVM. Ohm's law for DC states that:

$$I = \frac{E}{R}$$

where,
I is the current in amperes,
E is the voltage in volts,
R is the resistance in ohms.

Ohm's law for AC states that:

$$I = \frac{E}{X}$$

where,
I is the current in amperes,
E is the voltage in volts,
X is the reactance in ohms.

In the case of a capacitor, its reactance X_c is given by:

$$X_c = \frac{1}{2\pi fC}$$

where,
X_c is the capacitive reactance in ohms,
pi is equal to 3.1416,
f is the frequency in cycles per second,
C is the capacitance in farads.

Fig. 6 is a convenient chart that shows the reactance in ohms of capacitances from 0.2 to 10 microfarads at 60 cycles. You can also use the chart for other values of capacitance. For example, if you multiply values on the horizontal axis by 10, the values on the vertical axis can be divided by 10 to find the corresponding reactance value. You can also use the chart at frequencies other than 60 cycles. For example, if you multiply 60 cycles by 10, you may either divide values on the horizontal axis by 10, or you may divide values on the vertical axis by 10.

In the case of an inductor, its reactance X_L is given by:

$$X_L = 2\pi fL$$

where,
X_L is the inductive reactance in ohms,
pi is equal to 3.1416,
f is the frequency in cycles per second,
L is the inductance in henrys.

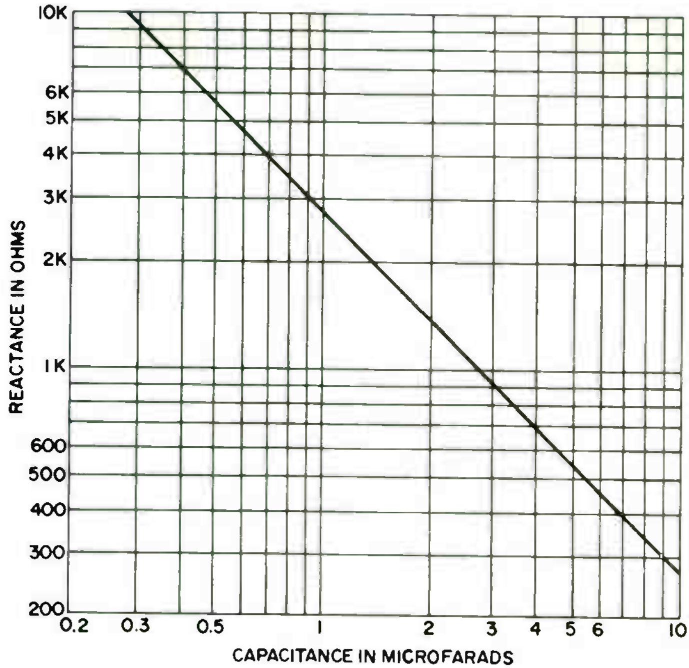


Fig. 6. Reactance of capacitors at 60 cycles.

Fig. 7 is a convenient chart that shows the reactance in ohms of inductances from 0.2 to 10 henrys at a frequency of 60 cps. The chart can be used for other values of inductance, also. For example, if you multiply values along the horizontal axis by 10, the values along the vertical axis will also be multiplied by 10. The chart can also be used at frequencies other than 60 cycles. For example, if you multiply 60 by 10, you can either divide values along the horizontal axis by 10, or you can multiply values along the vertical axis by 10.

It is important to remember that resistive voltages and reactive voltages add at right angles, as shown in Fig. 8. This is because the voltage across a capacitor is 90° out of phase with the voltage across a resistor. In other words, the *arithmetical* sum of e_r and e_c is greater than e in Fig. 8, but the *algebraic* sum of e_r and e_c is equal to e. Details of calculating voltage relations in capacitive circuits are explained subsequently.

As would be expected, resistance and reactance add at right angles, as depicted in Fig. 9. In other words, 1 megohm of resist-

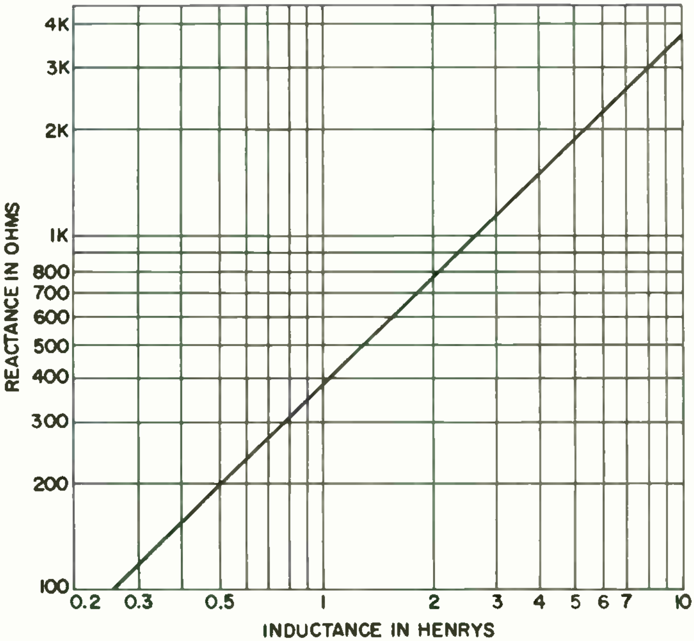


Fig. 7. Reactance of inductors at 60 cycles.

ance adds to 1 megohm of reactance to produce 1.414 megohms of *impedance*. The formula for impedance is:

$$Z = \sqrt{R^2 + X^2}$$

where,

Z is the impedance in ohms,
R is the resistance in ohms,
X is the reactance in ohms.

Ohm's law applies to impedances, just as it does to resistances and reactances:

$$I = \frac{E}{Z}$$

where,

I is the current in amperes,
E is the voltage in volts,
Z is the impedance in ohms.

Note that it makes no difference whether we use rms, peak, or peak-to-peak values in the Ohm's-law formulas. The only requirement is to be consistent. In other words, if we measure the

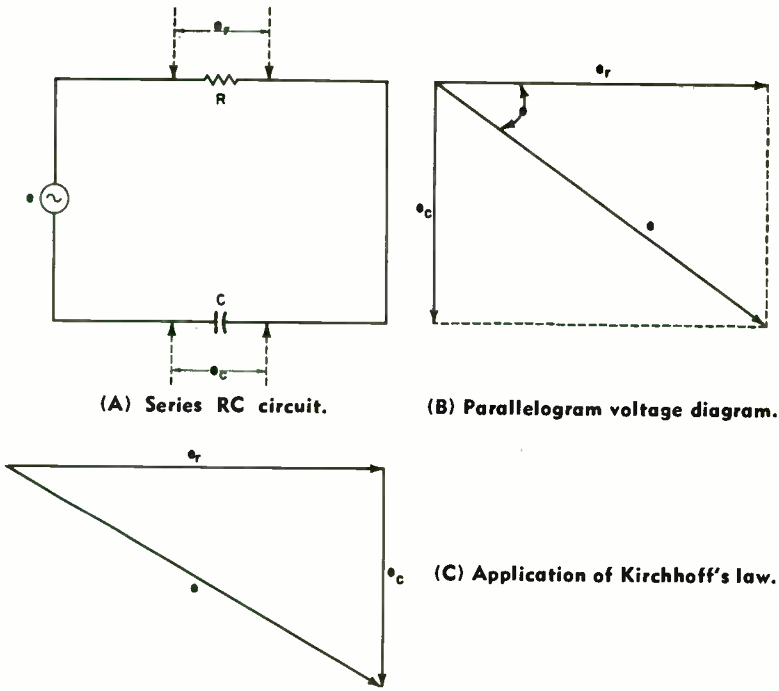


Fig. 8. Resistive and reactive voltages add at right angles.

voltage in rms volts, then we must obtain our calculation of current in rms amperes. Or, if we measure the voltage in peak-to-peak volts, then our answer will be in peak-to-peak amperes.

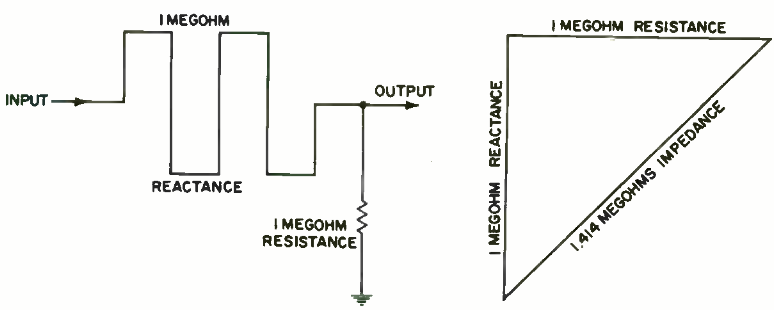


Fig. 9. Resistance and reactance add at right angles.

EQUIPMENT CHECKS

U1

To Check the Accuracy of Ohmmeter Indications (VOM or VTVM)

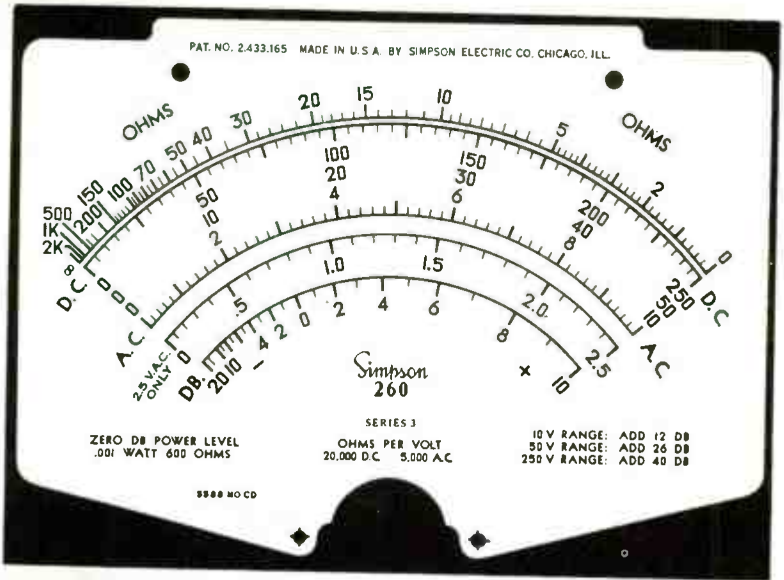
Equipment: Precision resistors (±1% rated accuracy). Values should be chosen to provide approximately center-scale indication on each ohmmeter range.

Connections Required: First short-circuit the ohmmeter leads for ohmmeter adjustment. Then connect meter leads across resistor for test.

Procedure: Adjust VOM or VTVM for "0" indication. If checking a VTVM, adjust for "∞" indication also.

Evaluation of Results: Check ohmmeter scale indication against rated value of resistor. Repeat the check on each resistance range.

The ohmmeter scale of a VOM or VTVM is nonlinear. The high-resistance end of the scale is cramped. This can be seen in the following illustration, which shows the ohmmeter scale, along with the other scales of a typical VOM.



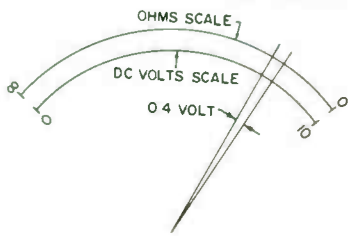
Dial scale of a typical VOM. (Courtesy of Simpson Electric Co.)

NOTE 1

Ohmmeter Accuracy Is Checked in Terms of DC Voltage Accuracy

An ohmmeter scale is cramped at the high-resistance end; hence, the absolute error usually increases as the pointer indicates higher values. The rated accuracy of an ohmmeter is commonly stated in *degrees of arc*. This figure refers basically to the accuracy of the DC voltmeter. For example, the DC voltage accuracy might be rated at ±2% of full scale. On a 10-volt scale, this rating indicates an accuracy of ±0.2 volt. In turn, a certain number of degrees of arc corresponds to this interval of 0.4 volt, as shown in the following illustration. This arc defines the accuracy of the ohmmeter scale.

Generally, the ohmmeter is assumed to be as accurate as the DC voltmeter. However, a weak ohmmeter battery can greatly lessen the accuracy of the ohmmeter. (See Note 4.)



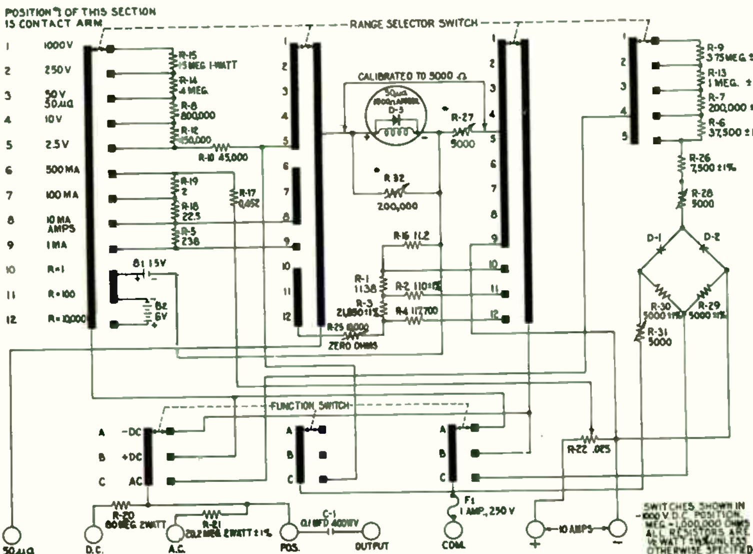
An accuracy of ±2% corresponds to an interval of 0.4 volt on a 10-volt scale.

NOTE 2

Ohmmeter Circuit May Be Fuse-Protected

There is a trend toward protection of VOM's against overload damage. Protective devices can be added to old models. Observe the VOM circuitry shown in the diagram below. A one-ampere fuse (F1) is provided to protect the 11.2-ohm resistor R16 against burnout, if the ohmmeter test leads should be accidentally applied to a "live" circuit. The resistance of the fuse is small, but since the fuse is connected in series with the test leads in the ohmmeter circuit, its resistance must be taken into account to maintain ohmmeter accuracy. Therefore, R16 has a value of 11.2 ohms. If the fuse is omitted, R16 must have a value of 11.5 ohms to obtain optimum ohmmeter accuracy.

Observe also varistor diode D3 connected across the coil of the meter movement. This is a silicon diode that has a very high resistance until the forward voltage exceeds a certain fraction of a volt. At higher forward voltages, the diode has a very low resistance. Thus, the meter movement is protected against burnout on its voltage-measuring function. Diode protection can be added to almost any service-type VOM. No recalibration is necessary when a suitable diode is used. Complete protection is not provided by a varistor diode, however, because although the meter movement is not damaged, it is still possible to overheat multiplier resistors on very large overloads.

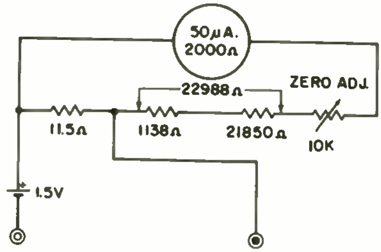


* R32 is adjusted for a circuit current of 50 microamperes, then R27 is adjusted for a circuit resistance of 5,000 ohms.

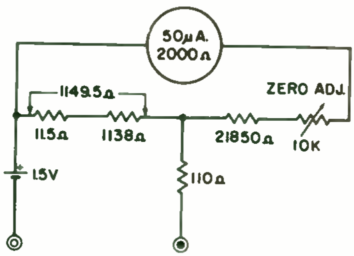
Ohmmeter section of a VOM may be protected by a fuse. (Courtesy of Simpson Electric Co.)

Note that if the permanent magnet in a meter movement weakens, the meter has subnormal indication. Maintenance adjustments R32 and R27 are provided to compensate for loss of magnetism. Since one resistance is connected in shunt with the moving coil and the other resistance is connected in series with the coil, calibration can be maintained exactly within the range of the resistances. To compensate for loss of magnetism, the shunt resistance R32 is increased in value. In turn, less current is bypassed around the moving coil. R27 is then decreased in value, so that the total resistance of the meter circuit remains at its correct value. Simplified circuits for a three-range ohmmeter are shown below.

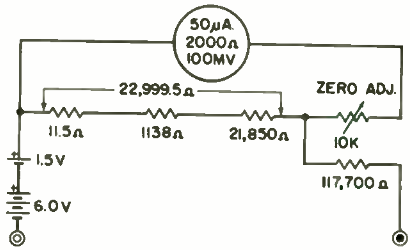
(A) Ohmmeter scale.



(B) Nominol circuit on R × 1 ronge includes resistance of test leads (not shown).



(C) A 110-ohm resistor is switched in on the R × 100 range to compensate for the resistonce of the test leods.



(D) A 117,700-ohm resistor is switched in on the R × 10,000 range to compensate for the resistance of the test leads.

Simplified circuits for o three-range ohmmeter.

U2

To Check the Distribution Error of an Ohmmeter Scale (VOM or VTVM)

Equipment: Precision resistors (±1% accuracy) to provide ohmmeter indications at 25%, 50%, and 75% of full scale.

Connections Required: First short-circuit the ohmmeter leads for ohmmeter adjustment. Then connect meter leads across resistor for test.

Procedure: Adjust VOM or VTVM for "0" indication. If checking a VTVM, adjust for "∞" indication also.

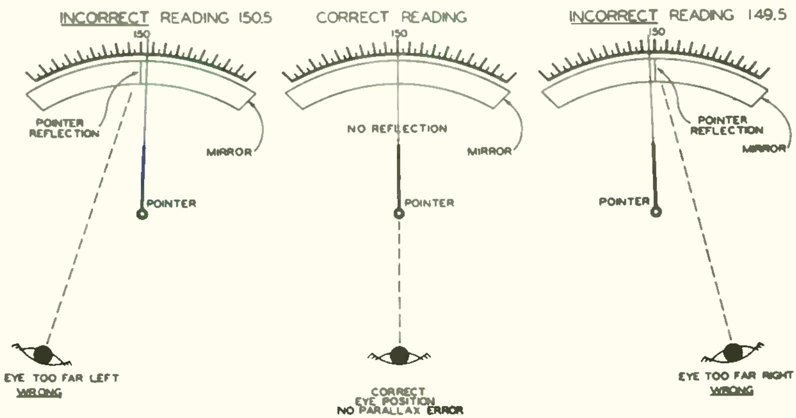
Evaluation of Results: The arc of error usually varies from one part of the scale to another. However, the error should not exceed the rated accuracy of the instrument at any point on the scale.

Distribution errors are inherent in the meter movement because of nonuniform flux distribution. Hence, a DC volts scale, for example, may not be quite linear. Meter manufacturers use different scale plates with differing amounts of nonlinearity to obtain a *practical correction* of *distribution error* in final production. Hence, you cannot necessarily use a scale plate from one movement on another movement even though the model and type of equipment may be the same.

NOTE 3

Minimizing Parallax Error

Some VOM's are provided with mirrored scales to provide maximum reading accuracy. A mirrored scale minimizes parallax error. This is an error of observation that occurs when the eye of the operator is not directly over the pointer of the meter. Oblique viewing causes an apparent displacement of the pointer to the right or left, depending on



Using the antiparallax mirror. (Courtesy of B&K Manufacturing Co.)

which side of the pointer the observer's eye is located. Observe the diagram below. To use the mirrored scale, one eye should be employed; the eye is then positioned to make the pointer and the reflection of the pointer in the mirror coincide. In turn, the scale can be read with maximum accuracy.

NOTE 4

Ohmmeter Accuracy Depends Upon Battery Condition

Good accuracy cannot be obtained from an ohmmeter unless its batteries are new. For example, when a battery slumps off enough that you wouldn't even notice it on the "zero set" adjustment, a resistance of 12½ ohms could read 11¼ ohms, a resistance of 100 ohms could read 80 ohms, and a resistance of 105,000 ohms could read 80,000 ohms.

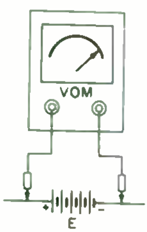
U3

To Check DC-Voltage Indication Accuracy Against DC-Current Indication Accuracy (VOM)

Equipment: Dry cell or battery and precision resistors (±1% rated accuracy).

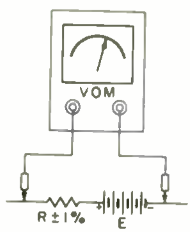
Connections Required: First connect test leads to dry-cell terminals to measure the indicated voltage as shown at A in the following illustration. Next connect dry cell and resistor in series (as shown at B) and measure the indicated current flow.

Procedure: Carefully note the indicated voltage and current values.



(A) Measuring battery voltage.

Test setup.



(B) Current measurement with resistor and battery in series.

Evaluation of Results: From the instrument instruction manual, determine the input resistance of the VOM on its various *current* ranges. (Or use the method explained in Note 5.) Add this input resistance to the value of the precision resistor used in the test. Then apply Ohm's law to determine whether the voltage and current indications are consistent.

NOTE 5

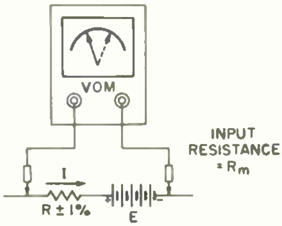
Measuring the Input Resistance of a VOM on Its Various Current Ranges

Sometimes the input resistance of a VOM on various current ranges is not given in the instrument instruction manual. In such a case, the input resistance can be measured by using a cell or battery and a pair of precision resistors. Connect one resistor as shown in the following illustration and measure the current, then connect a second resistor and measure the current. Values of the resistors should be chosen to give readings on the *same* current range. The first reading should be about ⅓ full scale. The second reading should be ⅔ or ¾ full scale. The input resistance of the VOM on the given current range is then:

$$R_M = \frac{I_2 R_2 - I_1 R_1}{I_1 - I_2}$$

where,
- R_M is the input resistance of the VOM,
- I_1 is the current measured with R_1 in circuit,
- I_2 is the current measured with R_2 in circuit.

Test setup.

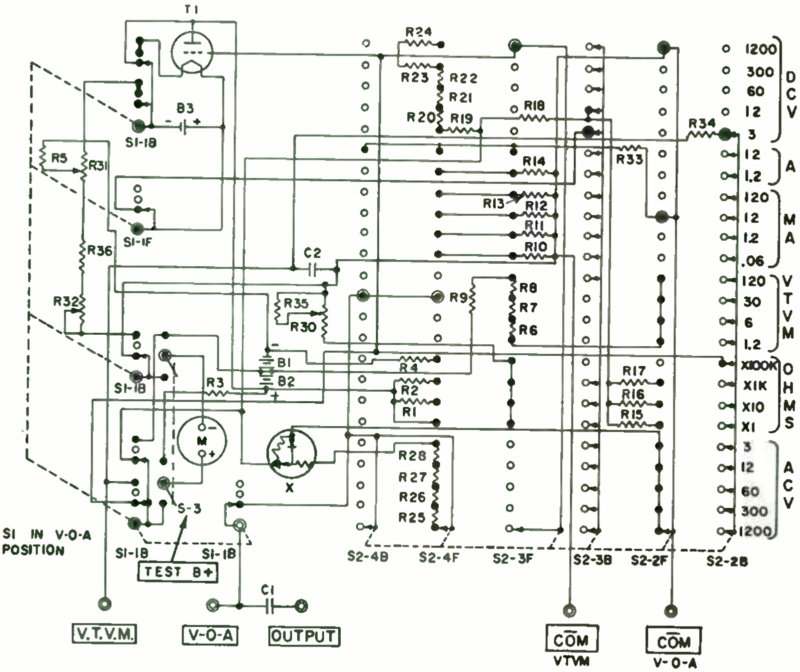


NOTE 6

Combined VOM and VTVM Functions

Some manufacturers provide both VOM and VTVM functions in a single instrument. The configuration for an instrument of this type is depicted in the diagram below. An advantage of the combination instrument is the very high input impedance provided by the VTVM function on low-voltage ranges. On the other hand, when measuring voltages in low-impedance circuits, the VOM function provides somewhat higher accuracy. For example, the VTVM function provides an input resistance of 11 megohms, with an accuracy of ±4% of full scale, using a fresh battery having a potential of 22.5 volts. Again, the VOM function provides a sensitivity of 20,000 ohms-per-volt, with an accuracy of ±3% at the scale indication.

Another type of combination VOM and VTVM comprises a 20,000 ohms-per-volt VOM with a plug-in adapter for VTVM operation. The VOM provides an accuracy of ±2% of full scale. On the other hand, the plug-in VTVM adapter provides an input resistance of 10 megohms with an accuracy of ±3% of full scale, using fresh batteries with potentials of 2.68 volts and 60 volts. Note that both these types of combination VOM-VTVM's are battery-operated in order to provide independence from a power outlet.



