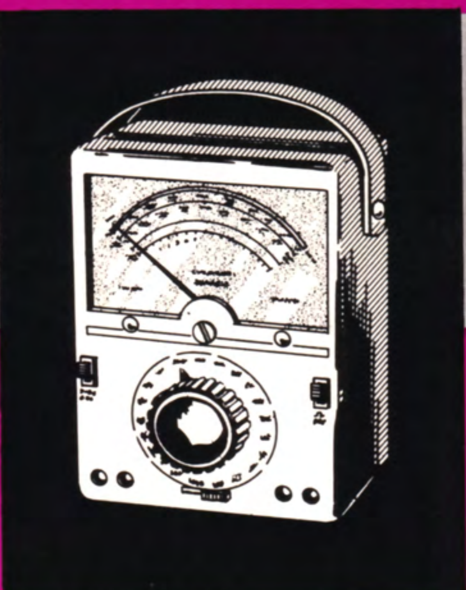
101 MORE WAYS

to use your... VOM and VTVM

by
ROBERT G. MIDDLETON

ALL-NEW & NEVER-BEFORE-PUBLISHED uses for the VOM's and VTVM's. Testing Household Devices, Special Uses, Test-Equipment Checks, Circuit Tests, and Component Tests.



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by ROBERT G. MIDDLETON

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PREFACE

Reaction to the previous *101 Ways to Use* volume on VOM's and VTVM's has been such that another book on the subject was literally demanded by readers.

Thus, *101 MORE Ways to Use Your VOM and VTVM,* contains 101 *more* helpful uses (not contained in the previous volume) for the VOM and VTVM in the following categories: testing household devices, special uses, test-equipment checks, and circuit and component tests.

The ability of a VOM or VTVM to show information relative to circuit action is exceeded only by the oscilloscope. Therefore, the VOM and VTVM are the test instruments most often used by anyone involved in making operational checks of practically all types of electronic or electromechanical equipment.

This handbook has the same general format as its companion volumes. As before, you will find the practical uses for the VOM and VTVM categorized and referenced for quick location.

ROBERT G. MIDDLETON

November, 1961

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INTRODUCTION

The VOM and VTVM are exceptionally useful instruments. Dollarwise, no other instrument can compare with the value of these basic pieces of equipment. Yet, without the knowledge of how a VOM or VTVM can be used, this value is not realized. Electronics technicians, experimenters, hobbyists, etc. often need more knowledge, and this book is intended to give both "know-how" and "can-do" in fields where they find their greatest use. It is not sufficient simply to know the capabilities of a meter, as set forth in its specification sheet. It is also necessary for you to recognize the different types of circuits which a meter can test, and to understand at least the fundamentals of circuit action, plus what results to expect when making tests.

The uses of VOM's and VTVM's are numerous in radio and television servicing. Many of them are contained in the previous volume of this series, *101 Ways To Use Your VOM and VTVM*. The present volume contains 101 *more* uses for your VOM and VTVM not covered in the previous volume. You'll learn about testing household devices, such as the thermostat in an oil-burner electrical system, heating pads, or the high- and low-heat functions in an automatic coffee maker. Also explained are ways to localize the cause of low or no heat in electric hot water heaters, how to check for a defective solenoid in an automatic washer or a faulty coil in an electric clock, and many more.

The VOM can serve as an indicator for a grid-dip meter, an external detector for an impedance bridge, a tachometer, etc. You will also learn how the VOM and VTVM are used as basic test instruments in mobile radio servicing. In this volume you are shown how to measure the sensitivity of an FM mobile receiver, plus how to check the control voltage in a mobile two-wire remote system and the dynamotor of a mobile system. These and many more out-of-the-ordinary uses are included in this volume.

This is a practical handbook for the professional technician; it is neither a theory book nor a textbook. 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. Finally, typical test results are included to tell you what to expect when making various measurements.

TESTING HOUSEHOLD DEVICES

U1

To Check the Detectors in a Door-Opener Receiver

Equipment: None.

Connections Required: Connect the DC probe of the VTVM, in turn, to test points A, B, and C, as indicated in Fig. 1.

Procedure: Observe meter readings for change in value as the transmitter is switched off and on.