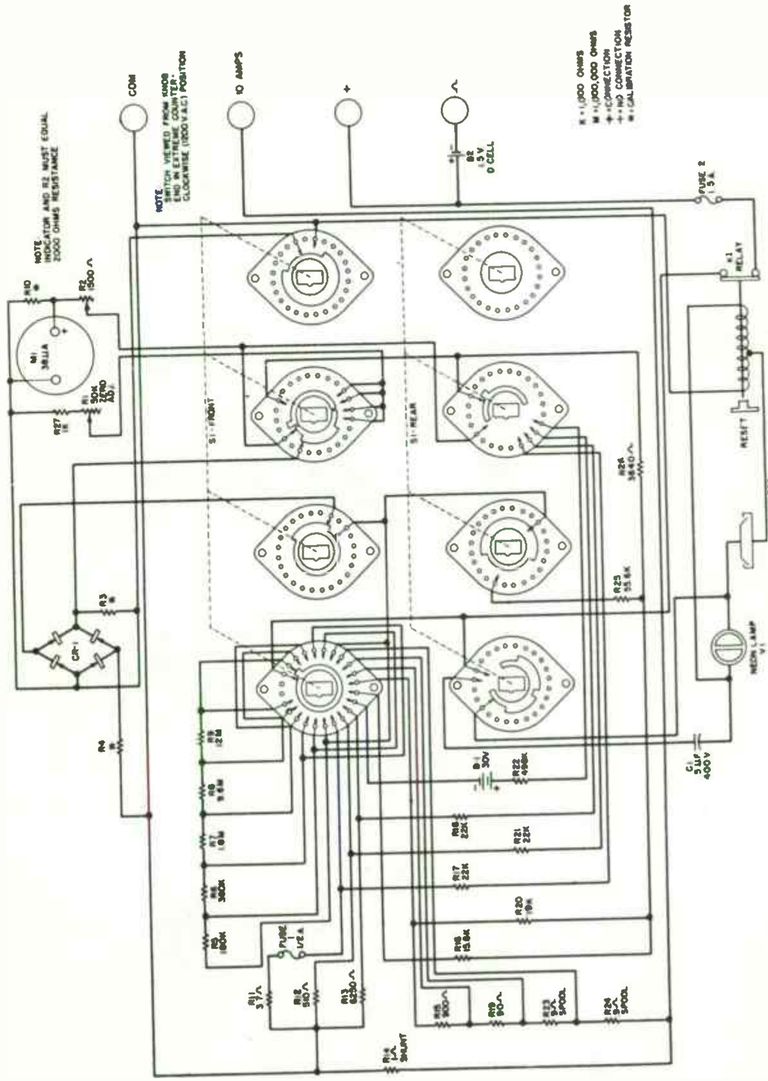
VOM and VTVM combined in a single instrument. (Courtesy of Triplett Electrical Instr. Co.)

NOTE 7

Relay Burnout Protection for Meter

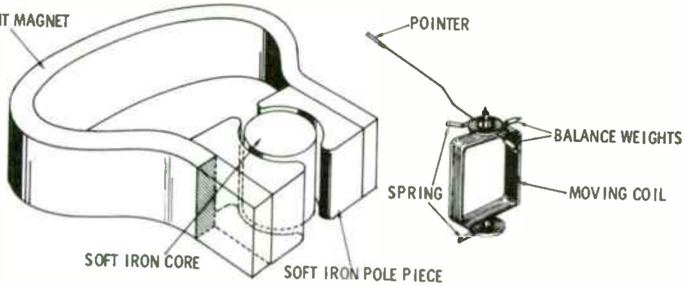
Some VOM's are provided with sensitive relays to open the meter circuit under overload conditions, and thereby protect the moving coil against burnout. The diagram below shows a typical arrangement. The contacts close when the pointer of the meter is driven off-scale, and the relay opens the input circuit to the VOM. After the relay is tripped, it remains open until the reset button is pressed. Additional protection of the VOM circuitry is provided by a 1.5-ampere fuse.

Note that a sensitive moving coil is wound with wire that is finer than a hair. A typical coil has 1500 turns of wire, with a resistance of approximately one ohm per turn. This coil is placed in an air gap of about 0.05 inch; thus, the construction can be compared with the close tolerances of a watch mechanism. An intense magnetic field, typically with a strength of 2500 gauss is provided in the air gap. (See diagram below.)



VOM with overload reloy protection. (Courtesy of The Hickok Electricol Instr. Co.)

By way of comparison, note that the earth's magnetic field has a strength of about 0.5 gauss. Thus, the meter movement has a magnetic field strength that is about 5000 times as great as that of the earth's magnetic field.



The moving coil may have as many as 2000 turns of wire 0.001 inch in diameter.

U4

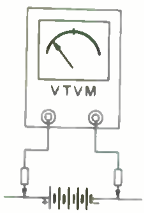
To Check the Positive Deflection Against the Negative Deflection in a Zero-Center VTVM

Equipment: VTVM with zero-center scale indication and dry cell or battery.

Connections Required: First connect VTVM leads to voltage source in one polarity as shown at A in the following illustration. Then connect leads in opposite polarity as shown at B.

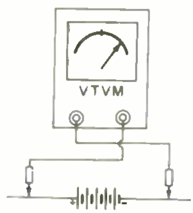
Procedure: Observe voltage indication obtained in each test.

Evaluation of Results: The same voltage indication (within rated error) should be observed in the two tests.



(A) First test.

Test setup.



(B) Test with leads reversed.

To Check the AC Voltage Indication Against the DC Voltage Indication in a VOM

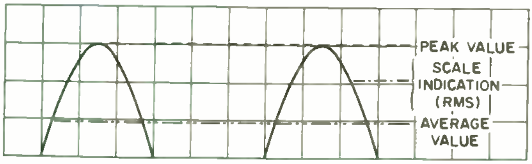
Equipment: Dry cell or battery.

Connections Required: Connect instrument leads to battery terminals.

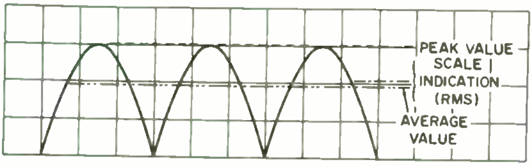
Procedure: Switch VOM from DC to AC voltage indication. Observe the voltage readings. (Read DC voltage scale when instrument is switched to DC voltage function. Read AC voltage scale when instrument is switched to AC voltage function.)

Evaluation of Results: Consult instruction book or inspect instrument to determine whether a half-wave rectifier or a full-wave bridge is used on the AC function. If a half-wave rectifier is used, the battery voltage when measured on the AC function should read 2.22 times higher than the reading observed on the DC voltage function. The reading is higher because a half-wave rectifier supplies an output that has an average value equal to 0.318 of peak. The meter movement responds to this *average* value. The AC scales of the VOM are calibrated in *rms* values or 0.707 of peak. A DC voltage having the *average* value will produce an *rms* scale reading that is 2.22 times higher. On the other hand, if a full-wave bridge or full-wave semibridge rectifier is used in the instrument, the battery voltage measured should be 1.11 times higher than the reading on the DC function, since a full-wave rectifier supplies an output that has an average value equal to 0.637 of peak. Therefore, the AC scale in an instrument having a full-wave rectifier is calibrated for an *rms* value equal to 1.11 times the *average* value to which the meter responded. (The foregoing relationships apply only to a sine wave.)

Note that it should make no difference which polarity of battery voltage is applied on the AC function when the VOM uses a full-wave bridge (See U6). On the other hand, if the VOM uses a half-wave rectifier, you must polarize the battery connections suitably to get a reading on the AC function. Wrong polarity in this case results in zero or small reverse reading on the AC function.



Output of half-wave rectifier.



Output of full-wave rectifier.

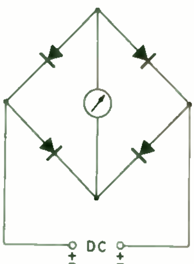
To Check for a Faulty Rectifier in a Full-Wave Bridge (VOM)

Equipment: Dry cell or battery.

Connections Required: Connect instrument leads to battery terminals.

Procedure: Operate VOM on its AC voltage function. Note scale indication. Then reverse instrument leads to battery and note scale indication again.

Evaluation of Results: The two scale indications should be very nearly equal. Unequal scale readings indicate that the full-wave bridge rectifier is faulty.

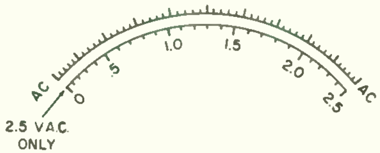


The basic full-wave bridge rectifier circuit.

NOTE 8

AC Voltage Values Are Read on Special Scales, Not on the DC Scales

Note that the AC voltage scales are cramped at the low-voltage end. The scales with the least full-scale value are most cramped because instrument rectifiers are nonlinear. When the multiplier resistance is small (on the low-voltage ranges), the rectifier nonlinearity shows up most prominently; therefore, the lowest voltage is cramped most. On the other hand, when the multiplier resistance is large (on the high-voltage ranges), the rectifier nonlinearity shows up to a lesser extent. This is a *swamping* effect. Nevertheless, VOM's commonly measure all AC voltage values on scales separate from the DC scales. There is an appreciable cramping at the low end of the AC scale, even when high voltages are being measured.

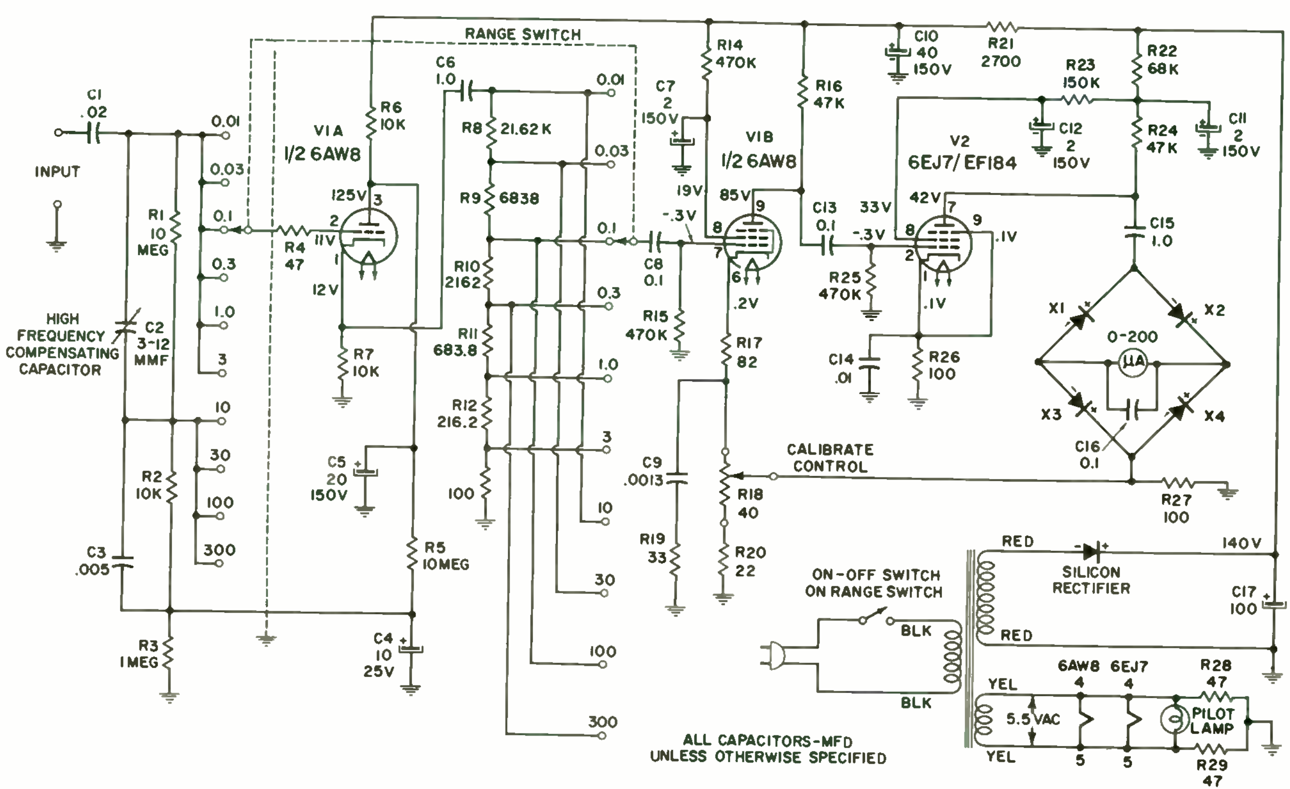


AC voltage scales, showing cramping at low end.

NOTE 9

Frequency-Compensated Multiplier in AC VTVM

You will often find frequency-compensated multipliers in AC VTVM's. This feature provides high input impedance with extended high-frequency response. An example is shown in the diagram below. Trimmer capacitor C2 operates in combination with C3 to obtain flat frequency response within ±1 db from 10 cps to 0.5 mc, and within ±2 db from 10 cps to 1 mc. The compensated multiplier provides an input impedance of 10 megohms and 12 mmf on ranges from 10 to 300 volts, and an input impedance of 10 megohms and 22 mmf on ranges from 0.01 volt to 3 volts. Trimmer capacitor C2 is a maintenance adjustment which normally requires no attention. R18, the calibration control, is also a maintenance adjustment. A calibration control may require readjustment at extended intervals, as the tubes eventually decline in G_m.



Frequency compensation provides flat response to 1 megacycle. (Courtesy of Heath Co.)

NOTE 10

Instrument Rectifiers Lessen Accuracy of AC Indication

The accuracy of a VOM is less on AC functions than on DC functions because of aging tolerances on the instrument rectifier. Thus, a VOM rated for 3% of full-scale accuracy on DC voltage and current ranges will customarily be rated for 5% of full-scale accuracy on AC ranges. Consider, for example, a 100-volt range: On the DC function, this rating means the accuracy will be within ±3 volts at any point on the 100-volt DC scale. On the other hand, the AC rating means the accuracy will be within ±5 volts at any point on the 100-volt AC scale.

NOTE 11

Common Causes of Inaccurate Scale Indication

Inaccurate indication in a VOM or VTVM can be traced to various causes.

1. Overloads can damage multiplier resistors and change their resistance values. On AC ranges, VOM contact rectifiers can be damaged by overload.

2. Overloads can also damage the meter movement.

3. Excessive jarring and vibration can weaken the permanent magnets in the movement.

4. Placing a degaussing coil over or near a meter can weaken the permanent magnets in the movement.

5. Static electricity on the meter faceplate, commonly caused by wiping with a cloth, can cause the pointer to deflect incorrectly or to stick to the faceplate.

6. Some VOM's use printed-circuit wiring. Overloads due to accidental application of DC voltage or AC voltage on the ohmmeter function can burn out sections of the printed circuit.

7. AC voltage applied to a VOM on its DC ranges does not move the pointer. However, excessive AC voltage can burn out the multiplier resistors or the meter movement without producing any deflection.

To Check the Ohms-Per-Volt Rating of a VOM on Its Various DC Voltage Ranges

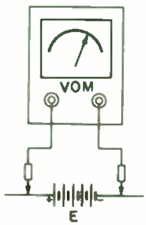
Equipment: Precision resistors with values equal to the ohms-per-volt rating of the VOM times the full-scale values of the various DC voltage ranges. For example, to check a rated 20,000 ohms-per-volt VOM with 2.5-, 10-, 50-, 250-, 1,000-, and 5,000-volt DC ranges requires precision resistors of 50,000 ohms, 200,000 ohms, 1 meg, 5 meg, 20 meg, and 100 meg. Any convenient DC voltage sources can be used.

Connections Required: First connect VOM leads directly to voltage source and measure the voltage value. Then connect the appropriate precision resistor in series with the instrument and the voltage source.

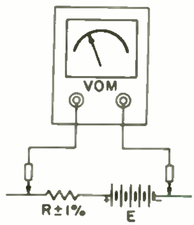
Procedure: Observe scale readings in the foregoing tests. Repeat for each DC voltage range.

Evaluation of Results: Scale indication drops to one-half (within limits of rated error) if the ohms-per-volt rating of the VOM times the full-scale value of the range is equal to the value of the precision resistor.

The same method can be used to check the ohms-per-volt rating of a VOM on its various AC voltage ranges. An AC voltage source is used, and the VOM is operated on its AC voltage functions.



Test setup for measuring voltage.



Test setup with resistor in circuit.

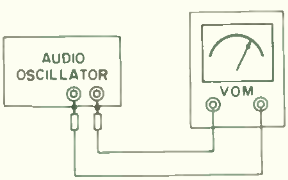
To Check the Frequency Response of a VOM on Its AC Voltage Ranges

Equipment: Audio oscillator.

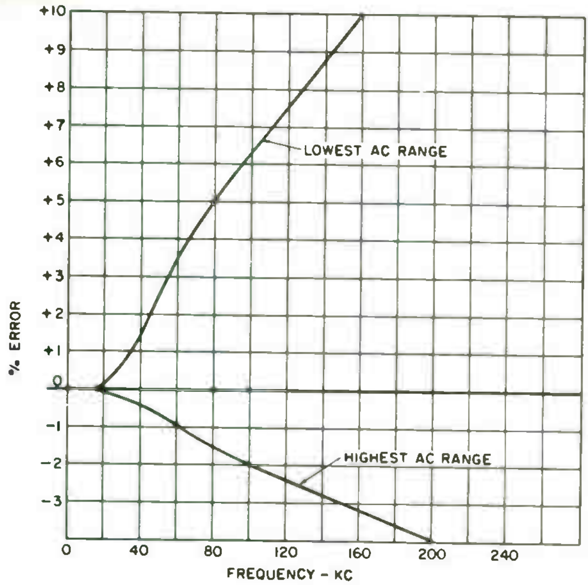
Connections Required: Connect VOM test leads to audio-oscillator output.

Procedure: Vary frequency of oscillator. Switch meter to adjacent ranges. Note voltage readings on adjacent ranges without changing the oscillator output.

Evaluation of Results: At some upper frequency, AC readings will become inaccurate. This occurs when the same reading is not obtained on adjacent ranges. The range-switching test is used to eliminate the possibility of nonuniform output from the oscillator at different frequencies. A VOM has a typical frequency response, as shown in the following. The rise or fall in response at high frequencies is caused by resonances. On some ranges, the stray capacitance in the meter bypasses part of the current. On other ranges, the stray capacitance resonates at high frequencies with the inductance of the movement. This resonance causes a false rise of voltage indication. At low frequencies, the pointer vibrates on the scale. This vibration is due to incomplete mechanical filtering of the rectified half cycles by inertia of the meter movement. VOM's vary greatly in frequency response. Those with half-wave, copper-oxide rectifiers are flat through the audio range only, or even less in some cases.



Test setup.



Typical AC voltage indication errors for VOM at high frequencies—full-wave bridge rectifier.

U9

To Check for Hum Voltage at the Ohmmeter Terminals of a VTVM

Equipment: VTVM with AC voltage ranges. (A second VTVM is used to check the ohmmeter section of the first VTVM.)

Connections Required: Connect the leads of the second VTVM to the ohmmeter terminals of the first VTVM.

Procedure: Set the first VTVM to its Ohms function. Set the second VTVM to its AC voltage function and to the lowest AC voltage range. Turn the range switch of the first VTVM through all its positions, from R × 1 to R × 1 meg. Observe scale of second VTVM for AC voltage indication.

Evaluation of Results: No AC voltage should be observed on any resistance range of the VTVM under test. AC voltage would be undesirable at the ohmmeter terminals because measurements of semiconductor diode resistance will then be in error.

Note that a VOM is *not* suitable for measuring the AC hum voltage from the ohmmeter terminals of a VTVM because the ohms-per-volt rating of the VOM is too low on its AC function to obtain a practical test.

NOTE 12

Standards Used to Calibrate VOM's and VTVM's

The most accurate standards of voltage and current are called primary standards. The primary standard of voltage is the Weston cell, and the primary standard of current is the silver-salt coulometer. However, primary standards are seldom used to calibrate service-type VOM's and VTVM's. Instead, secondary standards are utilized in most meter-repair depots. A typical secondary standard of voltage, current, and resistance is illustrated below.

Rated accuracy of the secondary standard on DC voltage and current is ±0.5% of full scale. Rated accuracy on AC voltage is ±0.75% of full scale. Rated accuracy of resistance values is ±1%. Note that there is no primary standard of resistance, because resistance is defined as an E/I ratio. The most accurate standard of resistance is called the international standard, and consists of a specified column of mercury utilized at 0°C. The calibrator illustrated does not employ the international standard of resistance, but uses instead precision wire-wound resistors. Special alloys are used in such wire-wound resistors to minimize the resistance change with temperature variations.

Typical calibrator for VOM's and VTVM's. (Courtesy of Simpson Electric Co.)

NOTE 13

Tolerances of Multiplier Resistors Connected in Series and in Parallel

Resistors in VOM and VTVM multipliers are usually rated at ±1% tolerance. Therefore, a nominal 1000-ohm resistor could have an absolute value from 990 ohms to 1010 ohms. If two resistors with a tolerance of ±1% each are connected in series, their tolerance is still ±1%. For example, if two resistors with a nominal value of 1000 ohms are connected in series, the combination series arrangement is 2000 ohms. If each resistor has a tolerance of ±1%, the range of absolute resistance is from 1980 ohms to 2020 ohms, or a variation of ±1% on the 2000-ohm nominal value. Again, consider the two 1000-ohm resistors connected in parallel. The nominal resistance of the combination is 500 ohms. If each resistor has a tolerance of ±1%, the tolerance of the parallel combination can range from 495 ohms to 505 ohms absolute. This is also a variation of ±1% on the nominal value of the parallel configuration.

NOTE 14

Multiplier and Movement Tolerances Are Additive

When a multiplier resistor is connected in series with a meter movement, the tolerances of the resistor and movement are additive. For example, a ±1% resistor connected to a ±2% meter movement gives a total tolerance of ±3%. Consider a meter movement that reads 2% low at full scale. If the multiplier resistor is 1% over its nominal value, the scale still reads lower by a total amount of 3%. Of course, if the multiplier resistor is 1% below its nominal value, the scale error is then reduced to 1%. Note that the same considerations apply for meter shunts; the total tolerance is the sum of the shunt tolerance plus the movement tolerance.

U10

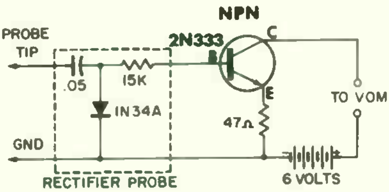
To Check a Signal Generator for Uniformity of Output

Equipment: Rectifier probe, transistor, 47-ohm resistor, 3K resistor, and 6-volt battery.

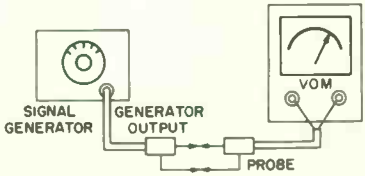
Connections Required: Construct a probe as shown in the following illustration and connect this probe to signal-generator output cable. Connect probe output cable to VOM as shown.

Procedure: Tune signal generator through the frequency range of interest. Note indication on DC current range of VOM (use 1-milliampere range).

Evaluation of Results: Some signal generators have uniform output over a wide range of frequencies. Others show considerable variation within a small frequency range. This variation must be taken into account when wide-band amplifiers are being checked.



Construction of a sensitive rectifier probe for checking signal-generator output.



Test setup.

DC VOLTAGE TESTS

U11

To Check an Electrolytic or Paper Capacitor for Leakage

Equipment: Power supply or battery.

Connections Required: First connect voltage source across capacitor terminals (observe polarity for electrolytic capacitors). Then disconnect voltage source and connect instrument test leads across capacitor.

Procedure: Apply working voltage or near working voltage to capacitor for the most conclusive test. For a very thorough test, wait about ten seconds after disconnecting the voltage source before connecting voltmeter to capacitor. Note initial reading of voltmeter when leads are connected.

Evaluation of Results: A good capacitor, after holding a charge for ten seconds, will initially measure practically the same voltage as the source. A poor capacitor will give a low or zero initial reading. Note that small capacitors cannot be tested satisfactorily: the initial reading cannot be obtained because the input resistance of the voltmeter rapidly discharges the capacitor.

To Measure Capacitance Values with a DC Voltmeter (VTVM)

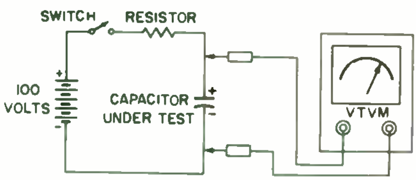
Equipment: Battery, resistor, and a watch with a second hand.

Connections Required: Connect battery, resistor, and the capacitor under test, as illustrated.

Procedure: Close the circuit and note the time required for the capacitor to charge to 63.2% of the final voltage.