Evaluation of Results: The typical system illustrated operates on a carrier frequency of 300 mc, which is modulated by

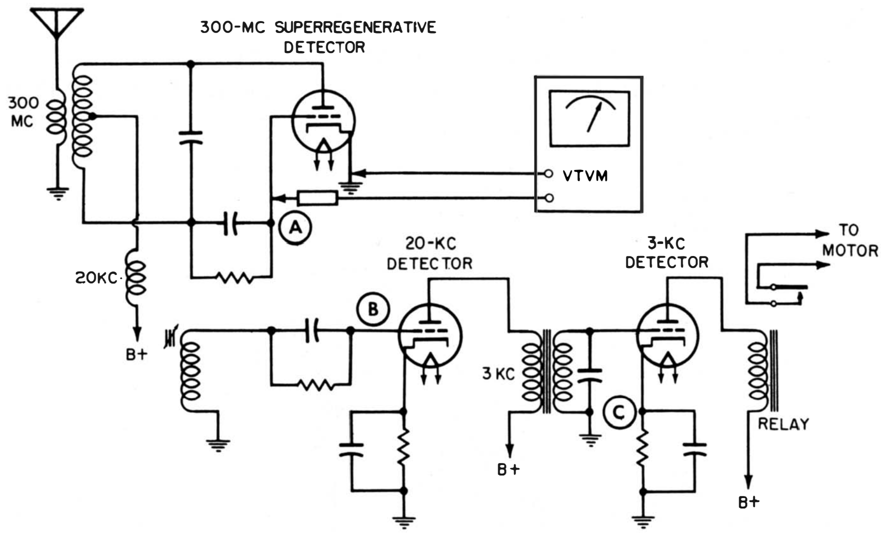


Fig. 1. Typical receiver for a door opener.

frequencies of 20 kc and 3 kc. To check the operation of this circuit first measure the grid voltage of the 300-mc detector. If this detector is oscillating, the grid voltage is negative; if not, the grid voltage is zero or slightly positive. If normal blocking is taking place, there will be an increase in negative voltage when the transmitter is operating. Otherwise, there is a defective component in the circuit. Next, check the grid voltage at the 20-kc detector; the voltage normally becomes more negative when the transmitter is operating. Finally, check the cathode voltage at the 3-kc detector; the cathode voltage normally becomes more positive when the transmitter is operating. As in any receiver, the common faults are shorted or open capacitors, off-value resistors, low or no plate-supply voltage, shorted turns or an open winding in a coil, plus the possibility of defective relay contacts.

U2

To Check a Thyratron Door-Opener Control

Equipment: None.

Connections Required: Connect meter test leads in turn across coils A, B, and C. If required, check relay contacts D. (See Fig. 2.)

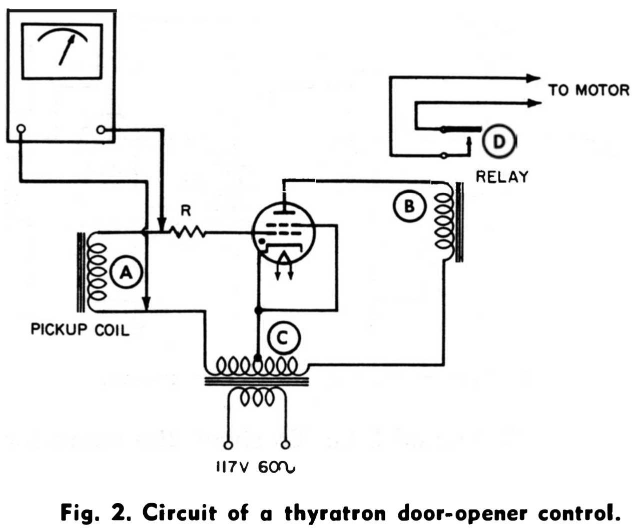


Fig. 2. Circuit of a thyratron door-opener control.

Procedure: Check coils for continuity. If the relay closes normally, the trouble will probably be found in the contacts. If the relay does not close, energize the power transformer, and check the AC voltage across secondary winding C.