Evaluation of Results: Suppose we use a 100-volt battery in the test. At the end of X number of seconds, the capacitor has charged to 63.2%. We then divide the number of seconds (X) by the value of the resistor to obtain the value of the capacitor. For example, if a 100-volt battery and a 1-megohm resistor require 40 seconds to charge a capacitor to 63.2%, the capacitor has a value of 40 microfarads. Or, if a 100-volt battery and a 100K resistor require 4 seconds to charge a capacitor to 63.2%, the capacitor has a value of 40 microfarads.

This test is accurate only for capacitors having high insulation resistance. If the resistor has a value of 1 megohm, and the VTVM has an input resistance of 10 megohms, the final charge on the capacitor when 100 volts is applied is 90.91 volts.



Test setup.

U13

To Measure Capacitance Values with a DC Voltmeter (VOM)

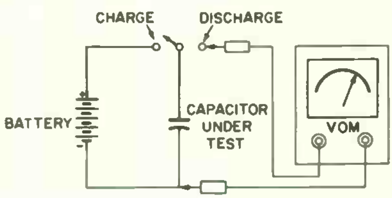
Equipment: Battery and a watch with a second hand.

Connections Required: First connect battery to capacitor, then connect capacitor to VOM as shown (or use SPDT switch).

Procedure: Observe the time required for the reading to fall to 36.8% of its initial value.

Evaluation of Results: If the reading takes X seconds to fall to 36.8% of the battery voltage, we find the capacitance value by dividing X by R_{in}, the input resistance of the VOM. For example, suppose we have a 100-volt battery. If the VOM is set to the 100-volt range, R_{in} is 2 megohms. If the reading takes 80 seconds to fall to 36.8 volts, the capacitor has a value of 40 microfarads. Or, if we have a 10-volt battery and operate the VOM on the 10-volt range, the input resistance is 200,000 ohms. If the reading takes 8 seconds to fall to 3.68 volts, the capacitance value is 40 microfarads. This test is accurate only for capacitors having high insulation resistance.

Test setup.



U14

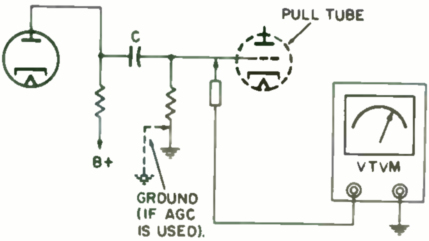
To Check a Coupling Capacitor for Leakage (VTVM)

Equipment: None.

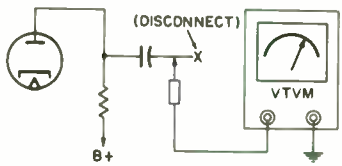
Connections Required: (Transformer-type receiver.) Pull the tube driven by the coupling capacitor to eliminate grid contact potential. Ground AGC line, if the grid resistor is not grounded. Connect VTVM test leads across the grid resistor.

Procedure: Set VTVM to lowest DC voltage range. Observe scale for any pointer deflection.

Evaluation of Results: Any DC voltage reading indicates that the coupling capacitor is leaking and should be replaced. This is a moderately sensitive test because B-plus voltage is applied to the capacitor. To make a highly sensitive test, disconnect the capacitor from the following circuit and measure from the open end of the capacitor to ground.



Test setup for in-circuit test.



Test setup for more sensitive test.

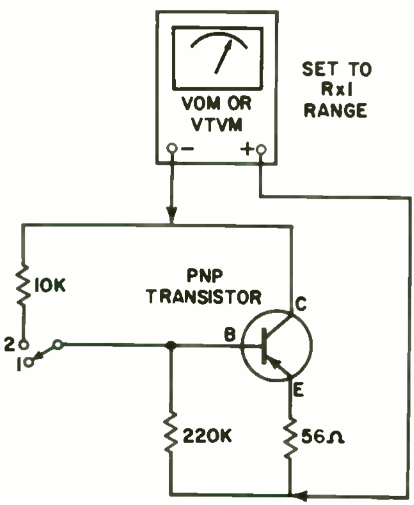
U15

To Make an Ohmmeter Test of a Transistor

Equipment: VOM or VTVM, 10K, 220K, and 56-ohm resistors, switch, transistor to be tested.

Connections Required: Connect equipment as shown in diagram below.

Procedure: Observe the pointer deflections obtained in position 1, and in position 2 of the switch. The VOM or VTVM is operated on its RX1 range.



Ohmmeter test of a transistor.

Evaluation of Results: The ohmmeter battery is used to power the test circuit, and applies a source potential of 1.5 volts. With the switch in position 1, the current flow is normally very slight, being only the leakage current of the transistor. However, with the switch in position 2, the amount of base current is determined by the 10K resistor. Normally, the current flow is much greater than before, and the pointer swings upscale on the VOM or VTVM. An audio-frequency transistor normally provides at least 8 times as much deflection in position 2 of the switch. If both readings are high, it is most probable that the transistor is shorted. If both readings are low, the transistor is defective and probably has too large a resistance in the forward direction.

NOTE 15

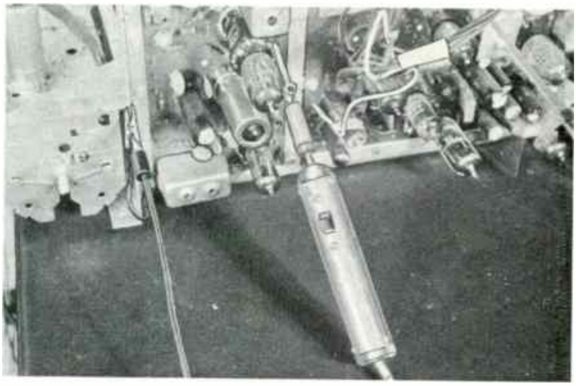
Ohmmeter Polarity in Transistor Test

A PNP transistor is depicted in U15. If you wish to test an NPN transistor, the test leads of the ohmmeter must be reversed. Most ohmmeters have the polarity of the test voltage marked on the instrument panel, or have red positive and black negative test leads. An occasional ohmmeter does not follow the red-and-black convention, and polarity markings may be absent. Hence, the beginner must consult the instruction manual in such a case.

NOTE 16

Polarity-Reversing Probe Can Be Used Instead of Reversing Test Leads

When making DC voltage tests in TV receiver circuits with a VOM, we often must reverse the test leads to measure positive and negative values. Many VOM's have no polarity-reversing switch. For finger-tip control of polarity indication, you can use a polarity-reversing probe, as shown in the following illustration. This is a simple switch-type arrangement for conveniently reversing the test leads of a VOM.



A polarity-reversing probe for a VOM. (Courtesy of Futuromic Co.)

U16

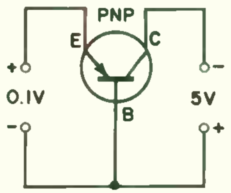
In-Circuit Transistor Testing by DC Voltage Measurements

Equipment: VOM, transistor, and associated circuit to be tested.

Connections Required: See Procedure.

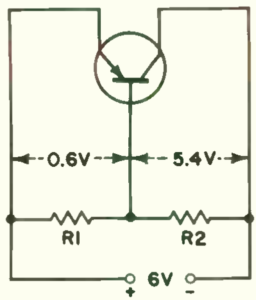
Procedure: Measure the base-to-emitter voltage, and measure the base-to-collector voltage for a common-base configuration such as depicted in the diagram below.

Evaluation of Results: In the basic PNP common-base configuration, the collector voltage is normally negative, and the emitter voltage is normally positive. The base of the transistor should be negative with respect to the emitter, and the base should be positive with respect to the collector. However, in the basic NPN common-base configuration, these polarities are reversed. The normal base-emitter bias voltage depends on the transistor material; germanium PNP or NPN types carry from 0.1 to 0.4 volt bias; silicon PNP or NPN types carry from 0.4 to 0.8 volt bias. If the measured voltages are significantly incorrect, it is indicated that the transistor is defective. Note that the foregoing bias voltages also apply to transistors connected in the common-emitter configuration.

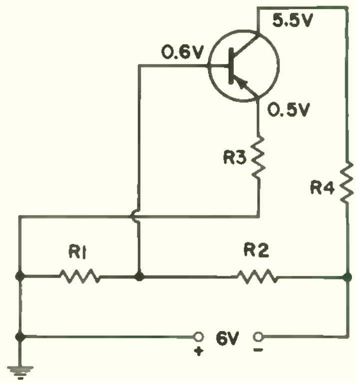


VOLTAGE MEASURED
WITH RESPECT TO GROUND

(A) Basic PNP transistor circuit.



(B) Biasing with one battery and a voltage divider.



(C) Positive end of battery is grounded.

A common-base configuration.

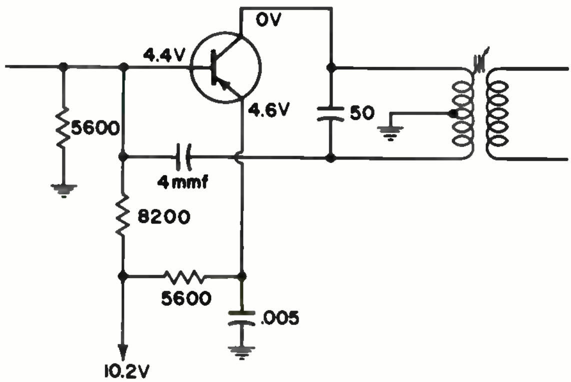
NOTE 17

Discussion of Transistor Voltages

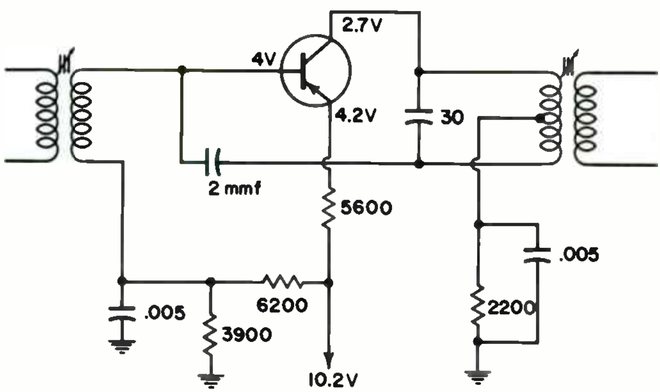
Observe that the negative terminal of the battery might be grounded instead of the positive terminal. In such case, the DC voltage distribution to ground is changed, although the base-emitter bias voltage has the same value. To avoid confusion, it is advisable to measure voltages from one electrode to another electrode of the transistor, instead of measuring voltages with respect to ground. This method also permits more accurate readings, because it does not require subtracting two values to calculate the emitter-base bias. Observe the two common-emitter configurations depicted in the diagram below. When a transistor becomes defective, you will often find a considerable change in electrode voltages. If the base-to-collector junction breaks down in (A), the emitter voltage falls from 4.6 volts to almost zero (voltage measured with respect to ground). This change results from the fact that there is practically no resistance to current flow from emitter to collector. The base voltage falls slightly in this event, due to increased base-current drain. In turn, the transistor has a large reverse bias between the base and emitter electrodes. Nevertheless, this reverse bias has not cut off the transistor, as will be explained, and there is heavy current flow from emitter to collector.

The abnormal DC voltage distribution shows that the emitter-base junction has also broken down. This damage follows breakdown of the base-collector junction. When the base-collector junction breaks down, the abnormal current drain causes the base voltage to drop. In turn, a large forward-bias voltage is applied between emitter and base. The excessive emitter current overheats the base-emitter junction, causing breakdown. In turn, the emitter voltage falls to practically zero. Observe that zero emitter voltage in (A) could also be caused by a short in the 0.005 capacitor. But in this case, the DC distribution is different—the transistor is merely cut off, and the base voltage increases to about 5.8 volts.

Again, zero emitter voltage in (A) can be caused by a short in the 4-mmf capacitor. In such case, a large forward bias is applied between base



(A) Zero-emitter voltage can be caused by shorted 4-mmf capacitor.



(B) Leaky transistor can affect DC voltage distribution.

Typical common-emitter IF circuits.

and emitter, causing excessive current flow and destroying both junctions in the transistor. The base voltage will read zero.

Next, consider the effect of a leaky transistor on the DC voltage distribution in (B). Leakage means that the collector-base junction has a poor front-to-back ratio. Accordingly, the transistor draws excessive current and the collector voltage increases due to an increased voltage drop across the 2200-ohm resistor. Since the collector-base junction has subnormal resistance, the base voltage decreases; however, subnormal junction resistance permits substantial current flow from base to collector. In turn, the emitter current is reduced, and the emitter voltage decreases. Observe in (B) that the normal forward bias between emitter and base is 0.2 volt. When the transistor is leaky in a typical trouble situation, the forward bias is reduced to 0.1 volt. However, the collector voltage increases because of substantial current flow from base to collector permitted by the leaky base-collector junction.

U17

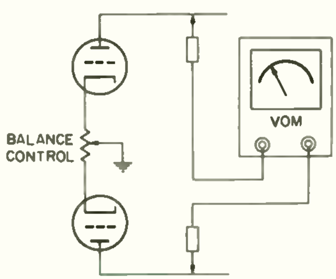
To Check a Push-Pull Amplifier for Balance (VOM)

Equipment: None.

Connections Required: Connect test leads of VOM to plates of push-pull tubes.

Procedure: Adjust amplifier balance control(s). Observe DC voltage readings.

Evaluation of Results: Amplifier is properly balanced when the VOM reads zero (use low DC voltage range as balance is approached). This test cannot be made satisfactorily with a VTVM because both sides of the circuit are "hot": a VTVM requires that one side of the circuit be grounded or nearly at ground potential.



Test setup.

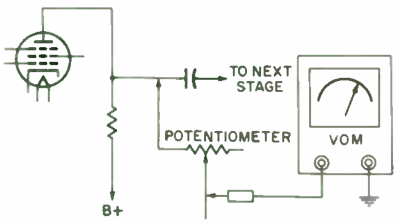
To Measure the Internal Resistance of a Circuit (Potentiometer Method)

Equipment: Potentiometer.

Connections Required: Connect potentiometer in series with VOM test lead. Apply arrangement to circuit under test, as shown in the following.

Procedure: With potentiometer set to zero resistance, read voltage value on the DC scale of the VOM. Then increase the potentiometer resistance until the voltage reading is reduced to one-half. Disconnect potentiometer and measure its resistance.

Evaluation of Results: The internal resistance of the circuit is equal to the resistance of the potentiometer minus the input resistance of the VOM. For example, if you are operating on the 30-volt range of a 20,000 ohms-per-volt VOM, its input resistance will be 600,000 ohms. If you measure a given voltage at the plate of an amplifier and find that a potentiometer resistance of 800,000 ohms is required to reduce the reading to one-half, the internal resistance of the plate circuit will be 200,000 ohms.



Test setup.

U19

To Measure the Internal Resistance of a Circuit (Range-Switching Method)

Equipment: None.

Connections Required: Connect VOM test leads to circuit under test.

Procedure: Make DC voltage readings on two ranges.

Evaluation of Results: Calculate the internal resistance by:

$$R_{in} = \frac{R_1 R_2 (E_2 - E_1)}{E_1 R_2 - E_2 R_1}$$

where,

R_{in} is the internal resistance of circuit,
R_1 is the input resistance of VOM on the first range setting,
E_1 is the scale reading on the first range setting,
R_2 is the input resistance of VOM on the second range setting.
E_2 is the scale reading on the second range setting.

U20

To Check the Operation of an Oscillotor

Equipment: None if VTVM is used. Isolating resistor if VOM is used.

Connections Required: Apply leads from meter to grid of oscillator tube and to chassis ground. Then apply leads from plate of tube to chassis.

Procedure: Measure DC voltage at grid and observe change as oscillator tank is tuned. Do the same at the plate.

Evaluation of Results: The DC voltage at the grid of an oscillator is a signal-developed bias which indicates the peak voltage of the AC signal at the grid. Zero (or nearly zero) grid voltage indicates that the oscillator is inoperative. Correct grid-voltage values are usually specified in receiver service literature. The DC voltage at the plate of an oscillator rises when the tube is oscillating (because of the negative grid-bias developed). Receiver service literature usually indicates normal operating voltage at the plate.

NOTE 18

VTVM Pointer Shift Caused by Internal Contact Potential

Contact potential is present in the tubes of a VTVM. This contact potential causes the zero setting of the pointer to shift from one DC voltage range to the next. Generally, the greatest shift is found when the VTVM is switched to its lowest DC voltage range. The pointer should be zero-adjusted with the test leads short-circuited. Otherwise, there will be a contact-potential error in the measurement when the test leads are connected across a circuit under test. For a completely accurate zero setting, the pointer should be zero-adjusted, and the test leads should be connected across a resistor having the same value as the internal resistance of the circuit to be tested. However, this step becomes of practical importance only when small voltages are to be measured in very high resistance circuits.

U21

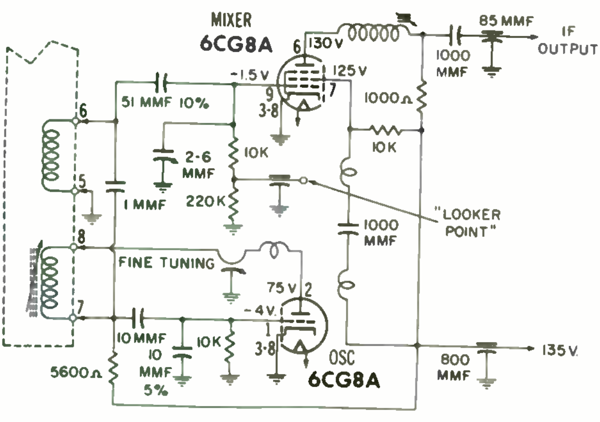
To Measure the Oscillator-Injection Voltage at the Mixer-Tube Grid

Equipment: None.

Connections Required: Apply voltmeter leads between "looker point" of RF tuner and chassis ground.

Procedure: Tune receiver to vacant channel. Short-circuit its antenna-input terminals. Switch RF tuner through the various channels. Observe DC voltage indication on meter.

Evaluation of Results: Proper tuner operation depends upon correct oscillator-injection voltage. The meter indicates the injection voltage indirectly as a signal-developed bias. Compare scale reading with service data or with another RF tuner of the same type known to be in good operating condition.



A typical oscillator-mixer circuit.

U22

To Check a Radio or Television Receiver for IF Oscillation

Equipment: None.

Connections Required: Apply leads from VOM or VTVM across the video-detector load resistor.

Procedure: Tune in a station signal and observe DC voltage indication.

Evaluation of Results: A high DC voltage reading, such as 5, 10, or 15 volts, indicates IF oscillation. In most instances, application of override AGC bias will stop the oscillation. Incorrect peak-alignment of IF coils is a common cause of IF oscillation.

U23

To Check the IF Sensitivity of a TV Receiver

Equipment: Calibrated IF signal generator; or uncalibrated generator and a good field-strength meter to check generator output. (Use a balun, as explained in the companion volume, *101 Ways to Use Your Sweep Generator*.)

Connections Required: Short the RF secondary coils of the RF tuner to ground. Connect a DC voltmeter across the video-detector load resistor. Apply the generator output through a 470-mmf capacitor to the grid of the mixer tube.

Procedure: Determine how many microvolts of signal must be applied from the generator to obtain a 1-volt rise above noise level at the picture-detector output.

Evaluation of Results: In a typical receiver, 300 microvolts or less are required. Consult receiver service notes or make comparative test on a receiver of the same type known to be in good operating condition.

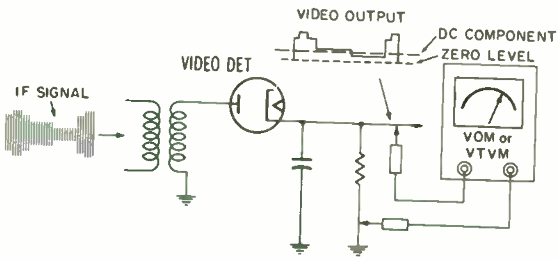
To Check the DC Voltage Output from a Video Detector

Equipment: None. (Pattern generator optional.)

Connections Required: Apply leads from VOM or VTVM across the video-detector load resistor.

Procedure: Tune in a station signal and observe DC voltage indication.

Evaluation of Results: The DC voltage indication fluctuates unless a pattern generator is used. The meter indicates the DC component or background voltage in the video signal. Average values are often specified in receiver service notes. Zero (or near zero) DC voltage indicates a faulty RF amplifier, IF amplifier, or video detector.



Video-detector circuit.

U25

To Check the Noise Level in the RF and IF System of a TV Receiver

Equipment: None.

Connections Required: Connect leads from VOM or VTVM across video-detector load resistor.

Procedure: Short antenna-input terminals of receiver. Tune to vacant channel. Observe DC voltage indication.

Evaluation of Results: Consult receiver service literature for the permissible voltage reading in the test, or compare with value found in a similar receiver known to be in good operating condition. Higher than permissible readings indicate noisy tubes or noisy resistors in the signal circuits. This handicaps reception of weak signals.

U26

To Adjust a Color-AFC Balance Control

Equipment: None.

Connections Required: Connect VTVM between arm of balance control and chassis ground.

Procedure: Tune in a color broadcast or drive the receiver from a color-bar generator. Operate VTVM on its lowest DC voltage range. Adjust the balance-control potentiometer.

Evaluation of Results: Potentiometer is correctly adjusted when VTVM indicates a slow positive and negative drift near the zero-volts point.

U27

To Measure AGC Voltage with a VOM

Equipment: None.

Connections Required: Connect VOM between the AGC line and chassis ground (or B−).

Procedure: Operate VOM on DC voltage function. Turn the range switch through the positions on which a useful reading can be obtained. Operate the receiver as specified in the service data to obtain a test under standard conditions.

Evaluation of Results: In general, different voltage indications are obtained on each range because the VOM loads the AGC circuit. The input resistance of the VOM increases when a higher range is used. The most accurate measurement will be obtained on the highest usable range. (See the following chart.)

Typical AGC Voltage Indications with a 20,000 Ohms-Per-Volt VOM

(True AGC voltage is −7.8 volts)

Range (Volts)	*Indication (Volts)*	*Actual Error (%)*
2.5	−1.7	78
10	−4.1	47
50	−6.6	15

Note that the foregoing also gives us a quick test for circuit loading. If *different* voltage values are measured on *adjacent* ranges of a VOM, we know that circuit loading is present.

NOTE 19

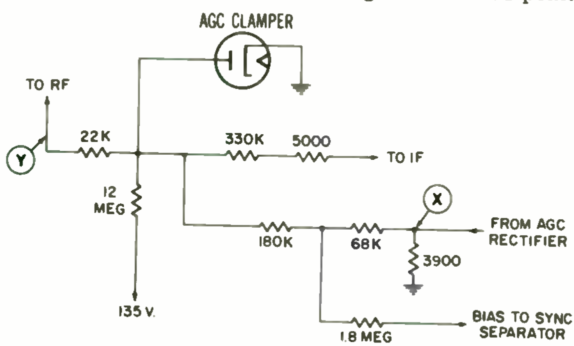
Microampere Range of VOM Is a Millivoltmeter

A VOM can measure low voltages (below 250 millivolts in low-impedance circuits) if a microamp current range is used as a DC voltage range. For example, a typical VOM has a 50-microamp range with a 250-millivolt drop at full scale. Hence, the "50" scale can be read in terms of microamps, or the "250" scale can be read in terms of millivolts. You will note that, although this 250-mv range is a 20,000 ohms-per-volt range, the input resistance of the VOM is only 5000 ohms (.250 × 20,000 = 5,000). Hence, DC voltage measurements on this range will be in error unless the circuit has a low internal resistance.

NOTE 20

Instrument Loading Causes a Different Error at Various AGC Circuit Points

The indicated value of AGC voltage depends upon the point of test in the AGC circuit and upon the VOM range used. For example, in the following diagram we will measure a higher value of voltage at X than at Y. The internal resistance of the circuit is much lower at X, and the VOM has correspondingly less loading effect at this point.



A typical AGC circuit.

NOTE 21

Floating Grid of Operating Tube Shows Contact Potential

When the AGC line is disconnected from an operating tube, negative voltage can still be measured at the open grid. This voltage is contact potential and disappears if the tube is cold. Using a 20,000 ohms-per-volt VOM, you will measure a typical value of −1 volt contact potential on the 10-volt range. On the 2.5-volt range, you will measure a lesser value, such as −¼ volt, because of the internal resistance of the contact-potential source. On a VTVM, contact potential will measure about −1 volt.

U28

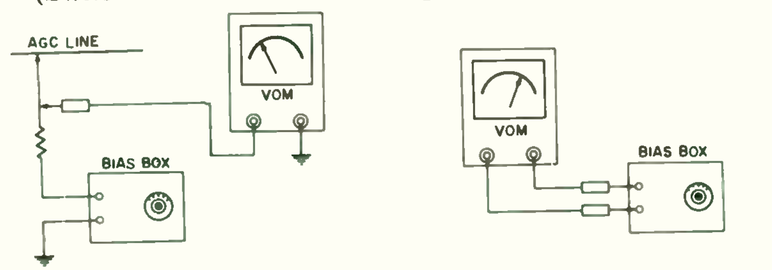
To Measure AGC Voltage Accurately with a VOM (Bias Box Method)

Equipment: DC bias box and fixed resistor. (Value of resistor is not critical, but should be approximately the same resistance as the internal resistance of the AGC circuit.) See U18

Connections Required: Connect VOM, bias box, and resistor as shown at A in the following diagram.

Procedure: Set the VOM to its lowest DC voltage range. Adjust bias box for zero indication on VOM scale. (You can make and break the VOM connection to the circuit to make sure you have a true zero; the pointer does not move at true zero.) Next, without changing bias-box setting, connect the VOM leads across the bias-box terminals, as shown at B in the following illustration.

Evaluation of Results: The reading obtained with the VOM connected across the bias-box terminals is the actual AGC voltage present at the point of test in the AGC circuit. (Switch VOM to suitable voltage range.)



(A) Bias box connected to AGC line.

(B) Measuring voltage at bias-box terminals.

Test setup.

To Accurately Measure AGC Voltage with a VOM (Potentiometer Method)

Equipment: Potentiometer.

Connections Required: Connect potentiometer in series with VOM test lead, as shown in the following. Apply arrangement between AGC line and chassis ground.

Procedure: Observe reading on DC volts scale of VOM, with potentiometer set for zero resistance. Then increase the potentiometer resistance to reduce the reading to one-half and measure resistance of the potentiometer.

Evaluation of Results: The AGC voltage can be calculated from the readings obtained in the foregoing tests by using the formula:

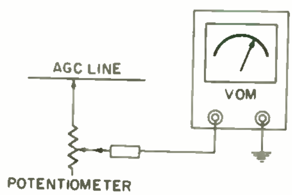
$$E = \frac{E_M R_1}{R_M}$$

where,

E is the true AGC voltage,
E_M is the initial reading in volts,
R_M is the input resistance of the VOM,
R_1 is the potentiometer resistance necessary to reduce the voltage reading in half.

For example, assume that we read 2 volts on the 10-volt range of a 20,000 ohms-per-volt VOM and that a potentiometer resistance of 500,000 ohms is needed to reduce the voltmeter reading to 1 volt. The true AGC voltage can then be calculated as follows:

$$E = \frac{E_M R_1}{R_M} = \frac{2 \times 500{,}000}{200{,}000} = \frac{1{,}000{,}000}{200{,}000} = 5 \text{ volts.}$$



Test setup.

U30

To Accurately Measure AGC Voltage with a VOM (Range-Switching Method)

Equipment: None.
Connections Required: Connect VOM test leads to AGC line.
Procedure: Observe meter readings on two DC voltage ranges.
Evaluation of Results: Calculate the actual AGC voltage from:

$$E = \frac{E_1 E_2 (R_2 - R_1)}{E_1 R_2 - E_2 R_1}$$

where,
E is the true AGC voltage,
E_1 is the meter reading on the first range setting,
R_1 is the VOM input resistance for the first range setting,
E_2 is the meter reading on the second range setting,
R_2 is the VOM input resistance on the second range setting.

U31

To Check for Circuit Loading in AGC Voltage Measurements with a VTVM

Equipment: Precision resistor having a value equal to the VTVM input resistance.
Connections Required: First connect VTVM leads to AGC circuit under test. Then insert resistor in series with VTVM lead.
Procedure: Observe voltage indications obtained in each test.
Evaluation of Results: The second voltage indication should be one-half the first indication. If the second indication is more than one-half, circuit loading is present.

To Measure the Cathode Current of a Horizontal-Output Tube with a DC Voltmeter (VOM or VTVM)

Equipment: None.

Connections Required: Connect voltmeter test leads across cathode resistor.

Procedure: Observe reading on DC scale of instrument. Determine value of cathode resistor. Current is calculated by Ohm's law. Adjust drive and linearity controls as follows.

Evaluation of Results: Adjust the horizontal-drive control for minimum current; maintain full sweep width without drive lines. Adjust the horizontal-linearity coil for a current dip or for minimum current without distortion. The meter indicates average cathode current. (Tube manuals give maximum ratings for both peak and average currents.) The 6BQ6 is rated for a maximum of 110 ma cathode current; 6CD6, 200 ma; 6DQ6, 140 ma.

If the horizontal-output circuit has no cathode resistor, the method described in U83 must be used.

NOTE 22

Current Drawn by Any Tube Electrode Can Be Measured

The current drawn by any tube electrode can be measured in the same manner as is explained in U32. However, if there is no series resistor in the circuit, the DC current must be measured by opening the circuit, as described in U83.

NOTE 23

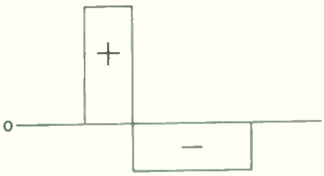
DC Voltage Indication Obtained in Corona Field

When working in the vicinity of the flyback system, you will sometimes observe that a DC voltage deflection occurs on the meter if the test prod is brought near the horizontal-output tube or other parts of the high-voltage circuit. This is a corona indication. DC voltage is indicated because of invisible spark rectification between the test prod and the corona field.

NOTE 24

AC Pulses Have an Average Value of Zero, Although Peak Voltages Differ

Beginners sometimes suppose that a pulse voltage can be measured on a DC voltmeter. This is not possible because the average value of an AC pulse voltage is zero. As illustrated in the following, the positive area of the AC pulse voltage is equal to the negative area of the AC pulse voltage. Therefore, a DC meter will indicate zero.



An AC pulse voltage.

U33

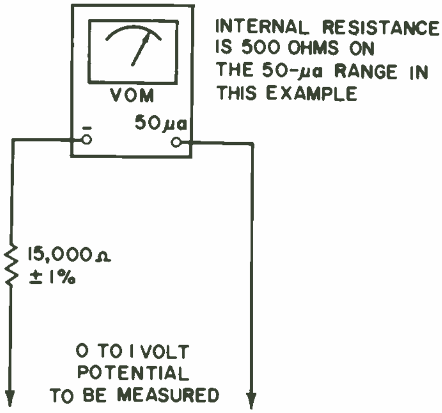
To Measure DC Voltages Below the Lowest Normal Range Provided by a VOM

Equipment: Precision resistor (±1%) of suitable resistance value.

Connections Required: Connect resistor in series with one of the test leads of the VOM as shown.

Procedure: Operate VOM on the selected low DC current range.

Evaluation of Results: Let us take a particular example, such as a VOM that has an internal resistance of 5000 ohms for 50 microamperes full-scale deflection. According to Ohm's law, 0.25 volt would have to be applied on the 50-microampere range of the VOM for full-scale deflection. In turn, if the external resistor is zero (test leads used directly), the 50-microampere range operates as a 0.25-volt full-scale voltmeter. We would use the 250-volt scale, and divide the indication by 1000. Again, if we wish to provide a 1-volt full-scale range we must bring the total resistance of the 50-microampere range to 20,000 ohms. Since the meter has an internal resistance of 5000 ohms in this example, the external resistance will have a value of 15,000 ohms. We would read the 100-volt DC scale on the meter, and divide the indication by 100.



Provision of a 1-volt DC full-scale range with a VOM having the noted characteristics.

NOTE 25

Precautionary Considerations

Since it is easily possible to burn out the meter movement if an error is made in calculation, do not take anything for granted, and check your calculations carefully before proceeding. The internal resistance of your VOM on its low-current ranges is usually specified in the operating manual. Also, be sure to make a preliminary measurement of the voltage on a conventional range of the VOM before using the modified low-current range. For example, suppose that you are planning to measure a voltage that you believe is less than 0.25 volt; first, make a rough measurement on the 2.5-volt range of the VOM. If the voltage should happen to exceed 0.25 volt appreciably, this fact should be determined before possible damage is incurred on the modified low-current range.

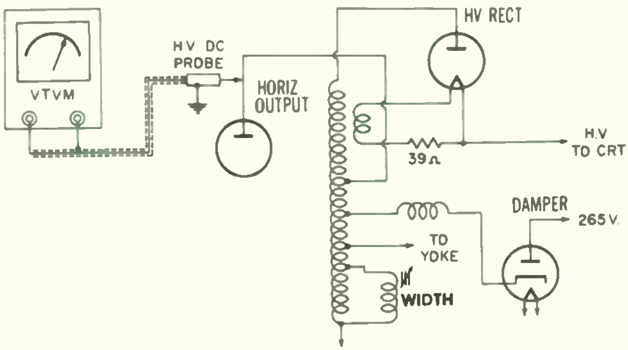
To Measure DC Voltage when High-Voltage AC Pulses Are Present (VTVM)

Equipment: High-voltage DC probe with 100-to-1 attenuation factor.

Connections Required: Apply probe between point of measurement and chassis ground (such as plate of damper tube to chassis). Feed probe output to input terminals of VTVM.

Procedure: Switch VTVM to one of its low DC-voltage ranges, such as 3 or 5 volts. Observe scale indication.

Evaluation of Results: Multiply scale indication by 100. This is the value of DC voltage at the point under test.



A typical flyback circuit.

NOTE 26

How High-Voltage DC Probe Protects Meter Against AC Pulses

When a high-voltage DC probe with a shielded output cable is used to check DC voltage in the presence of high-voltage AC pulses, the RC network (formed by the resistor and the capacitance between the resistor and the shield of the probe and between the lead-in wire and the shield of the cable) operates as a low-pass filter. The AC voltage is prevented from reaching the VTVM and possibly damaging its input circuit. Because the DC voltage is so much smaller than the AC voltage, a 100-to-1 probe is required to obtain the desired attenuation of AC voltage. A VTVM must be employed in this type of test because the probe multiplies *each* range of a VTVM by 100. On the other hand, a VOM cannot be employed because a probe is designed for the top voltage range of the instrument only. If the probe is used on the lower range of a VOM, the indication will not be useful and the attenuation factor (unless calculated) will be unknown. Hence, such tests are made with a VTVM only.

A high-voltage DC probe. (Courtesy of Precision Apparatus Co.)

U35

To Measure the Plate Dissipation of a Horizontal-Output Tube (VTVM)

Equipment: 100-to-1 high-voltage DC probe.

Connections Required: Connect VTVM to probe output cable. Measure plate voltage, as explained in U34. Then measure the plate current by using the conventional DC input cable for the VTVM. Measure plate current by reading the voltage drop across the plate decoupling resistor and by applying Ohm's law.

Procedure: Multiply the plate voltage by the plate current (in amperes) to get the plate dissipation (in watts).

Evaluation of Results: Check the measured plate dissipation against the maximum rating published in tube manuals.

To Measure Small Voltage Differences

Equipment: Battery of suitable terminal voltage.

Connections Required: Connect the battery in series with the source voltage, in reverse (bucking) polarity, as depicted in the diagram.

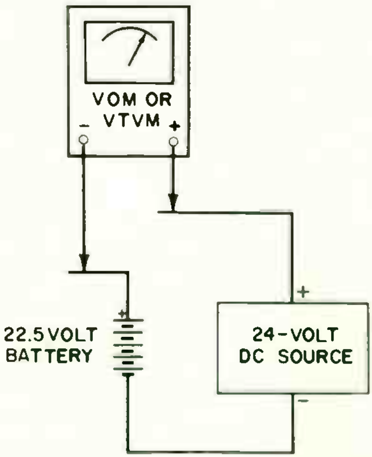
Procedure: Set the VOM or VTVM to a low-voltage range, in order to measure the difference voltage.

Evaluation of Results: This is a suppressed-zero scale technique. A suppressed-zero scale means that voltages below a certain value cause no up-scale deflection. Specialized meters of this type are commonly called "segmental" voltmeters. By "suppressing" the unnecessary portion of the scale, the critical range can be spread out over the entire scale length. This technique can be used to indicate very small variations in a voltage source. In the example shown below, small variations in a 24-volt source are being measured. The battery has a terminal voltage of 22.5 volts, and the meter is operated on a low DC-voltage range, such as 2.5 volts.

NOTE 27

Accuracy Considerations

This suppressed-zero scale technique does *not* increase the accuracy of the reading that would be obtained on a higher DC-voltage range, such as 50 volts, *unless* a precisely known bucking voltage is used. This technique,



Bucking-voltage method of obtaining a suppressed-zero scale indication.

when used with a bucking voltage that has an accuracy no higher than the inherent accuracy of the meter, merely makes possible the measurement of very small *changes* in the source voltage.

OHMMETER TESTS

U37

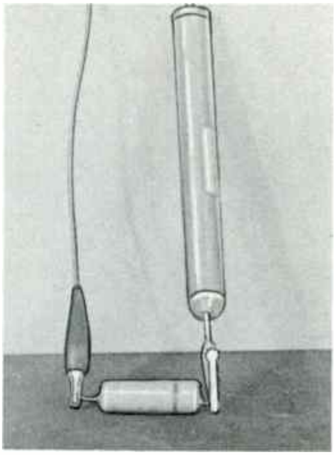
To Measure Resistance Values Up to 200 Megohms With a VOM

Equipment: High-ohms probe for VOM.

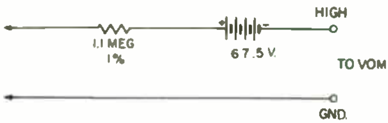
Connections Required: Plug probe into VOM input terminals. Connect probe across capacitor or other component under test.

Procedure: Operate VOM on its highest resistance range. Observe scale reading. Multiply reading by 10.

Evaluation of Results: Since resistance values beyond 200 megohms cannot be read on usual VOM's with a high-ohms probe, high-resistance measurements must be restricted to components having values within this range. Also note that a VOM high-ohms probe permits more accurate measurements of resistance values in the range from 1 to 20 megohms (compared with the use of ordinary test leads), because readings are obtained on the more expanded portion of the ohmmeter scale. The circuit given below is for a VOM having 120,000 ohms input resistance on the R × 10,000 ohms range and an internal battery of 7.5 volts. The 67.5 volts for the probe is obtained by using three 22½-volt hearing-aid batteries.



Checking the insulation of a paper capacitor with a high-ohms probe.



Circuit for a VOM high-ohms probe.

U38

To Measure Resistance Values Down to Small Fractions of an Ohm

Equipment: Low-ohms probe. (See Note 28.)

Connections Required: Plug low-ohms probe into VOM. Connect probe leads across component or circuit under test.

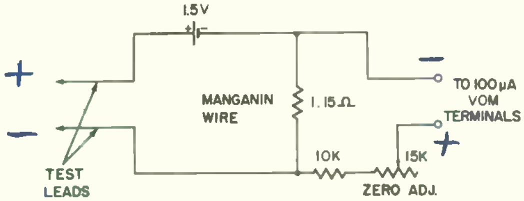
Procedure: Use the external zero-set adjustment, as for a usual ohmmeter function. VOM is operated, however, on its microampere range. (Internal battery of VOM is not used with low-ohms probe because heavy current is required for low-resistance measurements with a series ohmmeter.)

Evaluation of Results: Ohmmeter scale reading is multiplied by 0.1.

NOTE 28

Construction of a Low-Ohms Probe

The configuration for a low-ohms probe (or box) used with a VOM having a 100-microampere current range with an input resistance of 2,500 ohms (full-scale voltage drop of 250 millivolts) and 12 ohms center-scale indication is given below. Note that the circuit, including the 1.15-ohm Manganin-wire resistor and test leads, must have very low resistance. Use bus leads from Manganin-wire resistor, heavy ultraflex armature wire for the test leads, and heavy copper clips to terminate the test leads. Manganin wire is used for the resistance to maintain a constant value of 1.15 ohms whether hot or cold. Battery can be any 1.5-volt type with very low internal resistance and high current capability.



Circuit for a VOM low-ohms probe.

NOTE 29

Low-Ohms Probe Runs Down Short Circuits

A low-ohms probe or box is useful for running down short circuits. As the short-circuit point is approached, the resistance reading decreases. A low-ohms probe is also handy for checking switch-contact resistance, cold-soldered joints, and resistance values of small coils.

NOTE 30

Probe Values Must Be Suitable to Make Scale Track

When calculating configurations for high-ohms or low-ohms probes, keep in mind that we wish to make the VOM or VTVM ohms scale "track" when the probe is used. Thus, we cannot use just any values of voltage and resistance in the probe network. A convenient starting point is to observe the center-scale indication of the ohms scale. Next observe the battery voltage and the reference resistor used on the R × 1 range. In calculating probe configurations, maintain proportional values to obtain scale tracking.

To Check a Semiconductor Diode

Equipment: None.

Connections Required: Connect ohmmeter leads to diode terminals. Then reverse the test leads.

Procedure: Set ohmmeter to range which gives readable scale indications. Observe readings obtained in the two tests. To obtain the front-to-back ratio, divide the smaller reading into the large reading.

Evaluation of Results: The most useful evaluation is obtained by comparing the measured front-to-back ratio with that obtained from a known good diode of the same type, with same ohmmeter set to the same range.

NOTE 31

Readings Will Differ on Various Ranges

Semiconductor diodes, like transistors, are nonlinear resistance devices. Consequently, the actual resistance values indicated by an ohmmeter depend greatly upon the battery voltage and internal resistance of the ohmmeter. These values are not the same for different instruments and are different for the same instrument when it is switched to another range. The following readings are typical for a 1N34 germanium diode:

Ohmmeter Set to R × 1 Range

Forward resistance .... 140 ohms
Back resistance .... Unreadable

Ohmmeter Set to R × 100 Range

Forward resistance .... 400 ohms
Back resistance .... 200,000 ohms

Ohmmeter Set to R × 10,000 Range

Forward resistance .... 2,000 ohms
Back resistance .... 200,000 ohms

U40

To Check the Condition of a Globar Resistor

Equipment: None.

Connections Required: Make sure the receiver is off and the resistor is cold. Connect ohmmeter test leads across the Globar resistor. Then disconnect the ohmmeter. Turn receiver on for two or three minutes. Finally, turn receiver off, and reconnect ohmmeter leads across Globar resistor.

Procedure: Observe resistance readings obtained in each of the two tests.

Evaluation of Results: Compare readings with values specified in receiver service data. The cold resistance is normally about 15 to 150 times the hot resistance. Thermal resistors tend to change characteristics with age.

U41

To Check a Paper Capacitor for Leakage (VTVM)

Equipment: None.

Connections Required: Connect ohmmeter test leads across capacitor terminals.

Procedure: Set ohmmeter to its highest range (usually R × 1 Meg).

Evaluation of Results: A paper capacitor should test over 1,000 megohms insulation resistance. In general, if any resistance reading other than infinity is obtained in this test, the capacitor should be discarded. Since this test is made with only the ohmmeter voltage across the capacitor, it is inconclusive.

To Test a Paper Capacitor for Leakage With a High-Ohms Probe (VTVM)

Equipment: High-ohms probe.

Connections Required: Disconnect capacitor from circuit. Connect probe across capacitor terminals.

Procedure: Set ohmmeter to its highest range. Observe scale indication. Multiply reading by 10.

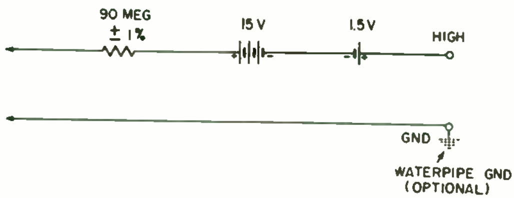
Evaluation of Results: A good coupling capacitor should check well over 1,000 megohms insulation resistance. A VTVM high-ohms probe permits measurement of resistance values up to 10,000 or 20,000 megohms. This test is not completely conclusive because the high-ohms probe usually applies only a small voltage—approximately 15 volts—to the capacitor under test.

NOTE 32

High-Ohms Probe

The circuit of a high-ohms probe for a VTVM having 10 megohms input resistance and a 1.5-volt ohmmeter battery is given in the following illustration. The 15-volt battery is a hearing-aid type and the 1.5-volt bucking battery is a penlight cell. This probe multiplies the R × 1 Meg range of the VTVM by 10.

Sometimes the resistance readings obtained with a high-ohms probe are unstable. This unstable condition is due to the line-operated power supply in the VTVM and can be corrected by grounding the case to a water pipe as shown in the illustration.



Circuit for a VTVM high-ohms probe.

To Check an Electrolytic Capacitor for Leakage

Equipment: None.

Connections Required: Connect ohmmeter leads to terminals of electrolytic capacitor (observe polarity).

Procedure: Observe indication on Ohms scale. Note that large capacitors can be charged more quickly by switching the ohmmeter progressively from the lowest range to the highest range.

Evaluation of Results: The test will indicate electrolytic capacitors which are definitely "bad." However, because limited voltage is applied, this test is not conclusive, except for low-voltage electrolytic capacitors in transistorized equipment. In the latter, you must be careful not to exceed the voltage rating of the capacitor. Note also that a VOM high-ohms probe commonly applies up to 75 volts across the capacitor under test; a VTVM high-ohms probe commonly applies up to 15 volts.

U44

To Make a Hot Check for Interelectrode Leakage In a Picture Tube

Equipment: Test leads.

Connections Required: Disconnect the high-voltage cable from the picture tube. Short the high-voltage terminal of the tube to chassis, to discharge tube. Connect ohmmeter between terminals of tube to be tested. Socket must be removed from tube, and temporary heater connections made with test leads.

Procedure: Operate ohmmeter on its highest resistance range. Check for leakage resistance from cathode to control grid, second grid, focusing anode (if present), and second anode. Repeat test from control grid to second grid, focusing anode (if present), and second anode. Make a final check from the focusing anode to the second anode.

Evaluation of Results: Any reading other than infinite resistance is cause for rejecting, or at least suspecting the usability of, the picture tube.

A hot check is more reliable than a cold resistance test. Observe that the positive ohmmeter lead must be connected to the cathode of the picture tube when making hot resistance tests. Otherwise, the ohmmeter battery will cause a small beam current to flow and falsely indicate the presence of leakage resistance.

NOTE 33

Burning Out Shorts or Leaks in Picture Tubes

If the ohmmeter shows the presence of leakage resistance in the test of U44, it is sometimes possible to burn out the leakage path. Use a filter capacitor as a voltage source. Charge up the filter capacitor from a plate-supply lead in the chassis. Then, touch the capacitor leads to the tube pins which have leakage resistance between them. If the ohmmeter shows that the leakage resistance is not completely burned out on the first application of surge voltage, the procedure can be repeated. Note that the plate-supply voltage or the second-anode voltage should not be used directly to clear leaks or shorts. Damage to the picture tube can result from use of excessive current or voltage in this procedure.

SIGNAL-TRACING TESTS

U45

To Check for Open Screen and Cathode Capacitors

Equipment: Signal-tracing probe.

Connections Required: Connect probe to VOM or VTVM. Apply probe across capacitor under test.

Procedure: Operate meter on DC voltage function and observe reading.

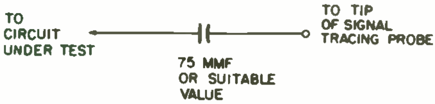
Evaluation of Results: When a screen or cathode capacitor opens, the AC voltage across the capacitor rises greatly. This fact is used to localize open capacitors. For example, when the screen capacitor in a typical horizontal-output circuit opens, the meter reading increases about 10 times. If a full-wave probe is used with a VTVM, the peak-to-peak voltage can be checked against the value in the receiver service literature.

CAUTION: In some receivers, the AC screen voltage is large enough to damage a semiconductor diode; therefore, a voltage divider should be used, as explained in Notes 34 and 35.

NOTE 34

Capacitance Divider for Signal-Tracing Probe

When testing in circuits with AC voltages greater than the rating of the semiconductor in the signal-tracing probe, use a simple 10-to-1 capacitance divider (see the accompanying diagram). The capacitance divider is merely a 50- to 150-mmf fixed capacitor. The exact value which will provide 10-to-1 attenuation depends upon the VOM range. For example, the value becomes progressively greater for 10-to-1 attenuation on the 50-volt, 10-volt, and 2.5-volt ranges of a 20,000 ohms-per-volt meter. On the other hand, a given capacitor provides 10-to-1 attenuation on all ranges of a VTVM. Note that a simple capacitance divider is useful in the horizontal circuits only. Another type of divider must be used in the vertical circuits. (See Note 35.)

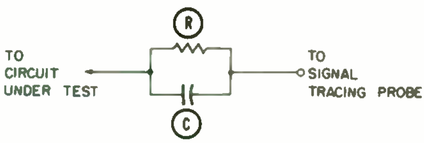


Capacitance divider for signal-tracing probe.

NOTE 35

Compensated Voltage Divider for Signal-Tracing Probe

To obtain 10-to-1 attenuation at both low and high frequencies, use an R-C divider with a signal-tracing probe, as shown in the following illustration. The values for R and C can be chosen for proper attenuation on any range of a VTVM. On the other hand, different values are required for various ranges of a VOM. Select R to provide 10-to-1 attenuation at 60 cycles. Select C to provide 10-to-1 attenuation at 15,750 cycles.