Evaluation of Results: This is the inductive-type door-opener control, in which the pickup coil is usually mounted under the floor. The car or truck has a vibrator which energizes a similar coil with AC. When the two coils are near each other, an AC voltage is induced in the pickup coil causing the thyratron to fire on positive peaks. The relay normally holds in as long as the vibrator is actuated. Assuming the thyratron tube is in good condition, failure to operate normally is traceable to defective windings or faulty relay contacts. It is also possible that grid-limiting resistor R is open, or greatly increased in value. If the electronic section and relay check out properly, the motor may be defective. See a later portion of this section for motor-test procedures.

U3

To Check the Thermostat in an Oil-Burner Electric System

Equipment: None.

Connections Required: Connect VOM test leads across the thermostat terminals. (See Fig. 3.)

Procedure: Operate the VOM on its AC-voltage function. Note the scale reading.

Evaluation of Results: If the oil burner fails to ignite and the meter reads 24 volts, the thermostat is defective and the contacts do not close normally. If the reading is zero volts, check the voltage across the relay contacts. If the reading is 117 volts, the relay is defective and the contacts fail to close. On the other hand, if the voltage is zero, the motor is not operative. Note that the 10-kv spark transformer is used to ignite the vapor in the oil burner.

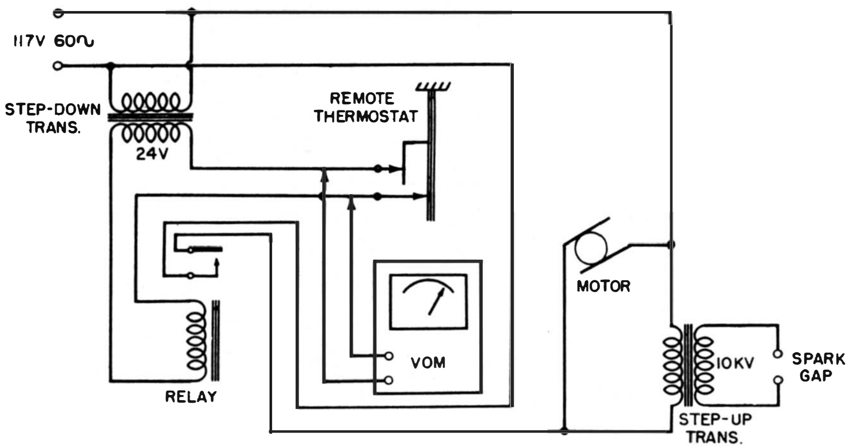


Fig. 3. Basic configuration of an oil-burner electrical system.

U4

To Localize an Intermittent in a Heating Pad

Equipment: None.

Connections Required: Connect ohmmeter test leads across the power-plug terminals of the heating pad.

Procedure: Switch the pad control to its low-heat position. Flex the pad while watching the meter reading. If the ohmmeter pointer swings, repeat the procedure with the control switch in the medium and high positions.

Evaluation of Results: A typical heating-pad circuit is shown in Fig. 4. An intermittent can result from loose or otherwise defective internal connections, a broken heater element, or, less often, mechanical defects in a thermostat. The tests described will assist in localizing the defect when the pad is cold. If the defect does not show up, a hot test is required. The circuits can be traced with the ohmmeter while the pad is heated artificially. Note in Fig. 4 that thermostat 1 is a protective device intended to operate as a circuit breaker in case one of the other thermostats should fail to open. Thermostats 1 and 2 normally open at about 180° Fahrenheit.

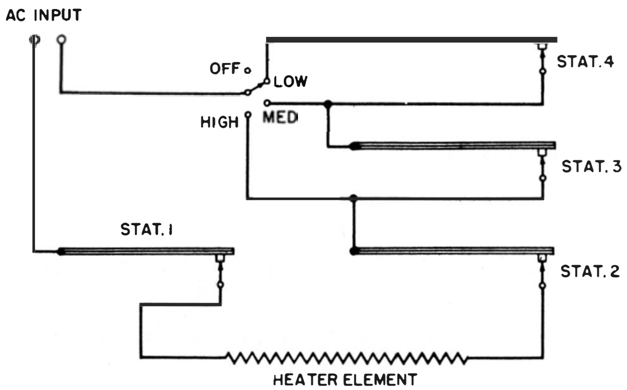


Fig. 4. Wiring diagram of a heating pad.