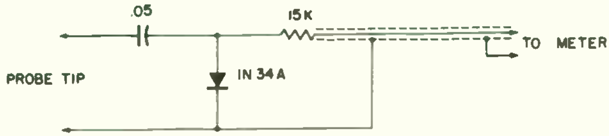


Wide-band voltage divider for signal-tracing probe.

NOTE 36

Half-Wave Signal-Tracing Probe

The following configuration is for a half-wave signal-tracing probe and can be used with either a VOM or VTVM. The probe is not intended for highly accurate voltage measurements, only for general signal-level checks.



Half-wave signal-tracing probe for VOM or VTVM.

NOTE 37

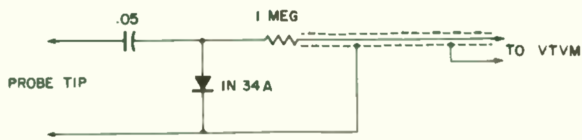
Low-Frequency Response of a Rectifier Probe

Better low-frequency response can be obtained if a larger charging capacitor is used in a rectifier probe. On the other hand, large values of charging capacitance cause a damaging surge of transient current through the semiconductor diode when the probe is applied to a plate-voltage source. Hence, a 0.05-mfd charging capacitor is a compromise between low-frequency response and transient protection for the diode. A rectifier probe has better low-frequency response when used with a VTVM because the current demand from the charging capacitor is less. Likewise, a rectifier probe has better low-frequency response when used with a 100,000 ohms-per-volt VOM than with a 20,000 ohms-per-volt VOM.

NOTE 38

Probe Provides Peak-Voltage Indication on VTVM

The peak voltage of an AC waveform can be measured with a rectifier probe and a VTVM (as shown in the following schematic). The probe replaces the usual DC input cable, which normally has a 1-megohm isolating resistor in the probe housing. Hence, a 1-meg calibrating resistor must be used in the rectifier probe. This type of rectifier probe will not work with a VOM because the calibrating resistor is much too large. The probe indicates positive-peak or negative-peak level, depending upon polarity of the 1N34A.

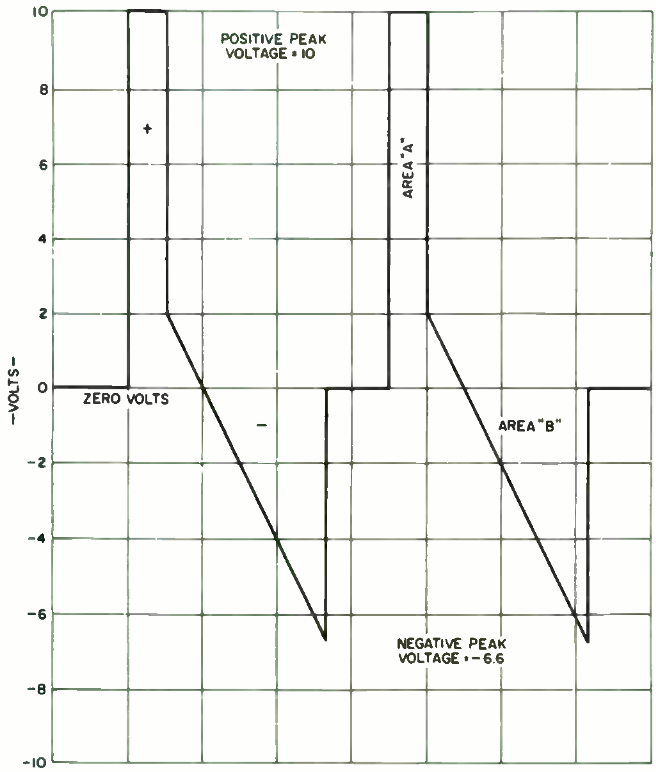


Half-wave signal-tracing probe for VTVM.

NOTE 39

Peak Voltages of Complex Waveforms

The positive-peak voltage of complex waveforms usually is different from the negative-peak voltage, as shown in the following illustration. In a complex waveform, there is always a zero-volt level which divides the waveform into positive and negative portions. The areas on either side of the zero-volt level are always equal. Whether you measure the positive-peak voltage or the negative-peak voltage depends upon the polarity of the semiconductor diode in the rectifier probe.



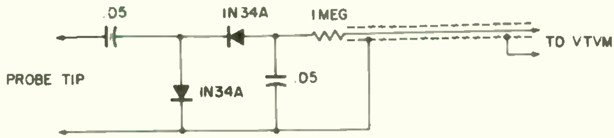
A complex waveform.

NOTE 40

Probe Provides Peak-to-Peak Voltage Indication with a VTVM

You can use a peak-to-peak rectifier probe and a VTVM to measure peak-to-peak voltages of complex waveforms. The probe replaces the usual

DC input cable to the VTVM. This cable usually contains a 1-meg calibrating (or isolating) resistor. Hence, a 1-meg calibrating resistor is used in the rectifier probe. Note that any probe using semiconductor diodes has a limited voltage range; therefore, input signals should not exceed about 75 volts peak-to-peak because the diodes may be damaged.



A peak-to-peak signal-tracing probe for a VTVM.

U46

To Make Signal-Tracing Tests With No Current Drain from the Circuit Under Test

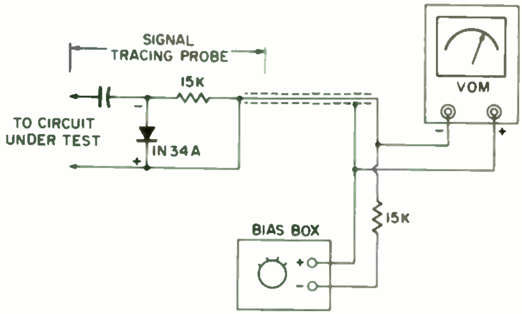
Equipment: DC bias box, signal-tracing probe, and fixed resistor.

Connections Required: Connect probe to resistor, bias box, and VOM, as shown. Apply probe to test point in receiver circuits.

Procedure: Set VOM to its lowest possible DC range. Adjust bias box from zero indication on voltage scale. Switch VOM to lowest DC voltage scale and readjust bias box for zero indication. (Meter connection can be made and broken for a very accurate balance indication.) Finally, apply VOM across bias-box terminals and read voltage indication.

Evaluation of Results: The voltage from the bias box cancels the voltage from the probe, so that the meter draws no current from the circuit under test. The value of voltage measured across the bias-box terminals is the peak voltage of the signal. Whether positive-peak or negative-peak voltage is measured depends upon the polarity of the semiconductor diode in the probe.

The value of the isolating resistor is not critical, but should have a value on the order of the isolating resistor in the probe. Note that the arrow on a semiconductor diode points in the direction opposite to electron flow. The diode in the probe can be reversed if the bias-box polarity is also reversed. This method also improves the low-frequency response from a VOM probe because the probe does not supply current to the meter.



Test setup.

NOTE 41

Capacitive Loading of Probe

The test method in U46 eliminates current drain from the circuit under test and thus gives more accurate peak-voltage measurements. On the other hand, note that the input capacitance of the probe is still present and can detune an IF stage, for example. For this reason, the probe and meter can give off-value indications in high-frequency tuned circuits.

U47

To Measure Peak-to-Peak Voltage Values Without Current Drain from the Circuit Under Test (VOM)

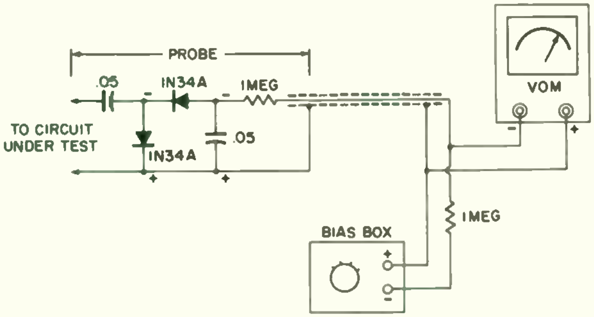
Equipment: VTVM-type signal-tracing probe, bias box, and resistor.

Connections Required: Connect equipment as shown. Apply probe to circuit under test.

Procedure: Adjust bias box for zero indication on DC voltage scale (lowest range) of VOM. Make and break VOM connection to obtain highly accurate zero indication. Finally, measure voltage at bias-box terminals.

Evaluation of Results: The voltage measured at the bias-box terminals is equal to the peak-to-peak voltage of the waveform. (See Note 41 for the exception.)

The low-frequency response of a VOM peak-to-peak probe is improved with this method because no current is taken from the probe by the meter.



Test setup.

NOTE 42

Built-in AC Rectifier of VTVM Increases Capacitive Loading Error

Some VTVM's do not use an external probe for measurement of peak-to-peak voltage values; instead, they have a built-in full-wave rectifier designed for high-frequency response. The advantage of the built-in arrangement is that the rectifier is placed after the range multiplier, so that higher values of AC voltage can be conveniently measured. On the other hand, a disadvantage of the built-in arrangement is that the input capacitance is much higher. This higher capacitance increases the loading error when high-frequency circuits are being tested.

U48

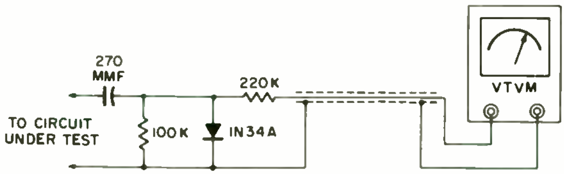
To Measure the Voltage in a Modulated Waveform (VTVM)

Equipment: Demodulator probe (see the accompanying illustration).

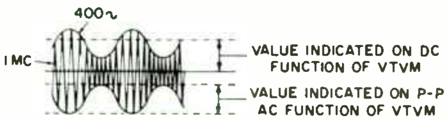
Connections Required: Connect probe to modulated waveform voltage source. Feed probe output to VTVM input connector.

Procedure: First, operate VTVM on its DC voltage function. This gives the peak voltage of the carrier frequency. Then operate the VTVM on its AC voltage function. This gives the voltage of the modulating waveform (usually a 400-cycle modulating frequency in standard test work).

Evaluation of Results: The demodulator probe provides both AC and DC output. The rectifier and filter network in the probe converts the high carrier frequency into a DC voltage. This DC voltage is equal to the peak carrier voltage. On the other hand, the rectifier and filter network of the probe passes the 400-cycle AC modulating voltage without rectifying or filtering it. Hence, it can be measured separately on the AC function of the VTVM. If the VTVM provides rms indication of sine waveforms, this measurement will be in rms values. On the other hand, if the VTVM provides peak-to-peak indication of AC voltages, this measurement will be in peak-to-peak values.



Test setup.



Modulated waveform.

NOTE 43

Measurement of Modulating Voltage Value

If a peak-to-peak demodulator probe is used in U48, the DC scale of the meter will indicate the peak-to-peak voltage of the carrier. The modulating voltage will be measured in rms or peak-to-peak values, depending upon the type of VTVM.

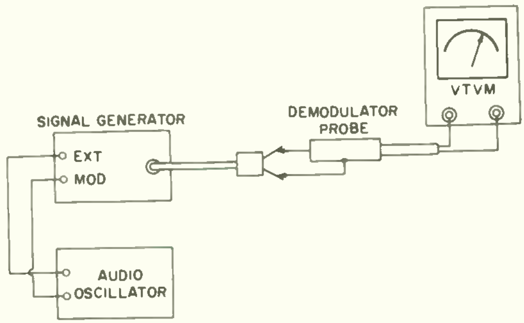
To Determine the Demodulating Capability of a Demodulator Probe (VTVM)

Equipment: Signal generator and audio oscillator.

Connections Required: Connect audio-oscillator output cable to External Modulation terminals of signal generator. Connect demodulator probe to signal-generator output cable. Connect VTVM to probe output cable.

Procedure: Operate signal generator on maximum output at about 1 mc. Vary frequency of audio oscillator through a suitable range. Operate VTVM on AC voltage function. Note change in scale indication as the audio oscillator is tuned to higher frequencies.

Evaluation of Results: The demodulating capability of the probe is the audio frequency at which the meter reading starts to drop.



Test setup.

U50

To Multiply the Sensitivity of a Signal-Tracer Probe

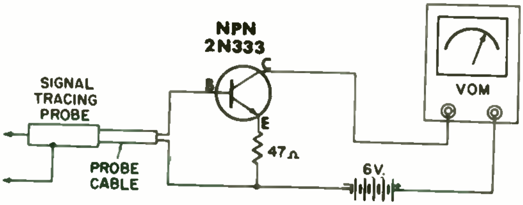
Equipment: Transistor, 3K resistor, 47-ohm resistor, and 6-volt battery.

Connections Required: Connect components as shown in the following diagram. (Battery voltage and probe cable terminals must be reversed if an NPN transistor is used.) Apply probe output to input of transistor circuit. Connect VOM to output of transistor circuit.

Procedure: Operate the VOM on its low-current range, such as 100 microamps. Apply signal-tracing probe to circuit under test.

Evaluation of Results: The transistor increases the sensitivity of the meter ten times or more. Hence, it is possible to check much lower-level circuits (such as the output of an RF tuner).

There is sometimes a small leakage current when no signal is applied to the signal-tracing probe. This is a characteristic of the transistor. By selecting transistors, you can minimize the leakage current. This leakage current causes the pointer to rest slightly above zero when there is no signal input.



Transistor probe amplifier.

NOTE 44

Transistor Extends Low-Frequency Response of Probe

When a transistor is used as shown in U50, the low-frequency response of a VOM signal-tracing probe is also extended greatly because there is much less current drain from the probe.

U51

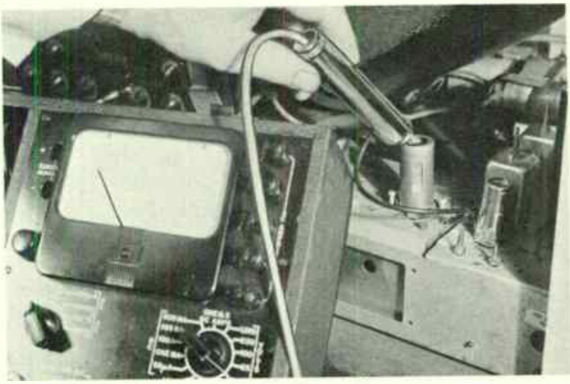
To Check the Local-Oscillator Stage

Equipment: Signal-tracing probe.

Connections Required: Plug output cable from probe into meter jacks. Apply probe between floating tube shield over oscillator tube and chassis ground.

Procedure: Operate VOM or VTVM on DC voltage range. Observe scale indication while turning channel-selector switch through its range.

Evaluation of Results: A zero indication indicates a dead oscillator. You will normally observe a reading from 0.5 to 2 volts, depending upon whether you use a VOM or VTVM and a half-wave or full-wave probe.



Checking local-oscillator operation.

U52

To Signal-Trace from the Output of the RF Tuner Through the IF Amplifier (VOM)

Equipment: Transistor probe accessory (see U50) and signal-tracing probe.

Connections Required: Connect components as shown in U50. Apply probe output to input of transistor circuit. Connect VOM to output of transistor circuit.

Procedure: Tune in TV station signal or use RF signal from pattern generator. Apply probe at RF tuner output and at following IF grid and plate terminals.

Evaluation of Results: A peak-to-peak probe and a transistor provide at least 20 times the sensitivity of a conventional probe and permit signal-tracing tests with a VOM at the RF-tuner output.

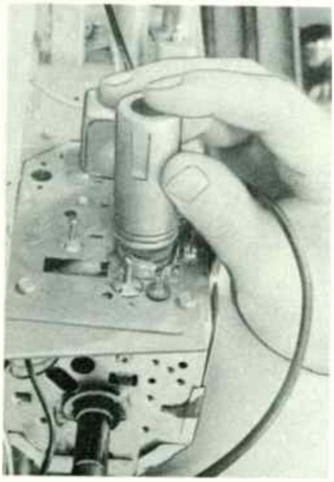
To Check the Operation of the Signal Circuits From the Mixer Tube to the Picture Detector

Equipment: Signal-tracing probe.

Connections Required: Plug output cable from probe into instrument jacks. Apply probe at input or output of picture detector.

Procedure: Operate instrument on DC voltage range. Lift the mixer tube shield, and grasp it while noting the scale indication.

Evaluation of Results: Stray fields are coupled to the plate of the mixer tube by body capacitance applied to the floating tube shield over the mixer tube. Zero indication shows that the signal is not getting through from the mixer to the picture detector. The indication level depends upon the strength of stray fields in the shop.

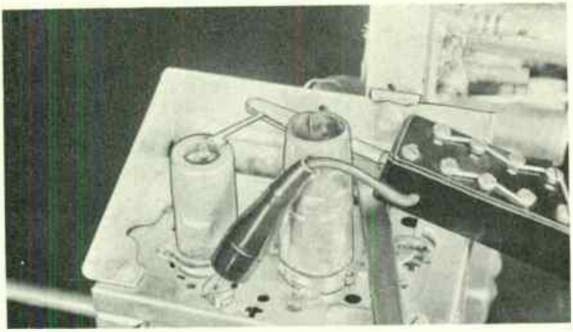


Coupling stray fields to mixer tube by body capacitance.

NOTE 45

Generator Must Be Used If Stray Fields Are Weak

In some shops, stray fields at IF frequencies are too weak for a practical test by the method explained in U53. In such case, the output from an IF signal generator must be applied to the floating tube shield over the mixer tube.



Applying output of signal generator to floating tube shield.

U54

To Check the Video Signal Output from the Picture Detector (VOM or VTVM)

Equipment: Signal-tracing probe.

Connections Required: Plug probe into meter. Apply probe between picture-detector output and chassis ground.

Procedure: Tune in TV station (or use pattern generator). Observe voltage reading on the DC volts function of the instrument.

Evaluation of Results: From 0.5 to 2 volts will be observed in normal operation, depending upon whether a VOM or VTVM is used with a half-wave or a full-wave probe.

U55

To Check the Video-Signal Drive to a Picture Tube (VOM or VTVM)

Equipment: Signal-tracing probe.

Connections Required: Plug probe output lead into instrument input jacks. Remove picture-tube socket and apply probe between signal-input electrode pin in picture-tube socket and chassis ground.

Procedure: Tune in a TV station, or use a pattern-generator signal. Observe reading on the DC voltage scale.

Evaluation of Results: With normal signal drive to the picture tube, the reading on the VOM scale will be approximately 20 to 30 volts. Somewhat higher readings are obtained with a VTVM.

Checking drive to picture tube.

U56

To Check the Sound Signal at the FM Detector

Equipment: Signal-tracing probe.

Connections Required: Connect probe output cable to meter. Apply probe in turn at cathode and plate terminals of FM detector tube.

Procedure: Operate instrument on DC voltage range. Observe scale indication with a TV station signal present.

Evaluation of Results: If a full-wave probe is used with a VTVM, voltages can be compared with data in receiver service literature. Otherwise, lower voltage readings will be obtained. These readings can be compared with those obtained from a receiver of the same type in good operating condition.

U57

To Signal-Trace the Sync Section of a TV Receiver

Equipment: Signal-tracing probe.

Connections Required: Connect probe cable to instrument. Apply probe between circuit terminal under test and chassis ground.

Procedure: Operate VOM or VTVM on its DC voltage function. Tune in a TV station (or use a pattern generator). Note the reading on the DC scale.

Evaluation of Results: If a full-wave probe is used with a VTVM, peak-to-peak voltage values can be compared with data in the receiver service literature. (A VTVM probe loads high-impedance circuits slightly more than a 10-to-1 low-capacitance probe for scope). If a half-wave probe is used with a VOM, lesser voltage values will be indicated, and circuit loading will be substantial.

U58

To Measure the Peak-to-Peak Voltage of the Vertical Sync Pulse (VTVM)

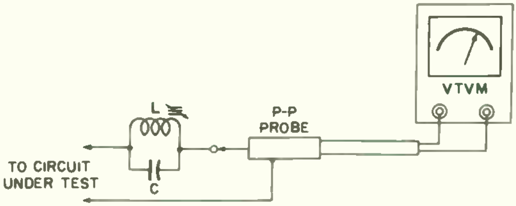
Equipment: Full-wave signal-tracing probe and LC circuit resonant at 15,750 cycles. (See the following illustration.)

Connections Required: Connect probe to parallel-resonant circuit. Plug probe output cable into VTVM. Apply lead from LC circuit to point under test. Return probe to chassis ground.

Procedure: Operate VTVM on its DC voltage function. Note peak-to-peak voltage value indicated on DC scale.

Evaluation of Results: The resonant circuit largely rejects the horizontal sync pulses, but passes the vertical sync pulses. Hence, the voltage of the vertical sync pulses in a composite sync signal can be checked individually.

Test setup.



U59

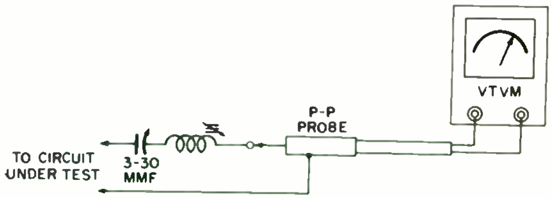
To Measure the Peak-to-Peak Voltage of the Horizontal Sync Pulse (VTVM)

Equipment: Full-wave signal-tracing probe and LC circuit resonant at 15,750 cycles. (See the following illustration.)

Connections Required: Connect probe to series-resonant circuit. Plug probe output cable into VTVM. Apply lead from LC circuit to point under test. Return probe to chassis ground.

Procedure: Operate VTVM on its DC voltage function. Note peak-to-peak voltage indicated on DC scale.

Evaluation of Results: The resonant circuit largely rejects the vertical sync pulses, but passes the horizontal sync pulses. Hence, the voltage of the horizontal sync pulses in a composite sync signal can be checked individually.



Test setup.

NOTE 46

Vertical Oscillator Disabled to Make Integrator Test

When signal-tracing through the vertical integrator, you must disable the vertical-oscillator tube. Otherwise, the energy from the oscillator will be coupled back through a stage or two of the integrator and will give a false indication of signal level.

U60

To Check the Drive Voltage to the Vertical-Output Tube (VOM or VTVM)

Equipment: Signal-tracing probe.

Connections Required: Connect probe to instrument and apply probe between grid of vertical-output tube and chassis ground.

Procedure: Operate the meter on its DC voltage function and observe scale indication.

Evaluation of Results: If a peak-to-peak (full-wave) probe is used with a VTVM, the indicated voltage can be compared with the specified p-p voltage in the receiver service literature. If a 20,000 ohms-per-volt meter is used, the reading will be lower. In a typical receiver, a VOM indicates a normal drive voltage of approximately 4 volts.

U61

To Check the Sync and Comparison Waveforms at the Horizontal-Phase Detector

Equipment: Signal-tracing probe.

Connections Required: Connect probe output cable to VOM or VTVM. Apply probe in turn to the signal terminals of phase-detector circuit.

Procedure: Observe indication on meter DC scale with and without a sync signal (from a TV broadcast station or a pattern generator). Next, observe the scale reading with and without the horizontal-oscillator tube disabled.

Evaluation of Results: With no sync signal, the scale reading indicates the level of the comparison waveform from the horizontal-sweep circuit. With a sync signal, the scale reading indicates the level of the combined comparison waveform and sync waveform. A reading can be made with a sync signal and with the horizontal oscillator disabled, so that the level of the sync signal alone can be determined. If a full-wave probe is used with a VTVM, peak-to-peak voltage values can be compared with those in receiver service literature.

CAUTION: Loss of drive to the horizontal-output tube can overheat or damage it in receivers that depend entirely upon signal-developed bias to obtain a suitable operating point for the tube. Therefore, the output tube and the horizontal-oscillator tube must both be pulled in these receivers.

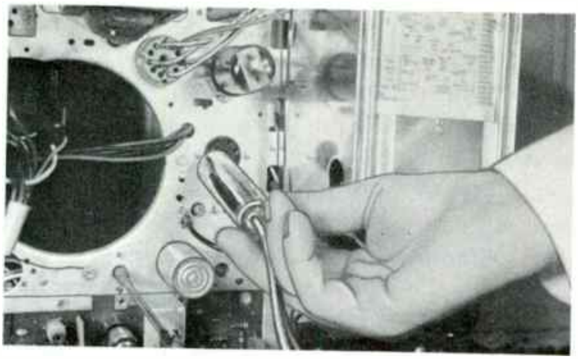
To Check the Drive Voltage to the Horizontal-Output Tube

Equipment: Signal-tracing probe.

Connections Required: Connect probe to meter. Pull the horizontal-output tube (transformer-type receivers only). Apply probe between grid terminal of socket and chassis ground.

Procedure: Operate instrument on DC voltage function and observe reading.

Evaluation of Results: A typical reading of 20 volts is normally obtained when a half-wave probe and a 20,000 ohms-per-volt VOM are used. A full-wave probe and a VTVM permit the peak-to-peak voltage of a drive waveform to be checked against value specified in receiver service literature.



Checking drive to horizontal-output tube.

U63

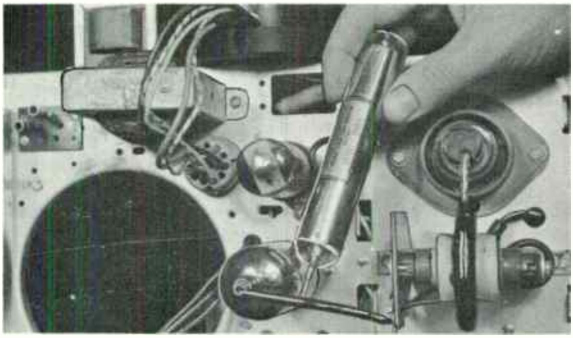
To Check for Presence of Horizontal-Output Voltage

Equipment: Signal-tracing probe.

Connections Required: Plug probe output cable into instrument jacks. Hold probe tip halfway up side of glass envelope on horizontal-output tube. Clip probe return lead to chassis ground.

Procedure: Operate meter on DC voltage range. Observe scale indication.

Evaluation of Results: A normally-operating horizontal-output stage will indicate approximately 2 volts on a 20,000 ohms-per-volt VOM when a half-wave probe is used. Higher indications are obtained with a VTVM and with a full-wave probe. Zero indication shows that there is no output voltage.



Checking for presence of horizontal-output voltage.

AC VOLTAGE TESTS

U64

To Measure Audio-Amplifier Gain in Decibels

Equipment: Audio oscillator.

Connections Required: Apply output from audio oscillator to input of audio amplifier. Connect VOM or VTVM, first across input load impedance and then across output load impedance. (If DC voltage also is present, see U65.)

Procedure: Apply signal below overload level to amplifier. Note readings on decibel scale at both the input and the output of the amplifier.

Evaluation of Results: Correct the scale readings for the values of the load impedances, unless the meter is connected to a value of load impedance for which the decibel scale is calibrated. (See Note 49.) Then, subtract the input reading from the output reading to obtain the gain in decibels.

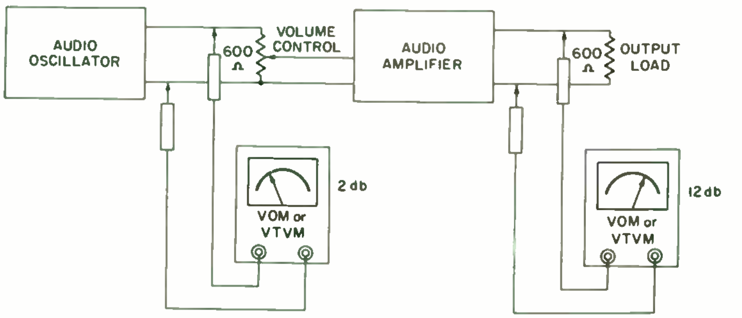
NOTE 47

Decibels Proportional to Ear Response

It is helpful to measure audio gains and losses in decibels because the db unit is proportional to ear response, whereas voltage units are not. Decibel units are based on power levels and are additive and subtractive. Thus, if we take a loss of 20 db in a volume control and if we have a gain of 30 db in a following amplifier, the system gain will be 10 db. Note that a gain of 6 db is judged as "about twice as loud" as the original level. Likewise, a loss of 6 db is judged about "half as loud" as the original level. The db scales on a voltmeter read correct db values only when measurements are made across a value of load impedance for which the db scales have been calibrated (see Note 49). An example of a db check across 600-ohm loads with instruments calibrated to read db across 600 ohms is given in the following illustration. With the audio oscillator supplying a signal level of 2 db to the 600-ohm volume control and the audio amplifier supplying a signal level of 12 db to the 600-ohm load, the gain of the amplifier is 10 db.

Many VOM's and VTVM's have only one db scale, which is usually calibrated for operation on the lowest AC voltage range. Accordingly, when the meter is operated on a higher AC voltage range, you must add a suitable number of db to the scale reading. The number of db to be added will be noted on the meter scale plate or in the instrument instruction manual.

NOTE: Although two meters are shown in this and the following illustrations, it should be understood that only one meter is necessary and the test leads are merely connected to the different points. Two meters are included to show the readings obtained at each point.



Test setup.

Power Ratio	Voltage Ratio	db − ← + →	Voltage Ratio	Power Ratio
1.000	1.0000	0	1.000	1.000
.9772	.9886	.1	1.012	1.023
.9550	.9772	.2	1.023	1.047
.9333	.9661	.3	1.035	1.072
.9120	.9550	.4	1.047	1.096
.8913	.9441	.5	1.059	1.122
.8710	.9333	.6	1.072	1.148
.8511	.9226	.7	1.084	1.175
.8318	.9120	.8	1.096	1.202
.8128	.9016	.9	1.109	1.230
.7943	.8913	1.0	1.122	1.259
.6310	.7943	2.0	1.259	1.585
.5012	.7079	3.0	1.413	1.995
.3981	.6310	4.0	1.585	2.512
.3162	.5623	5.0	1.778	3.162
.2512	.5012	6.0	1.995	3.981
.1995	.4467	7.0	2.239	5.012
.1585	.3981	8.0	2.512	6.310
.1259	.3548	9.0	2.818	7.943
.10000	.3162	10.0	3.162	10.00
.07943	.2818	11.0	3.548	12.59
.06310	.2512	12.0	3.981	15.85
.05012	.2293	13.0	4.467	19.95
.03981	.1995	14.0	5.012	25.12
.03162	.1778	15.0	5.623	31.62
.02512	.1585	16.0	6.310	39.81
.01995	.1413	17.0	7.079	50.12
.01585	.1259	18.0	7.943	63.10
.01259	.1122	19.0	8.913	79.43
.01000	.1000	20.0	10.000	100.00
10^{-3}	3.162×10^{-2}	30.0	3.162×10	10^{3}
10^{-4}	10^{-2}	40.0	10^{2}	10^{4}
10^{-5}	3.162×10^{-3}	50.0	3.162×10^{2}	10^{5}
10^{-6}	10^{-3}	60.0	10^{3}	10^{6}
10^{-7}	3.162×10^{-4}	70.0	3.162×10^{3}	10^{7}
10^{-8}	10^{-4}	80.0	10^{4}	10^{8}
10^{-9}	3.162×10^{-5}	90.0	3.162×10^{4}	10^{9}
10^{-10}	10^{-5}	100.0	10^{5}	10^{10}

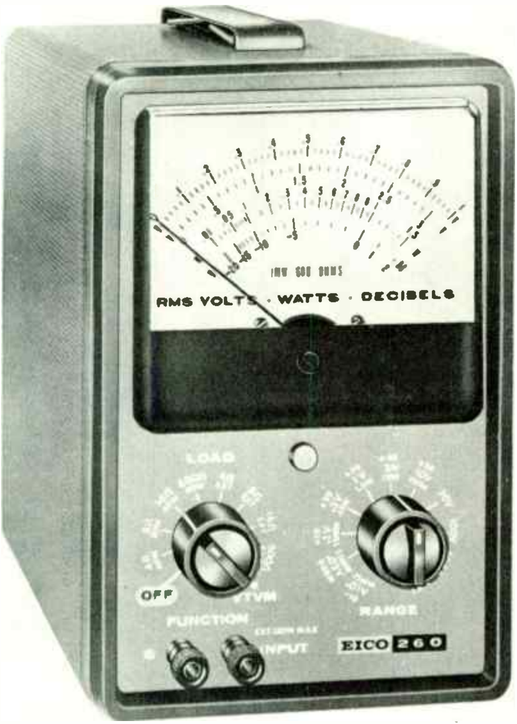
Db expressed as power and voltage (or current ratios).

NOTE 48

A Poor Waveform Can Cause Inaccurate Db Measurements

A good waveform is essential for accurate decibel measurements. For example, if an audio oscillator supplies a good waveform to an amplifier which in turn introduces harmonic distortion, the measurement of db gain will be incorrect. The same considerations of waveform error discussed for AC voltage measurements also apply to decibel measurements.

Note that some AC voltmeters also indicate power and db values, as the one seen in the illustration below. With this type of meter, you can measure db either in terms of voltage ratios or power ratios. The accompanying chart shows the number of db corresponding to various power ratios.



Typical AC volt-watt-db meter. (Courtesy of EICO Electronics Instr. Co., Inc.)

Power ratios expressed in + db.

Power Ratio	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
1	.000	.414	.792	1.139	1.461	1.761	2.041	2.304	2.553	2.788
2	3.010	3.222	3.424	3.617	3.802	3.979	4.150	4.314	4.472	4.624
3	4.771	4.914	5.051	5.185	5.315	5.441	5.563	5.682	5.798	5.911
4	6.021	6.128	6.232	6.335	6.435	6.532	6.628	6.721	6.812	6.902
5	6.990	7.076	7.160	7.243	7.324	7.404	7.482	7.559	7.634	7.709
6	7.782	7.853	7.924	7.993	8.062	8.129	8.195	8.261	8.325	8.388
7	8.451	8.513	8.573	8.633	8.692	8.751	8.808	8.865	8.921	8.976
8	9.031	9.085	9.138	9.191	9.243	9.294	9.345	9.395	9.445	9.494
9	9.542	9.590	9.638	9.685	9.731	9.777	9.823	9.868	9.912	9.956

For Power Ratios between 0.01 and 0.099, use above table to get db for 100 times the ratio and subtract 20 db.

For Power Ratios between 0.1 and 0.99, use above table to get db for 10 times the ratio and subtract 10 db.

For Power Ratios between 1 and 9.9, use above table directly.

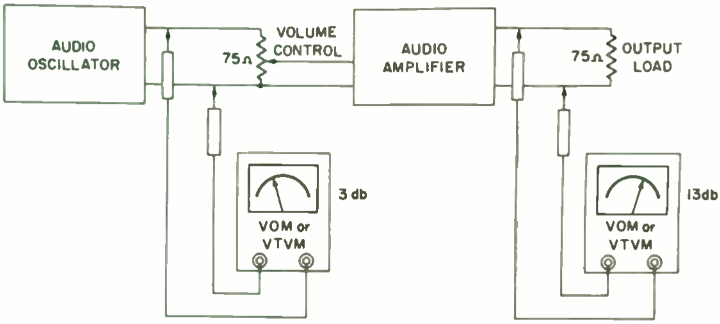
For Power Ratios between 10 and 99, use above table to get db for 1/10th of the ratio and add 10 db.

For Power Ratios between 100 and 990, use above table to get db for 1/100th of the ratio and add 20 db.

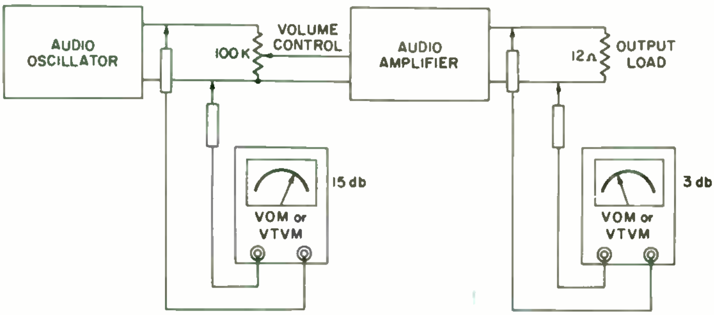
NOTE 49

Measuring Db Across Various Load Impedance Values

When measuring db levels across impedances other than those for which the db scale of the meter has been calibrated, you must recognize two important situations: (1) If the impedances are *different* from the *reference* value of the meter, but are *equal* in value, we can observe the scale readings and find the db gain or loss by taking the difference between the two readings. The reference impedance of the meter for db readings might be 600 ohms. If the input and output impedances of an amplifier are both 75 ohms, we can still use the meter designed for 600-ohms impedance. This is shown at A in the following illustration. Neither the 3-db nor the 13-db figure is correct by itself, but the difference of 10 db is correct because the readings were obtained across equal impedances. Therefore, in this example, the gain of the amplifier is 10 db. (2) On the other hand, if the impedances differ from the reference value of the meter and the two impedances are *unequal* as shown at B, the difference figure is *not correct*. Here, the first measurement is made across 100,000 ohms and the second measurement is made across 12 ohms. A gain is present in the amplifier, although the readings indicate a loss of 12 db. This is one of the principal mistakes beginners make when measuring db values with a voltmeter. You must use logarithms to convert the figures obtained with unequal impedances to useful gain figures.



(A) Equal impedances.



(B) Unequal impedances.

Test setup.

NOTE 50

Relative and Absolute Db Levels

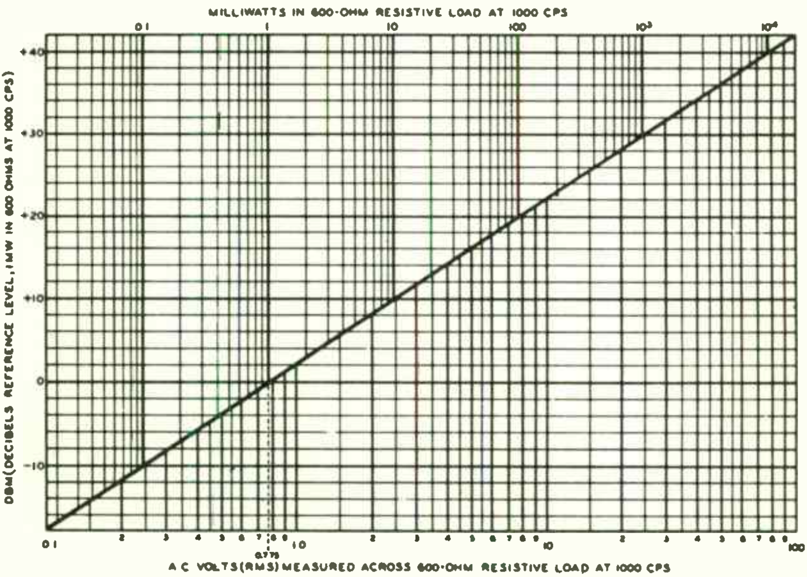
Distinction must be made between *relative* db levels versus *absolute* db levels. A db scale has a certain arbitrary level chosen as zero db. This zero-db level might be 1 milliwatt in 600 ohms or 6 milliwatts in 500 ohms—it makes no difference. All db values below the reference level are taken as minus, and all db levels above the reference level are taken as plus. Often, red and black figures are used on the db scale to call attention to the change in sign. We must use the proper sign when comparing db levels at different ends of the scale. If we read db values across an impedance with a value equal to the reference value for the meter, we can use a suitable table to convert a db reading into a power value. This is an *absolute* db reading and corresponds to a definite power value. On the other hand, if we read db values across 1,000-ohm loads, for example, with a meter calibrated for a 500-ohm load, the absolute readings on the db scale will *not* be correct; but if we take a *pair* of readings across 1,000-ohm loads, we can take the *difference* between these readings, and it will be the actual number of db *between* the two levels. This is an example of *relative* db readings.

The graph shown below can be used to determine dbm values corresponding to rms ac voltage values across a 600-ohm resistive load. A dbm value is defined as the number of decibels above or below a reference level of 1 milliwatt in 600 ohms at 1000 cycles Zero dbm, therefore, would indicate a power level of 1 milliwatt; 10 dbm, 10 milliwatts; and 20 dbm, 100 milliwatts. The graph provides rapid conversion of rms voltages to corresponding dbm values. Associated power levels can be read along the top of the graph. If the rms voltage is measured across a resistive load other than 600 ohms, the correction factors given below with the chart must be added algebraically to the dbm values read from the chart. For resistive loads not given in the table, the following formula should be used for determining the correction factor:

$$\text{Correction Factor} = 1 - \log \frac{600}{R}$$

where R is the load in ohms. If R is greater than 600 ohms, the correction factor is negative.

Because dbm are defined with respect to a 600-ohm load, power levels correspond to voltage values. Dbm can be measured in terms of rms voltages across a 600-ohm resistive load. For example, 0.775 rms volt indicates 0 dbm; 7.75 rms volts indicate 20 dbm. These measurements must be made with a sine wave to avoid waveform error. Note that the decibel has its closest correspondence to ear response at 1000 cycles.



Graph for conversion of rms voltages to dbm values. (Courtesy of Radio Corporation of America.)

RESISTIVE LOAD AT 1000 CPS	DBM*
600	0
500	+0.8
300	+3.0
250	+3.8
150	+6.0
50	+10.8
15	+16.0
8	+18.8
3.2	+22.7

*DBM IS THE INCREMENT TO BE ADDED ALGEBRAICALLY TO THE DBM VALUE READ FROM THE GRAPH.

NOTE 51

DB Measurements Across Reactive Loads

Sometimes we measure db across impedances which are reactive as well as resistive. In other words, the load may contain capacitance or inductance, in addition to resistance. If so, the db reading and its corresponding power do not indicate *real* power alone, but a combination of real power and reactive power. We are usually interested in real power only. Hence, db measurements are most meaningful when made across resistive loads. Let us take an extreme example of this point. Suppose we have an audio amplifier terminated in a 500-ohm load consisting of a fixed capacitor. If we check across the capacitor with a meter calibrated to read db in 500 ohms, we find a db indication which corresponds in turn to a power of—let us say—2 watts. Now, this is *reactive* power (VARS), which does no useful work. There is no real power output from the amplifier—it does no useful work except for delivering 2 watts of power to the capacitor, which in turn returns 2 watts to the amplifier tube. Most situations usually represent substantially resistive loads with a certain amount of reactance, which we customarily neglect. We assume, for practical purposes, that an output transformer and speaker are purely resistive circuit components.

U65

To Measure AC Voltage or Decibels When DC Voltage Is Present

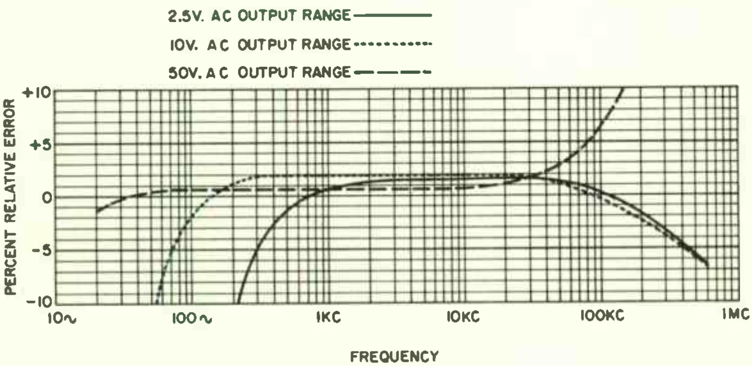
Equipment: None (a large blocking capacitor may be required).

Connections Required: Connect test leads across point under test. (If the blocking capacitor is used, connect it in series with one test lead of the VOM.)

Procedure: Operate VOM on Output function. Note voltage indication on AC scale. If frequency is low, insert the series blocking capacitor and operate the meter on its AC voltage function.

Evaluation of Results: A VOM contains an internal blocking capacitor to prevent DC current from flowing into the instrument. This capacitor passes only the AC voltage which is present. The internal blocking capacitor may have a value from 0.1 to 1 mfd, depending upon the type of VOM. At low frequencies, the blocking capacitor has an appreciable reactance and reduces the apparent value of the AC voltage. Therefore, a larger blocking capacitor is necessary; and the meter must be operated on its AC voltage function if an accurate reading is to be obtained.

Note that an output voltage consists of the AC component only in a pulsating DC waveform. This occurs commonly in vacuum-tube and transistor amplifier circuits. As mentioned previously, the value of the blocking capacitor limits the low-frequency response, as shown for a typical VOM in the graph below. Although the low-frequency end of the meter response is chiefly affected, the blocking capacitor also imposes a slight error in the midband region. This occurs because the meter movement is inductive. Accordingly, the blocking capacitor tends to form a resonant circuit with the moving coil and its associated circuitry. In turn, there is a noticeable resonant rise of voltage across the coil winding in the midband range.



Accuracy for output measurements with a typical VOM. (Courtesy of Simpson Electric Co.)

To Determine Whether the Output from an Audio Oscillator Contains Harmonics

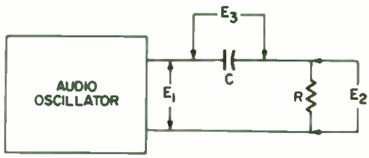
Equipment: Capacitor, resistor, and audio oscillator.

Connections Required: Connect capacitor and resistor in series across the audio-oscillator output, as shown. (Choose values for R and C that will give approximately the same voltage values at E_2 and E_3.) Apply AC voltmeter across audio-oscillator output, then across capacitor, and finally across resistor.

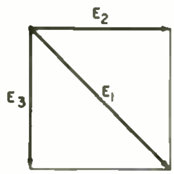
Procedure: Note voltage readings in each of the three measurements.

Evaluation of Results: Let each volt represent a certain length, and plot as shown in the illustration. E_2 and E_3 are drawn at right angles. The length of E_1 will equal the diagonal of a rectangle if no harmonics are present in the source voltage.

If a VTVM is used, less circuit loading occurs. However, both sides of the audio oscillator output must be above ground or the ground lead of the VTVM will load the circuit in the measurement of E_3.



Test setup.



Plot of voltages.

NOTE 52

Basis of Distortion Test

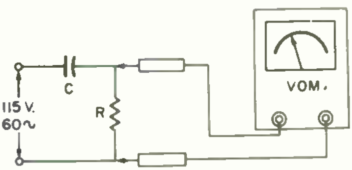
The principle of the test explained in U66 is that a capacitor has lower reactance for higher frequencies and causes a different phase shift at different frequencies. For example, if we apply a square wave instead of a sine wave to the RC series circuit, E_2 will become a small pip voltage and E_3 will become a distorted sawtooth. Thus E_1, E_2, and E_3 will not form a rectangle.

To Measure Capacitance Values from .001 to 1 Mfd (VOM)

Equipment: 2,960-ohm resistor and 231-ohm resistor.

Connections Required: Connect resistor and the capacitor under test in series as shown. (Note: For capacitance values from .001 to .01 mfd, no resistor is used.) Connect instrument across resistor (or from capacitor to opposite side of line). Energize capacitor and resistor from a 115-volt, 60-cycle power outlet.

Procedure: Note reading on AC scale and determine the capacitance value by referring to the following tabulation. The following tabulation is for AC voltmeters having a sensitivity of 1,000 ohms-per-volt and operated on the 10-volt range only. For VOM's with other AC voltage sensitivities or for operation on other ranges, make a new tabulation. Use close-tolerance capacitors while making the new tabulation.



Test setup.

CAUTION: Use a range higher than 115 volts to make the initial test. This will protect the meter if the capacitor under test should be shorted.

Readings Obtained for Different Values of Capacitors

Capacitor Value (Mfd)	Approximate Reading (AC Volts)	Capacitor Value (Mfd)	Approximate Reading (AC Volts)	Capacitor Value (Mfd)	Approximate Reading (AC Volts)
.001	0.6	.01	1	.1	1
.002	1.1	.02	2	.2	2
.003	1.5	.03	3	.3	3
.004	1.9	.04	4	.4	4
.005	2.5	.05	5	.5	5
.006	3.0	.06	6	.6	6
.007	3.6	.07	7	.7	7
.008	4.0	.08	8	.8	8
.009	4.4	.09	9	.9	9
.01	4.8	.1	10	1.0	10
R = ∞		R = 2,960 Ω		R = 231 Ω	

To Measure the Capacitance of an Electrolytic Capacitor

Equipment: Battery, audio oscillator, and 1-ohm precision resistor.

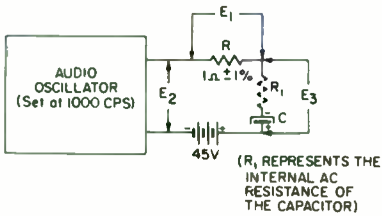
Connections Required: Connect components as shown. (The 45-volt battery supplies the polarizing voltage.) Connect the AC voltmeter in turn across the audio-oscillator output, across the resistor, and across the capacitor.

Procedure: Set the audio oscillator to 1,000 cps and note the AC voltage readings obtained. (If DC voltage is found across R, use Output function of the meter to measure AC voltage values.)

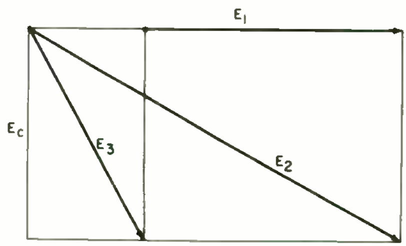
Evaluation of Results: Let each volt represent a certain length and plot a rectangle, as shown. If the audio oscillator is operated at 1,000 cps, the capacitance value is found from the formula:

$$C = \frac{E_1}{6280E_C}$$

An AC VTVM will provide somewhat better accuracy should DC be present across resistor R. The reason is that, on the Output function many VOM's use a .1-mfd blocking capacitor which feeds into a 5,000 ohms-per-volt network. A VTVM, on the other hand, requires little signal current.