NOTE 1

Heat Generated by an Element Increases When There Are Shorted Turns (Constant-Voltage Source)

When there are shorted turns in an element, the amount of heat increases. This results from the use of *constant-voltage* sources. The amount of heat is given by $W = I^2R$. Shorted turns result in less resistance, but more current flow. Since the power consumed (developed heat) goes up as the square of the current, an element with shorted turns operates at a higher temperature. On the other hand, if a load resistor is connected to a *constant-current* source, the heat generated decreases if there are shorted turns. Less heat is generated because the current is constant, and hence I^2 is also constant. Less resistance results in a smaller I^2R product, or lower power dissipation by the load resistor. The first case (constant-voltage source) is met in the devices energized from a 117-volt power outlet. The second case (practically constant-current source) is met in plate-load resistors for pentodes in speech amplifiers, or video amplifiers—if some of the turns in the plate-load resistor should become shorted, the power dissipated decreases. If half the turns should become shorted, *e.g.*, only half as much heat is generated. Note, however, that the active turns operate at the same temperature as before the short, because the current through the active turns remains practically the same.

To Check the High-Heat Function in an Automatic Coffee Maker

Equipment: None.

Connections Required: Connect ohmmeter test leads across AC input terminals for preliminary check, as shown in Fig. 5. Proceed from A to B and B to C, as required.

Procedure: Check for continuity across the AC input terminals and, if open or high resistance, check continuity from A to B (check of magnetic-switch contacts). If switch contacts are functioning properly, check for continuity from B to C, to determine if the high-heat element is burned out.

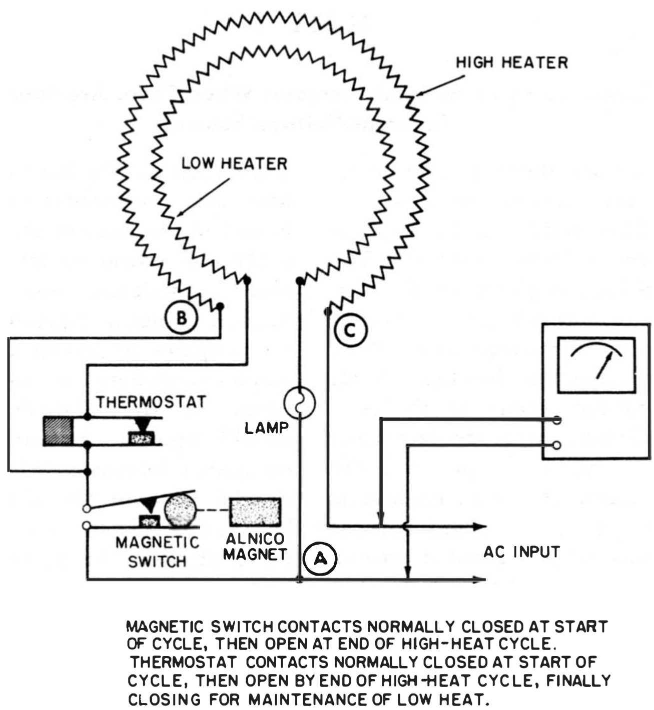


Fig. 5. Wiring diagram of an automatic coffee maker.

Evaluation of Results: When the operating button is pressed the alnico magnet normally remains attracted to the lower flask which contains a ferrous disk. Thus, the high-heat circuit is completed through the contacts of the magnetic switch until the stream pressure lifts the disk and releases the magnet, opening the switch contacts. Subsequently, cooling results in closure of the thermostat contacts, maintaining low heat. With this understanding of sequential action, failure of the high-heat function can readily be localized with an ohmmeter.

NOTE 2

Normally Paralleled Heater Elements Should Not Be Connected in Series

When replacing heater elements which are normally connected in parallel, we must be careful to retain the original connections, and not reconnect them in series. Consider the two connection diagrams shown in Fig. 6. Suppose each of the elements in the parallel branches dissipates 500 watts, or a total of 1 kw. If the two branches are connected in series, the total power dissipation decreases to 250 watts. Let us see why this is so. The heat generated (power dissipated) is given by E^2/R, and the total resistance of the series arrangement is four times that of the parallel arrangement. Hence, the heat generated is reduced to one-fourth. Conversely, when heater elements are normally connected in series, they must not be connected in parallel.

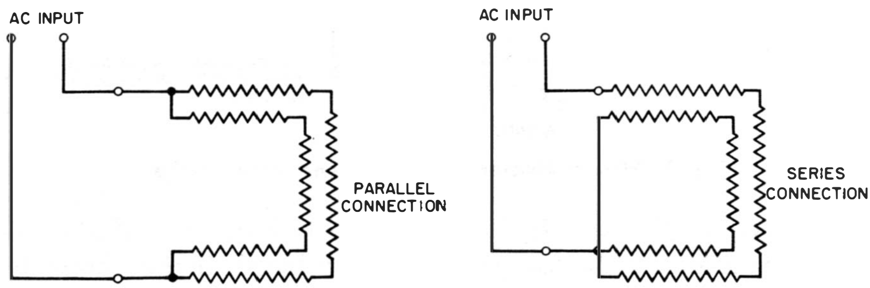


Fig. 6. Series connection of heater elements develops 25% of heat developed by parallel connection.

U6

To Check the Low-Heat Function of a Two-Heat Coffee Maker

Equipment: None.

Connections Required: Connect ohmmeter leads across thermostat terminals, as shown in Fig. 7.

Procedure: With the unit at room temperature, check for closure of the thermostat contacts (switch open). The resistance should be practically zero. If the ohmmeter does read zero, measure the resistance between terminals A and B (Fig. 7).

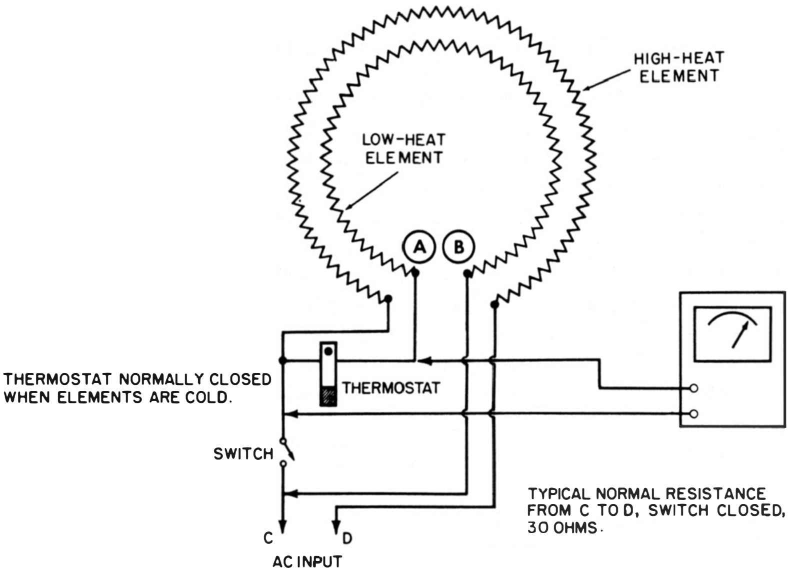


Fig. 7. Wiring diagram of a two-heat coffee maker.

Evaluation of Results: If the resistance is large, or infinite, the thermostat should be repaired or replaced. If the ohmmeter reads zero, the trouble is probably in the low-heat element. Check by noting the resistance reading between A and B. If the meter indicates an open circuit, the low-heat element should be replaced. Generally, it is impractical to repair an open heater element. The function of the thermostat is to keep the coffee in the lower flask at a desired temperature after the switch has been turned off.

NOTE 3

Relation of Current and Power in a Resistive Appliance

A resistive element draws current which is in phase with the voltage; hence, the power consumed is the product of voltage times current. The power is also equal to I^2R or E^2/R. This makes it easy to determine the required resistance of a heating element which is so badly damaged that its original resistance cannot be estimated. For example, consider an electric iron rated at 1,100 watts. A heating element drawing 10 amperes from a 110-volt line should be used, or the element should have a resistance of 11 ohms. Note that the cold resistance of an element is a little less than its hot resistance, but the difference is not great, as in the case of a lamp filament.