Test setup.



Plot of voltages.

To Measure the Power Factor of an Electrolytic Capacitor

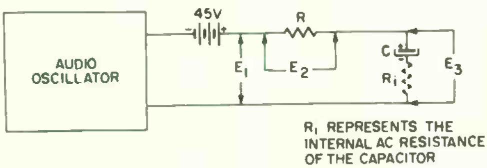
Equipment: Resistor, battery, and audio oscillator.

Connections Required: Connect components as shown. (The 45-volt battery supplies the polarizing voltage.) Connect AC voltmeter in turn across the audio-oscillator output, across the resistor, and across the electrolytic capacitor.

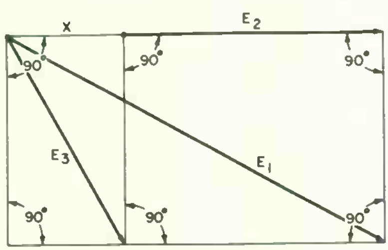
Procedure: Note the AC voltage readings in the three tests. (If a DC voltage drop is present across R, operate instrument on Output function.)

Evaluation of Results: Combine the three voltages (represented as line lengths) into a rectangle, as shown. This gives us a length for X. Divide X by E_3 to obtain the power factor of the electrolytic capacitor.

A more accurate test is obtained with an AC VTVM than with a VOM. The VTVM has less current drain and thus loads the test circuit less.



Test setup.



Plot of voltages.

NOTE 53

"Perfect" Capacitor Has Zero Power Factor

An ideal capacitor has zero power factor. A capacitor with more than zero power factor can be represented as a capacitance in series with a resistance. This is the basis of the test explained in U69. An ideal capacitor returns all of its charge to the driving circuit. A poor capacitor consumes power internally, and this consumed power is not returned to the circuit. A leaky capacitor is equivalent to a capacitance in parallel with a resistance. This also causes a power factor other than zero. In this test, leakage is treated as an equivalent series resistance. However, we can measure leakage separately by making a DC voltage check across R. Ohm's law then tells us the value of leakage resistance.

NOTE 54

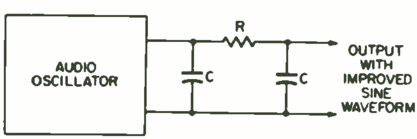
Turnover in AC Voltage Measurements

Turnover sometimes is encountered in AC voltage measurements. It is present when a supposedly sine waveform has even harmonics and shows up as a change in AC voltage reading when the test leads are reversed. You can make a *turnover test* for harmonics *with any type of half-wave rectifier*. The half-wave rectifier can be inside a VOM or it can be external, in a signal-tracing probe for example. On the other hand, note carefully that you *cannot* check turnover with a full-wave probe or full-wave bridge rectifier—the even harmonic error cancels, and instead we measure a voltage based on *both* half cycles of the waveform.

NOTE 55

How to Improve an Audio-Oscillator Waveform

Sometimes an audio oscillator does not provide a good waveform because harmonics are present. These harmonics cause inaccurate AC voltage readings. A poor waveform from an audio oscillator can be greatly improved if a suitable RC low-pass filter is used, as shown in the following illustration. The values of R and C depend upon the test frequency—lower frequencies require larger values. A good working rule is to make R and C as large as possible, consistent with the needed output voltage level for the given application.



An R-C low-pass filter for removing harmonics.

To Measure the Impedance of an Inductor

Equipment: Precision 10-ohm resistor and audio oscillator.

Connections Required: Connect resistor and inductor in series with output from audio oscillator. Connect AC voltmeter across the inductor, then across the resistor.

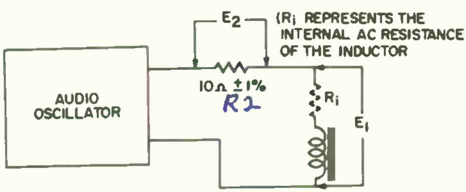
Procedure: Adjust audio oscillator to desired test frequency, such as 60 cycles, 400 cycles, or 10,000 cycles. Observe readings across the inductor and resistor.

Evaluation of Results: The 10-ohm resistor drops 1 volt for each 100 ma of current. Consequently, the current equals .1 × E_2. The voltage divided by the current gives the impedance of the inductor. Therefore, the impedance of the inductor can be calculated by the formula: If R2 = 100Ω ÷ by 10Ω .1 = .01

$$Z = \frac{E_1}{0.1E_2}.$$

Note that the audio oscillator which is used in this type of test should have sufficient output to provide ample voltage drop across the inductor. If a VOM is utilized, no difficulty will be met due to circulating ground currents. On the other hand, if a VTVM is employed, it is advisable to use an audio oscillator which has double-ended output. It will minimize measurement errors resulting from circulating ground currents (via instrument power supplies). The audio oscillator must also provide good waveform (low harmonic output) to minimize measurement errors.

Test setup.



NOTE 56

Ohmmeter Measures the DC Resistance of an Inductor — Not the AC Resistance

It is sometimes supposed that the AC resistance of an inductor can be measured with a DC ohmmeter. Often, the AC resistance is considerably higher than the DC resistance because of core loss and eddy currents in copper. These losses generally increase as the frequency increases. Accordingly, the AC resistance of an inductor cannot be measured accurately except with suitable AC tests.

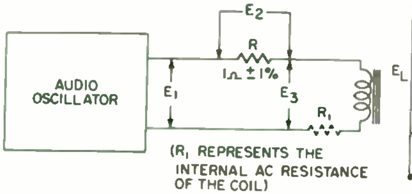
To Measure Inductive Reactance and Inductance

Equipment: Precision 1-ohm resistor and audio oscillator.

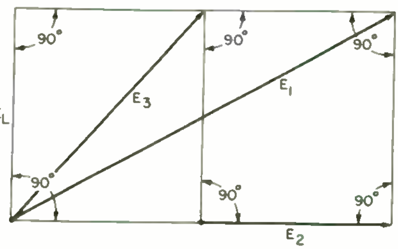
Connections Required: Connect resistor and coil in series across audio-oscillator output. Connect AC voltmeter in turn across audio-oscillator output, across resistor, and across coil.

Procedure: Observe the AC voltage readings in the three tests. Operate the audio oscillator at a frequency of f cps.

Evaluation of Results: Represent the voltages as line lengths. Combine into a rectangle, as shown in the accompanying diagram. The length for E_L is the voltage across the inductive reactance. We can calculate the inductive reactance in ohms by dividing E_L by E_2. We calculate the inductance in henries by dividing E_L by 6.28f E_2.



Test setup.



Plot of voltages.

U72

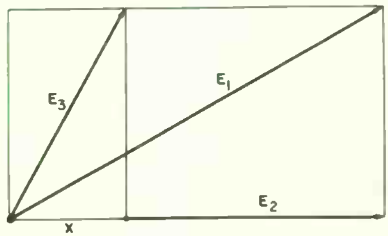
To Measure the Power Factor of a Coil

Equipment: Precision 1-ohm resistor and audio oscillator.

Connections Required: Connect resistor and coil in series across audio-oscillator output. Connect AC voltmeter in turn across audio-oscillator output, across resistor, and across coil.

Procedure: Observe the AC voltage readings in the three tests. Operate the audio oscillator at a frequency of f cps.

Evaluation of Results: Let each volt represent a certain distance and plot E_1, E_2, and E_3 into a rectangle as shown in the following illustration. Measure the length of X and divide X by E_3 to find the power factor of the coil. In an "ideal" coil, X equals 0; hence, the power factor is equal to zero. On the other hand, if the coil has a very low inductance and a very high resistance, X becomes almost the same as E_3 and the power factor approaches 1.



Plot of voltages.

U73

To Measure the Turns Ratio of a Transformer (Audio-Output, Power, or Flyback Transformers)

Equipment: Audio oscillator.

Connections Required: Connect audio-oscillator output to the transformer primary. Apply AC voltmeter across primary terminals of transformer, then across secondary terminals.

Procedure: Set audio oscillator to an audio frequency, such as 1,000 cycles, for an audio-output transformer test; to approximately 60 cycles for a power transformer test; and to approximately 5,000 cycles for a flyback transformer test. Observe voltmeter readings obtained at terminals of primary and secondary windings.

Evaluation of Results: The turns ratio of any two windings is equal to the voltage ratio measured across the windings.

Impedance Ratio = The square of the Turn Ratio

To Measure the Power Consumption of a Radio or TV Receiver (VOM or VTVM)

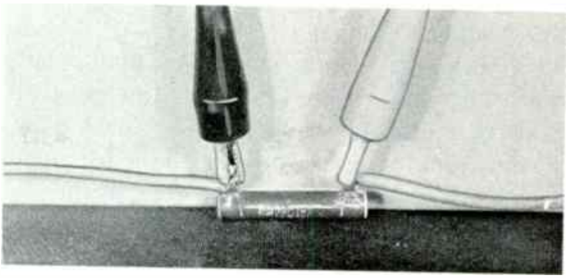
Equipment: 1-ohm power resistor.

Connections Required: Connect resistor in series with the line, as shown in the following illustrations. Connect the meter across the resistor.

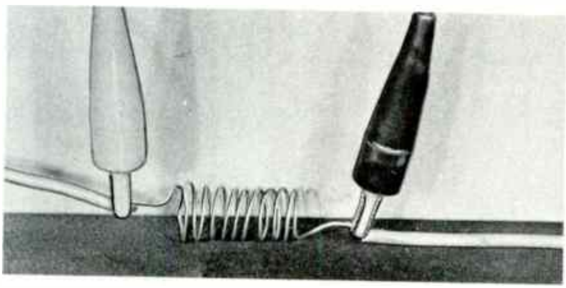
Procedure: Operate the meter on its AC voltage function. Turn the receiver on and observe the scale reading.

Evaluation of Results: If the resistor is actually 1 ohm, a current of 1 ampere will cause a scale indication of 1 volt. Thus, we measure the amperes drawn by the receiver. Multiply this amperage by the line voltage to obtain the volt-amperes drawn by the receiver.

The number of volt-amperes drawn is generally greater than the number of watts used by the receiver. The reason is that the input impedance to the power supply is not purely resistive, but has a certain amount of reactance. However, the volt-ampere value is customarily regarded as the watts drawn by the receiver.



A standard power resistor connected in series with the line to the receiver.



A Manganin wire spiral used as a power resistor in the line.

NOTE 57

Good Waveform Required for Accurote Power Measurements

The test described in U74 will be incorrect if the power line does not supply a good sine waveform. Normally, the power waveform is reasonably good. Sometimes, however, it is poor. To make a waveform check, see U66. You can use the same method to check the power-line waveform. Power-line harmonics, if present, are usually odd, particularly third (iron) harmonics. In some heavily industrialized areas, even harmonics also are found in the power-line waveform.

U75

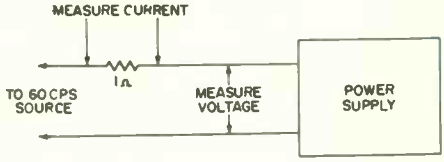
To Measure the AC Impedance of a Circuit

Equipment: 1-ohm power resistor.

Connections Required: Connect resistor in series with the line, as shown in the following illustration.

Procedure: Measure voltage drop across resistor and calculate the current flow. Then measure voltage applied to circuit (see illustration).

Evaluation of Results: The voltage value divided into the current value gives the input impedance of the circuit. This impedance value is for the test frequency only. At other frequencies, other impedance values will be found.



Test setup.

U76

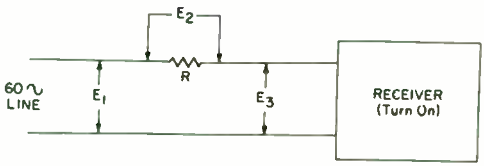
To Measure the Power Factor of a Radio or TV Receiver Power Supply

Equipment: Power resistor.

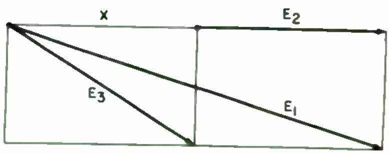
Connections Required: Connect power resistor in series with line to receiver. Connect AC voltmeter in turn across the power resistor, across the line, and across the receiver input.

Procedure: Note AC voltage values obtained in the above three connections. Let each volt represent a certain distance. Then fit E_1, E_2, and E_3 into a rectangle, as shown.

Evaluation of Results: Measure the length of X, and divide the length of X by the length of E3. This is the power factor of the circuit.



Test setup.



Plot of voltages.

NOTE 58

Resistive Circuit Has Unity Power Factor

When the power factor is equal to 1 (when $X = E_3$), the circuit has a purely resistive input. On the other hand, when the power factor is equal to zero (when $X = 0$), the circuit has a purely reactive input. Most circuits have both a resistive and a reactive input.

NOTE 59

Power-Factor Measurement Inaccurate If Waveform Is Poor

Keep in mind that the test described in U76 cannot be made accurately unless the line voltage has a good sine waveform. Harmonics in the supply voltage can cause startling errors. When the waveform is poor, it is quite possible to read more AC voltage across the resistor than across the line itself. This is a typical example of waveform error which is both surprising and baffling to the beginner.

U77

To Check the Ripple Voltage in a Power Supply

Equipment: None.

Connections Required: Connect meter test leads from power-supply output to chassis ground.

Procedure: If a VOM is used, operate on Output function. If a VTVM is used, operate on AC voltage function.

Evaluation of Results: If a peak-to-peak VTVM is used, the value of ripple voltage indicated can be compared against the minimum ripple voltage specified in receiver service literature. On the other hand, a VOM is subject to waveform error, and a comparative test must be made on a receiver of the same type in good operating condition.

U78

To Check the Voltage Across the Vertical-Deflection Coils

Equipment: None.

Connections Required: Connect test leads from VOM to terminals of vertical-deflection coils.

Procedure: Operate VOM on Output function. Otherwise, the VOM may be damaged by the DC voltage at the vertical-deflection coils.

Evaluation of Results: A reading of several volts normally is obtained. The normal reading depends upon the type of yoke, size of picture tube, and voltage range. A comparison test can be made against a receiver of the same type in good operating condition.

NOTE 60

Typical VOM Indications of Vertical-Output Voltage

Typical "Output" voltage indications of vertical-deflection voltage with a 20,000 ohms-per-volt VOM (1,000 ohms-per-volt sensitivity on Output function) are as follows:

On 10-volt range of VOM ....4.5 volts
On 50-volt range of VOM ....7.0 volts

Higher voltage indications are obtained with a 100,000 ohms-per-volt VOM (5,000 ohms-per-volt sensitivity on Output function):

On 8-volt range of VOM ....7.5 volts
On 40-volt range of VOM ....8.0 volts

Note that some 20,000 ohms-per-volt VOM's have a 5,000 ohms-per-volt Output sensitivity.

DC CURRENT TESTS

U79

To Measure the Grid Current of a Tube (VOM)

Equipment: None.

Connections Required: Open the grid-return circuit. Complete the circuit with the VOM test leads.

Procedure: Tube can be checked under no-signal condition or with applied signal. Make initial measurement on high-current range to avoid possible damage to the VOM. Switch progressively to lowest current range if necessary.

Evaluation of Results: Tubes that are properly biased and not gassy will have very low values of grid current. Sometimes a tube develops grid emission, which causes appreciable grid-current flow.

NOTE 61

Removable Pin-Type Test Adapter

To measure current from the tube side of the chassis, use the type of test adapter that has a removable pin between the clips of each terminal. Remove the pin and connect the meter test leads between the clips.

To Measure the Screen Dissipation of an Output Tube

Equipment: None.

Connections Required: Open the screen lead and complete the circuit through the VOM. Then close the screen lead and connect the meter test leads from screen to cathode.

Procedure: Observe the current and voltage readings obtained.

Evaluation of Results: Multiply the screen current by the screen voltage to obtain the screen dissipation. Since the current is in amperes and the voltage is in volts, the screen dissipation will be in watts. Check value of screen dissipation against value specified in tube manual.

NOTE 62

Use Caution in Connecting VOM for Current Measurements

Beginners must be cautious when measuring current values and *never* connect across a voltage source. If appreciable voltage is applied to a milliammeter or microammeter, it will be instantly burned out. A current meter must always be connected in series with the circuit under test. Make the initial measurement with the VOM set to its highest current range. Then reduce the range setting as required.

NOTE 63

Bypass Capacitor Protects Current Meter from AC Pulses

The dissipation of any tube electrode (plate, grid, etc.) can be measured by this method. If you are measuring DC current in a lead which also carries strong AC current pulses, the VOM should be protected by shunting a 0.25-mfd capacitor across the test leads. The capacitor bypasses the AC pulse voltage, but permits the DC current to pass through the meter.

U81

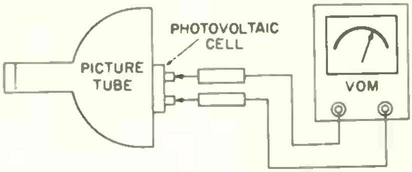
To Check the Uniformity of Raster Brightness (VOM)

Equipment: Photovoltaic cell.

Connections Required: Connect VOM test leads to terminals of light cell.

Procedure: Operate VOM on its lowest current range (such as 50 microamperes). Tune receiver to vacant channel. Advance brightness control for medium level of raster. Slide the light cell over the entire face of the picture tube and note the meter readings.

Evaluation of Results: If the picture tube is in good condition and if there are no spurious AC voltages at the picture-tube electrodes, the meter reading will be practically constant at any point on the raster.



Checking raster brightness.

U82

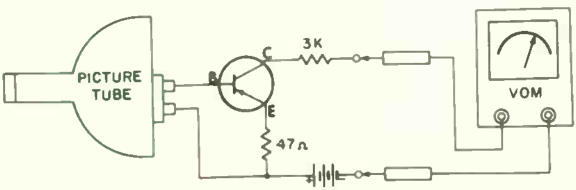
To Make Tests at Very Low Light Levels

Equipment: Transistor, 47-ohm resistor, 3K resistor, and 6-volt battery.

Connections Required: Connect as shown in the following illustration.

Procedure: Operate VOM on its lowest current range.

Evaluation of Results: The transistor increases the sensitivity of indication approximately ten times.



Checking raster brightness at low-brightness levels.

U83

To Measure the Cathode Current of a Horizontal-Output Tube (VOM)

Equipment: None.
Connections Required: Open the cathode lead to the output tube. Connect the meter to the ends of the lead to complete the cathode circuit.
Procedure: Operate the VOM on its DC current function.
Evaluation of Results: Adjust the horizontal-drive control for minimum current, maintaining full sweep width without drive lines. Adjust the horizontal-linearity coil for a current dip or for minimum current without sweep distortion.

U84

To Check the Adjustment of a Horizontal-Linearity Coil (For Flyback Circuits as Noted in Receiver Service Data)

Equipment: None.
Connections Required: Remove flyback fuse. Connect VOM test leads across fuse clips.
Procedure: Use suitable current range (500 ma for color receivers). Note DC current reading. Adjust linearity coil (also adjust width coil in some receivers).
Evaluation of Results: Correct adjustment is indicated by a minimum current reading.

U85

To Measure the Current Drain on a Power Supply

Equipment: None.
Connections Required: Disconnect power-supply output lead from filter. Connect test leads to complete the circuit.
Procedure: Operate VOM on DC current function. Note reading on scale.

Evaluation of Results: Some receivers have two or three power-supply outputs. Each output is tested separately and the scale readings added to obtain the total current demand. Note that the demand depends upon the settings of the receiver controls. Also, the demand in some receivers fluctuates widely during warm-up.

ALIGNMENT APPLICATIONS

U86

To Align an AM IF Transformer

Equipment: Signal generator and 0.1-mfd capacitor.

Connections Required: Connect output from signal generator to grid of IF tube preceding the transformer to be aligned. If a transformerless set is under test, connect a 0.1-mfd capacitor in series with the generator ground lead to the receiver chassis. Connect VOM or VTVM across the speaker voice coil.

Procedure: If a VOM is used, operate on the Output function. If a VTVM is used, operate on the AC voltage function. Set the generator for modulated-RF output. Tune generator to IF frequency specified in receiver service literature (usually 455 kc). Observe other procedures specified in the service literature, such as setting the receiver tuning capacitor fully open. Adjust tuning slugs (or trimmers) in the IF transformer. Use as low output as possible from the generator to avoid overload.

Evaluation of Results: Adjust the IF tuning slugs (or trimmers) for maximum indication on the meter.

NOTE 64

Eliminating Hum Modulation of Generator Signal

In transformerless radios, hum modulation of the generator signal may be troublesome unless a small blocking capacitor is used. For example, use a 0.001-mfd capacitor in U86, instead of a 0.1-mfd capacitor if necessary.

To Measure the Stage Gain of an AM IF Amplifier

Equipment: Signal generator and 0.1-mfd fixed capacitor.

Connections Required: Connect output from signal generator to grid of IF stage being checked. If a transformerless set is under test, connect a 0.1-mfd capacitor in series with the generator ground lead to the receiver chassis. Connect VOM or VTVM across the speaker voice coil.

Procedure: Observe meter reading. Then apply generator output to preceding or succeeding IF grid. Do not change the output from the generator. Again observe the meter reading.

Evaluation of Results: The stage gain is equal to the ratio of the two meter readings. Note that the measurement will be incorrect if an IF stage is overloaded; therefore, keep the signal-generator output at the lowest point which will give a readable signal.

U88

To Align an Overcoupled IF Transformer by Alternate Loading

Equipment: Signal generator, blocking capacitor, and 300-ohm resistor.

Connections Required: Same as for usual AM alignment. Make the first test by connecting the 300-ohm resistor across the primary of the IF transformer. Make the second test by disconnecting the resistor from the primary and connecting it across the secondary of the IF transformer.

Procedure: Tune generator to the center of the passband (such as 455 kc). Use modulated RF output. Adjust secondary trimmer when the resistor is connected across the IF transformer primary. Adjust primary trimmer when the resistor is connected across the secondary. Finally, remove resistor from transformer.

Evaluation of Results: Alternate loading permits correct adjustment of overcoupled transformers by a simple peaking procedure. An overcoupled transformer (used for hi-fi reception) normally has a double hump. Shunting the resistor across the primary lowers its Q and changes the double-humped response to a single peak. Thus, the secondary can be peak-aligned to the center frequency. Likewise, shunting the resistor across the secondary permits the primary to be peak-aligned to center frequency. Finally, when the resistor is disconnected, the transformer has its correct double-humped wide-band response.

NOTE 65

Alternate Loading Method Applies to Overcoupled Transformers Only

When an IF stage is normally stagger-aligned or is normally over-coupled *and* stagger-aligned, the alternate loading method cannot be used. Instead, sweep-alignment procedures are advised. For details of sweep alignment, see the companion volume, *101 Ways to Use Your Sweep Generator.*

U89

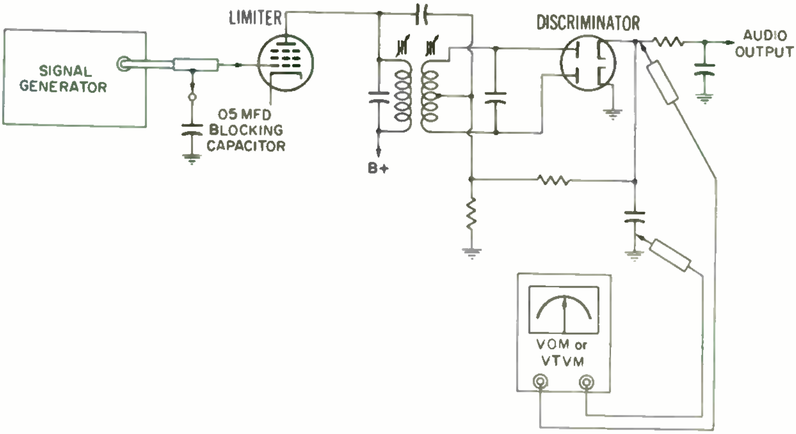
To Align an FM Discriminator Secondary

Equipment: Blocking capacitor (about 0.05 mfd) and signal generator.

Connections Required: Connect blocking capacitor in series with generator ground lead. Apply generator signal between grid of limiter tube and chassis ground. Connect VOM or VTVM between audio-output lead of discriminator and chassis ground.

Procedure: Tune signal generator to IF center frequency (usually 10.7 mc). Operate VOM or VTVM on DC volts function. Use unmodulated RF output from generator. Adjust secondary slug on discriminator transformer. Observe any precautions specified in receiver service literature.

Evaluation of Results: Align secondary for zero-voltage indication. A positive and a negative meter reading are obtained on either side of the correct alignment point.



Test setup.