NOTE 4

Blown Built-in Fuse Can Cause Percolator Circuit to Test Open

Some percolators contain a built-in fuse (see Fig. 8). The fuse will blow if the switch is left turned on when the percolator is empty. An ohmmeter test at the plug terminals would show an open circuit. In some instances, the percolator must be disassembled to gain access to the fuse. The fuse may be mounted inside a cylindrical heat element. If a new fuse blows promptly, there is a short circuit present. The defect can usually be found by visual inspection. If not, a low-ohms meter can be used to locate the short. Note also that a poor contact between the fuse and a terminal can also cause a slow blow. The high-resistance contact generates abnormal heat at the fuse holder.

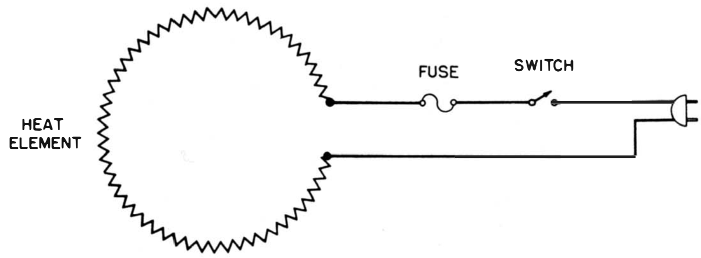


Fig. 8. Wiring diagram of a simple percolator.

U7

To Localize an Open Circuit in a Waffle Iron

Equipment: None.

Connections Required: Connect the ohmmeter test leads across the thermostat terminals, as shown in Fig. 9.

Procedure: The resistance should be practically zero across the terminals of a cold thermostat. If necessary, check farther into the circuit, such as from A to B and C to D.

Evaluation of Results: If there is appreciable resistance across the cold thermostat, it must be repaired or replaced. If the thermostat is good, check the upper element for continuity from A to B. Likewise, check the lower element for continuity

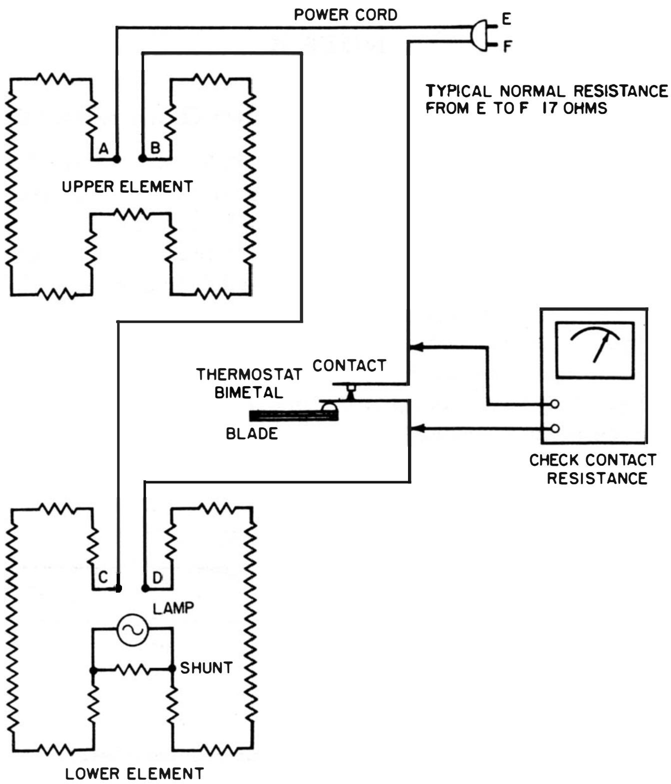


Fig. 9. Wiring diagram of a waffle iron.

from C to D. If the shunt is open, the pilot lamp burns out immediately when the waffle iron is operated. In general, an open element or shunt should be replaced rather than repaired.

NOTE 5

Heat Generated by an Element Decreases Faster Than the Line Voltage

Remember that the heat generated by a resistive element is given by E^2/R. Hence, when the line voltage is low, the power dissipated (heat generated) falls faster than the voltage—the power varies as the square of the line voltage. Let us take a practical example: A heating element which normally operates at 117 volts generates 36% less heat if the line voltage drops 20%. In other words, a 20% drop in line voltage from 117 volts results in 93.6 volts available to energize the heating element. In terms of power, this is a decrease from 117^2 to 93.6^2. The spread between the power ratio is obviously considerably greater than that between the voltage ratio. The dissipated heat goes down faster than the line voltage, and, conversely, the dissipated heat increases faster than the line voltage. This is the reason why a projector lamp, operated from a slightly high line voltage, can have a disappointingly short life, for example. Even an ordinary incandescent lamp has double life expectancy when it is operated at 5% below rated voltage, which will reduce the light output 17%.