U90

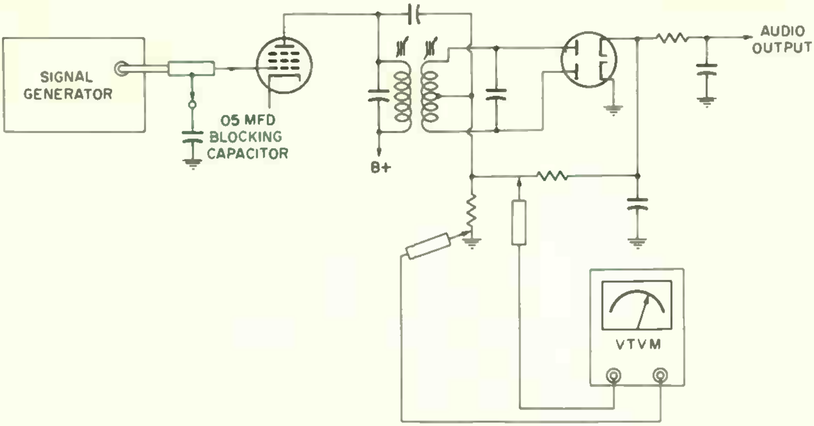
To Align an FM Discriminator Primary

Equipment: Signal generator and blocking capacitor (about 0.05 mfd).

Connections Required: Connect blocking capacitor in series with generator ground lead. Apply generator signal between grid of limiter tube and chassis ground. Connect DC probe of VTVM to center tap of discriminator secondary winding.

Procedure: Observe any precautions specified in receiver service literature, such as receiver control settings. Tune signal generator to specified IF frequency (usually 10.7 mc). Use unmodulated RF output from generator. Adjust slug or trimmer in discriminator transformer primary. Operate VTVM on DC volts function.

Evaluation of Results: Adjust trimmer for maximum reading on meter.



Test setup.

U91

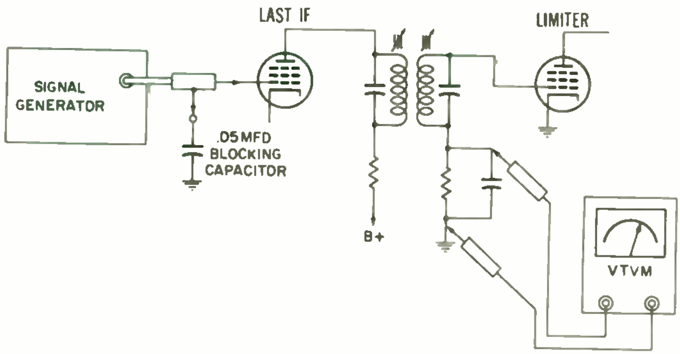
To Peak-Align an FM IF Transformer

Equipment: Signal generator and blocking capacitor (about 0.05 mfd).

Connections Required: Connect blocking capacitor in series with the generator ground lead. Apply generator output between grid of IF tube preceding transformer and chassis ground. Connect DC probe of VTVM at limiter grid. Return VTVM to chassis ground.

Procedure: Observe any incidental notes specified in receiver service data. Tune signal generator to IF center frequency (usually 10.7 mc). Operate VTVM on DC volts function. Operate generator on unmodulated RF output. Adjust slugs or trimmers for primary and secondary of transformer.

Evaluation of Results: Alignment is correct when the meter shows maximum indication on DC volts scale.



Test setup.

U92

To Plot the Response Curve of an FM Receiver

Equipment: Signal generator and graph paper.

Connections Required: Connect terminated output cable from signal generator to antenna-input terminals of receiver. Connect DC probe of VTVM at limiter grid. Return VTVM to chassis ground.

Procedure: Tune FM receiver to desired channel. Mark off a suitable range of frequencies on the graph paper. At right angles, mark off an appropriate range of voltage readings. Tune generator through the receiver passband and note the voltage readings at a sufficient number of frequencies to obtain the shape of the response curve.

Evaluation of Results: Compare plotted response curve with specified curve in receiver service literature.

Unless the signal-generator output cable is correctly terminated, the generator output can vary enough over the passband to cause an erroneous curve plot. Standing waves in the generator cable will cause this output variation.

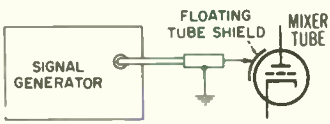
To Peak-Align a TV IF Amplifier

Equipment: Signal generator and AGC override bias box. (If a VOM is used, a 50,000-ohm resistor should be inserted in series with the "hot" lead to the meter.)

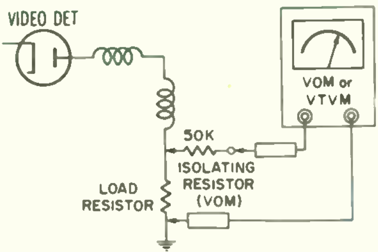
Connections Required: Apply output from signal generator to a floating tube shield over the mixer tube (a floating tube shield is a shield lifted clear of the chassis). Connect output from bias box to IF AGC line. Connect VOM through 50K isolating resistor across video-detector load resistor. If a VTVM is used, no isolating resistor is required.

Procedure: Use about −3 volts of AGC override bias. Disable local oscillator by cutting off the grid or plate pin from the tube base. Set signal generator to peaking frequency, as specified in receiver service literature. Operate meter on DC voltage function. Turn slug in IF coil until meter indicates maximum value. Repeat the procedure for each IF stage.

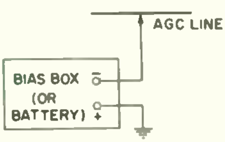
Evaluation of Results: When the meter reading is maximum, the stage is peaked to the generator frequency, regardless of the tuning of the other IF stages.



(A) Mixer connections.



(B) Detector connections.



(C) AGC line connections.

Test setup.

NOTE 66

Peak Alignment Provides a Rough Adjustment Only

Peak alignment, although often adequate, is always somewhat incomplete because of component tolerances in the IF amplifier. For this reason, better receiver operation is obtained if the peak alignment is followed with compromise adjustments of individual stages. These adjustments must be done with a sweep generator and oscilloscope. For details, see the companion volume, *101 Ways to Use Your Sweep Generator*.

U94

To Adjust a Trap in a TV IF Amplifier

Equipment: Signal generator and AGC override bias box. (If a VOM is used, a 50,000-ohm resistor should be inserted in series with the "hot" lead to the meter.)

Connections Required: Apply output from signal generator to a floating tube shield over the mixer tube (a floating tube shield is a shield lifted clear of the chassis). Connect output from bias box to IF AGC line. Connect VOM through 50K isolating resistor across video-detector load resistor. If a VTVM is used, no isolating resistor is required.

Procedure: Set generator as accurately as possible to the trap frequency specified in receiver service literature. Turn slug in trap and observe meter reading.

Evaluation of Results: Trap is properly adjusted when meter reading is minimum. In most cases you will find a null, with a little response on the other side of minimum. To clarify a null, increase generator output or reduce value of AGC override bias.

To Check the Frequency Response of the IF Amplifiers of a TV Set

Equipment: Signal generator and AGC override bias box. (If a VOM is used, a 50,000-ohm resistor should be inserted in series with the "hot" lead to the meter.)

Connections Required: Apply output from signal generator to a floating tube shield over the mixer tube (a floating tube shield is a shield lifted clear of the chassis). Connect output from bias box to IF AGC line. Connect VOM through 50K isolating resistor across video-detector load resistor. If a VTVM is used, no isolating resistor is required.

Procedure: Tune signal generator through the IF passband, and plot the voltage readings on graph paper.

Evaluation of Results: Compare the plotted curve with specified curve in receiver service literature. Note that the signal generator should have reasonably uniform output (see U10).

NOTE 67

Sweep Alignment and Square-Wave Tests Are Required for Optimum Performance

Optimum response from a TV receiver is obtained if a sweep-alignment test is followed with a transient test. This test is made with a square-wave generator and an oscilloscope. For details, see the companion volume, *101 Ways to Use Your Oscilloscope*. Ideal frequency-response curves do not always give the best possible picture reproduction. This is due to component tolerances, which cause the phase response of the complete signal system to depart from the ideal. For good picture reproduction, phase response is more important than frequency response. There is only one practical way you can adjust a receiver for best phase response: make over-all square-wave tests from the antenna-input terminals of the receiver to the video-amplifier output. Faulty phase response causes displacement of picture elements, plus associated distortions.

To Check a TV IF Amplifier for Regeneration

Equipment: Signal generator and AGC override bias box. (If a VOM is used, a 50,000-ohm resistor should be inserted in series with the "hot" lead to the meter.)

Connections Required: Apply output from signal generator to a floating tube shield over the mixer tube (a floating tube shield is a shield lifted clear of the chassis). Connect output from bias box to IF AGC line. Connect VOM through 50K isolating resistor across video-detector load resistor. If a VTVM is used, no isolating resistor is required.

Procedure: Tune signal generator for midband response of IF amplifier. Then reduce the generator output to a very low value. Finally, reduce the bias-box voltage and watch how the meter response rises.

Evaluation of Results: The meter response should rise smoothly, without any abrupt jumps up or down. Jumps in the meter reading indicate regeneration. If the reading suddenly jumps to a very high value, such as 10 or 15 volts, the IF stage has broken into oscillation.

U97

To Check an IF System for Mixer Regeneration

Equipment: Signal generator and AGC override bias box. (If a VOM is used, a 50,000-ohm resistor should be inserted in series with the "hot" lead to the meter.)

Connections Required: Apply output from signal generator to a floating tube shield over the mixer tube (a floating tube shield is a shield lifted clear of the chassis). Connect output from bias box to IF AGC line. Connect VOM through 50K isolating resistor across video-detector load resistor. If a VTVM is used, no isolating resistor is required.

Procedure: Set signal generator for a response of 1 volt DC at the midband frequency of the IF amplifier. Then rotate the receiver channel-selector switch through the low and high channels while observing the meter reading.

Evaluation of Results: When there is no regeneration, the meter reading will not change during this switching test. On the other hand, if the meter reading varies greatly, the mixer is objectionably regenerative.

U98

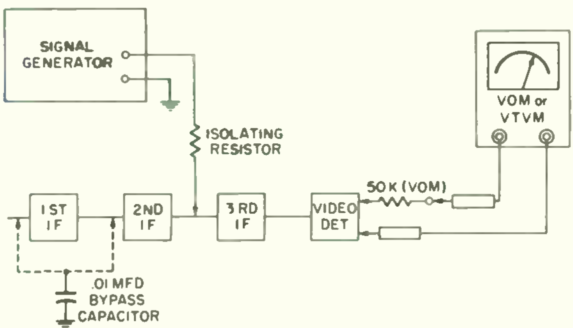
To Signal-Trace an IF Amplifier for a Regenerative Feedback Loop

Equipment: Signal generator, 0.01-mfd bypass capacitor, 50K isolating resistor (if VOM is used; otherwise, use DC probe of VTVM without isolating resistor), and injection resistor (value determined by trial).

Connections Required: Connect VOM through isolating resistor across video-detector load resistor (or connect VTVM DC probe across load resistor). Apply signal-generator output to grid of last IF tube through an injection resistor which should be as large as possible, yet permit reasonable deflection on the meter.

Procedure: Tune a signal generator to midband region of IF passband. Observe meter reading. Then shunt the bypass capacitor in turn from each preceding tube grid to chassis. Note any change in meter reading.

Evaluation of Results: Any change in meter reading shows the bypass capacitor is being applied inside a feedback loop. No change in meter reading shows you have moved out of the feedback loop. This test does not show where the regenerative loop ends. However, it does show where the regenerative loop begins.



Test setup.

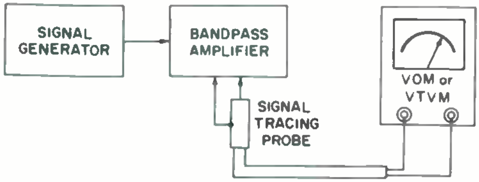
To Peak-Align a Bandpass Amplifier

Equipment: Signal generator and high-frequency rectifier (signal-tracing) probe.

Connections Required: Apply generator signal to grid of bandpass amplifier tube. Connect probe to VOM or VTVM. Apply probe across a low-impedance point in the bandpass-amplifier output circuit.

Procedure: Set signal generator to peaking frequencies specified in receiver service literature. Adjust slug in associated bandpass-amplifier coil for maximum DC indication on meter. Repeat for each tuned circuit in the bandpass-amplifier network.

Evaluation of Results: Peak alignment is often satisfactory, but for best receiver operation, a final sweep-alignment check is recommended. For details, see the companion volume, *101 Ways to Use Your Sweep Generator.*



Test setup.

U100

To Measure the Gain of a Bandpass Amplifier

Equipment: Signal generator and high-frequency rectifier (signal-tracing) probe.

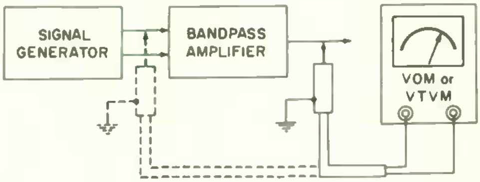
Connections Required: Apply generator signal to grid of bandpass amplifier tube. Connect probe to VOM or VTVM. Apply probe across a low-impedance point in the bandpass amplifier output circuit. Then, apply probe across the generator output terminals.

Procedure: With meter connected at output of bandpass amplifier, tune signal generator for maximum meter indication.

Then apply probe at the signal-generator output. Observe drop in meter reading.

Evaluation of Results: The ratio of the two meter readings is the gain of the bandpass amplifier.

Test setup.



U101

To Check Chroma Channel Gains

Equipment: Signal generator and high-frequency rectifier (signal-tracing) probe.

Connections Required: Connect signal-tracing probe to VOM or VTVM. Apply generator output to grid of bandpass amplifier tube. Connect probe in turn to a low-impedance point in the R−Y circuit, in the B−Y circuit, and in the G−Y circuit (grid terminals of picture tube are suitable).

Procedure: Adjust signal generator to 3.56 mc (this insures loss of color sync, which is required in this test). A rainbow pattern will be observed on the picture-tube screen. Observe meter readings while the probe is applied in turn at the chroma-channel outputs.

Evaluation of Results: Check relative meter readings against specified gains of chroma channels in receiver service data.

APPENDIX

POWER AND ENERGY

Electrical power refers to the rate at which work is being done. Voltage is an electrical force which causes electrons (current) to flow in a closed circuit. However, when voltage exists between two points but electrons cannot flow, no work is done. When voltage causes electrons to move, work is done. Electrical work is equal to electrical energy. We measure power in watts; one watt is equal to one joule per second.

$$\text{Volts} \times \text{Amperes} = \text{Watts, or Joules per second.}$$

We measure electrical work or energy in watt-seconds or watt-hours.

$$\text{Volts} \times \text{Amperes} \times \text{Seconds} = \text{Watt-seconds.}$$

$$\text{Volts} \times \text{Amperes} \times \text{Hours} = \text{Watt-hours.}$$

VOLTAGE IS MORE THAN AN ELECTRICAL PRESSURE

It is often said that voltage is an electrical pressure that causes an electric current. While this is basically true as far as it goes, it is not inclusive enough. Observe the simple capacitive circuit depicted in Fig. A-1. A 1-volt source connected across a 1-farad capacitor causes a flow of 6.25×10^{18} electrons, or 1 coulomb of electricity. We then have a charge separation across the capacitor, with the right-hand plate negative with respect to the left-hand plate. This requires the accomplishment of work. In particular, to produce a charge separation of 1 coulomb (6.25×10^{18} electrons) with a potential difference of 1 volt requires 1 joule of work. In other words, current is always accompanied by work, because we cannot get something for nothing in an electrical circuit.

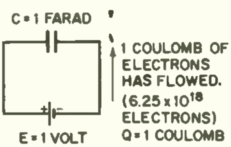


Fig. A-1. One volt causes a flow of 6.25×10^8 electrons in a one-farad circuit.

Electric charge consists of electrons. Electric current consists of electrons in motion. For example, in Fig. A-2 we have a plate current of 10 milliamperes. This simply means that 6.25×10^{18} electrons leave the cathode and enter the plate each second. Of course, electrons will not flow unless they are pushed or pulled. Energy must be applied to a circuit to cause current (electron) flow. The amount of *energy* that is required to move one unit of charge is called *voltage*. Let us see why voltage is energy per unit charge (not simply electrical pressure). If we move a charge (such as 6.25×10^{18} electrons) from one plate of a capacitor to the other plate, work has been accomplished. Work is numerically equal to energy.

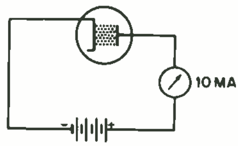


Fig. A-2. Current consists of electrons in motion.

Work, of course, is equal to force times distance. If you move one pound vertically through a distance of one foot, you have accomplished one foot-pound of work. If a horse moves 2×10^6 pounds vertically through one foot, he has accomplished one horsepower-hour of work. The horsepower is a rate of doing work (consuming energy); one horsepower is equal to 746 watts. With these fundamental facts in mind, let us ask: "What is a volt?"

The voltage between two points is the ratio of work to electrical charge. In other words, voltage is a potential difference, that we express as $V_1 - V_2$, and we say that:

$$V_1 - V_2 = \frac{W}{Q}$$

where,

$V_1 - V_2$ is the voltage between two points,
W is the work that has been done,
Q is the electrical charge that has been moved between the points.

The volt is the potential difference established between two points when one unit of work has been done in moving one unit of electrical charge from one point to the other. To summarize, although the volt is basically a measure of work done (energy consumed) per unit charge moved, we usually take the superficial point of view that voltage is merely an electrical pressure. But when we forget what a volt really is, we cannot understand the time constant of an RC or RL circuit.

ELECTRIC CURRENT

Electrical current is a movement of electric charge. If a DC voltage transfers 1 coulomb of electric charge past a point for 1 second, the rate of current is 1 ampere. A coulomb, of course, comprises 6.25×10^{18} electrons. The rate of current is thus expressed in coulombs per second. When there is current in a circuit, it encounters an opposition that we call resistance. What is resistance? A little reflection leads us to conclude that resistance is defined in terms of voltage and current. In other words, resistance is a voltage/current ratio, or $R = E/I$. If the applied voltage is equal to 1 volt, and the current is equal to 1 ampere, the circuit resistance is equal to 1 ohm.

There is no other way to define or measure resistance, other than as an E/I ratio. Consider the circuit in Fig. A-2. We say that the diode has a certain value of plate resistance. How shall we measure this plate resistance? The only way we can do this is to measure the voltage that is applied to the diode, and the current through the diode. Then, the plate resistance of the diode is equal to E/I. An ohmmeter measures resistance by automatically solving the Ohm's law formula $R = E/I$. In other words, an ohmmeter applies a known voltage to the component under test, and indicates the current. In turn, the ohmmeter scale is calibrated in E/I units, or ohms.

RESISTANCE, CAPACITANCE, INDUCTANCE, AND TIME

We know that work is equal to force multiplied by distance. We also know that work is numerically equal to energy, and therefore that energy is equal to force multiplied by distance. Power is equal to voltage multiplied by current, or $Watts = EI$. In other words, power is the rate of energy consumption, or power is equal to energy per unit of time:

$$P = \frac{W}{T}$$

where,

P is power,
W is work,
T is time.

Thus, the basic dimensions of electrical quantities are expressed in terms of force, distance, time, and charge. This understanding will make it obvious why resistance multiplied by capacitance is equal to time. Let us go through this basic principle step-by-step.

Electric current has the dimensions of charge divided by time, or $I = Q/T$. In other words, current is measured in terms of coulombs flowing past a point in one unit of time. Recall that voltage is a unit of work per unit charge. One volt is the work that has been accomplished (or energy that has been consumed) in moving a unit of electric charge (Q) through a unit of distance (L). Therefore, voltage has the dimensions of FL/Q. Now resistance is measured according to Ohm's law, $R = E/I$. In turn, resistance has the dimensions of FLT/Q^2. When we write $R = FLT/Q^2$, we are writing a dimensional formula.

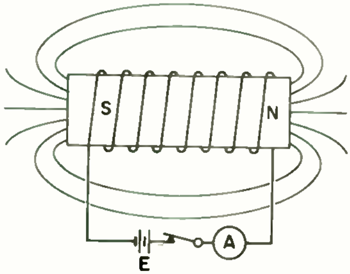
We know that $Q = CE$, or, electric charge is equal to capacitance multiplied by voltage, or $C = Q/E$. In terms of dimensions:

$$C = \frac{Q^2}{LF}$$

where,

C is capacitance,
Q is charge,
L is distance,
F is force.

Recall that the time constant of an RC circuit is given in seconds, where $T = RC$, with T in seconds, R in ohms, and C in farads. From the foregoing discussions of dimensions, we see that $RC = FLT/Q^2 \times Q^2/LF = T$. In other words, FL in the numerator cancels out FL in the denominator; Q^2 in the numerator cancels out Q^2 in the denominator. We are now left with $RC = T$, *where R is resistance in ohms, C is capacitance in farads, and T is time in seconds*. Now WE KNOW WHY RESISTANCE MULTIPLIED BY CAPACITANCE GIVES TIME IN SECONDS.



A-3. Expanding or contracting flux lines produce self-induction.

Let us proceed to analyze the time constant of an inductive circuit. Observe the relations depicted in Fig. A-3. When the switch is closed, there is current through the coil winding; in turn, a magnetic field is produced. Magnetic-flux lines expand outward and cut the turns of the coil. This induces a counter-voltage that opposes the battery voltage. Induced voltage is proportional to the number of turns multiplied by the rate of change of magnetic flux. The number of turns, such as 10, or 100, has no physical dimensions; pure number has no physical dimension. Hence, magnetic flux has the dimensions, $\phi = FLT/Q^2$.

Magnetic flux imposes an opposition to current; resistance also imposes an opposition to current. Hence, it is not surprising that resistance and magnetic flux have the same physical dimensions. Now, the time constant of a series RL circuit is equal to L/R. Let us ask what the physical dimensions of inductance may be. Inductance is expressed by the formula, $E = LI/T$. Note that L represents inductance in henrys. To avoid confusion with length in our dimensional analysis, let us write inductance as L, and length as L. The formula for inductance states that the voltage across the terminals of a coil is equal to its inductance in henrys, multiplied by the rate of current change through the coil (I/T). If the current changes at the rate of 1 ampere per second through a 1-henry coil, the terminal voltage of the coil will be 1 volt.

Now, let us observe the physical dimensions of inductance. If $E = \mathit{L}I/T$, then $\mathit{L} = TE/I$. Since T is time, E is FL/Q, and I is Q/T, we write:

$$\mathit{L} = TFLT/Q^2, \quad \text{or,} \quad \mathit{L} = FLT^2/Q^2.$$

We have thus obtained the physical dimensions of inductance. The time constant of a series $\mathit{L}R$ circuit is equal to L/R. Let us see what the physical dimensions of L/R may be: $\mathit{L}/R = (FLT^2/Q^2)/(FLT/Q^2)$. F, L, and Q^2 cancel out, and we are left with $\mathit{L}/R = T$. Therefore, the physical dimension of L/R is time, just as the physical dimension of RC is time.

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101 WAYS to Use Your VOM and VTVM

SECOND EDITION

by Robert G. Middleton

Television servicemen and electronics technicians are required by the nature of their work to be familiar with a large variety of test equipment. It is almost always assumed that these men have a good working knowledge of the tools of their trade. Often, however, a certain routine is developed so that each piece of test equipment performs only a limited number of tasks. The procedures worked out may not be the most efficient, yet a familiar routine tends to be used whenever possible as long as the results are anywhere near satisfactory.

The **101 Ways to Use Your Test Equipment** series has been written to encourage servicemen and technicians to explore the total possibilities of their test equipment. Each book takes a major unit or a group of related pieces of equipment and shows the ways it can be used—some conventional, some unusual and imaginative. Test setups, procedures, and results are described and illustrated in detail.

101 Ways to Use Your VOM and VTVM describes the many uses of these two essential pieces of equipment. In addition to explaining and illustrating the many uses for this equipment, it also gives the procedures and tests for checking the accuracy of the equipment itself. The uses of the VOM and VTVM range from simple voltage and resistance checks to alignment applications.

Every serviceman, technician, and experimenter should have the complete series of **101 Ways to Use Your Test Equipment** books on his reference shelf to answer questions regarding the possible uses of test equipment and to supply the best procedures for achieving the desired results.

ABOUT THE AUTHOR

Bob Middleton, one of the few full-time writers in the electronics field, is widely known for his many books and articles on servicing and test equipment. Even though he has many years of experience in the troubleshooting of equipment, Mr. Middleton is not content to rely on this experience alone. Much of his time is spent in his own well-equipped laboratory—trying to find the answer to a confusing symptom or seeking new and better ways to service equipment or use test instruments.

Mr. Middleton is the author of nine other volumes in this series; seven volumes cover the sweep generator, oscilloscope, signal generator, square-wave and pulse generators, and audio, ham, and color-tv test equipment. Two other volumes encompass additional uses of the oscilloscope and VOM and VTVM. He is the author of many other helpful test-equipment and servicing books published by Howard W. Sams & Co., Inc.

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