U8

To Localize the Cause of Low or No Heat in a Water Heater

Equipment: None.

Connections Required: Connect ohmmeter test leads in turn from A to B and from C to D. Connect leads also from C to E and from A to E, if necessary. (See Fig. 10.)

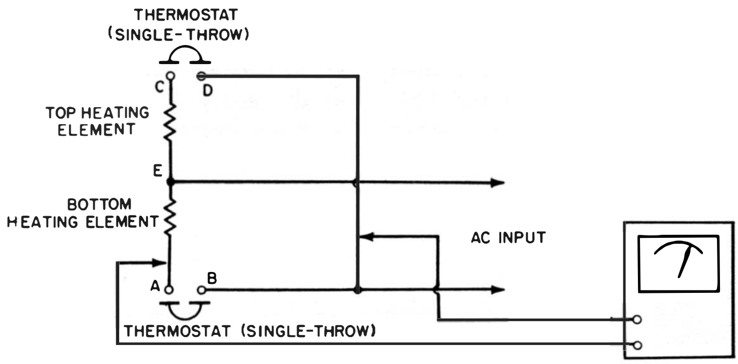


Fig. 10. Wiring diagram of a two-element water heater.

Procedure: When the water heater is turned on from a cold start, both thermostats are normally closed. The ohmmeter should read zero from C to D and from A to B. Otherwise, the faulty thermostat should be repaired or replaced. If the thermostats test all right, make continuity tests of the heating elements from C to E and from A to E.

Evaluation of Results: When one heating element is defective, the complaint will be either low heat or limited supply of hot water. However, do not be misled by low line voltage. If other appliances such as electric irons or portable heaters are plugged into the same line which powers the water heater, it is possible the line voltage may be reduced and cause the water heater to appear defective. Hence, always check the line voltage first. Also, always check the line voltage *under full load,* otherwise the meter reading might be meaningless. The same principles observed in battery-voltage testing apply to line-voltage measurements.

NOTE 6

Crimp Collars Can Be Used to Repair Open *Nichrome* Heater

Household appliances often utilize heaters of *Nichrome* wire or ribbon. In general, an open heater should be replaced. However, repair is possible. Soldering, of course, is impractical. Likewise, reconnection by twisting is poor practice. Crimp collars are available for connecting the ends of *Nichrome* wire. The open ends of the wires are inserted into the collar, and the collar is then firmly flattened over the wires. This provides a usable connection under the operating conditions of the heater element. Note also that *Nichrome* wire, with which a heater can be rewound, is available in various diameters. The wire does not generally come in the form of ordinary spooled copper wire but is wound in the shape of a small spiral or spring. Therefore, do not confuse the actual length of the wire with the length which may be marked or advertised on the spool—the total length can be much greater.

U9

To Localize the Cause of Low or No Heat in an Electric Iron

Equipment: None.

Connections Required: Connect ohmmeter test leads in turn from A to B, A to C, B to D, C to E, and E to F (Fig. 11).

Procedure: Check for continuity in each test. In case there is no continuity (or high resistance) from A to B, the ensuing tests help to localize the fault. On the other hand, if there is continuity but the iron only comes up to low heat, observe the contact resistance from C to E (across thermostat contacts). The contact resistance should be practically zero, even on a low-ohms meter or VOM adapter.

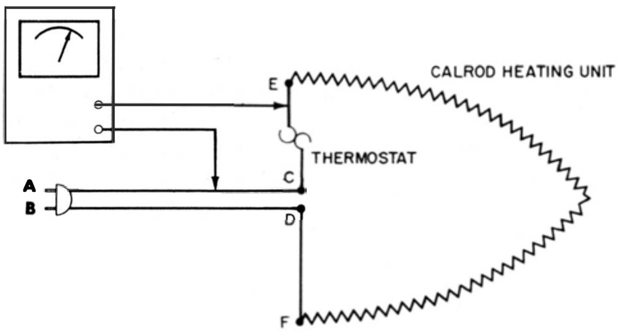


Fig. 11. Wiring diagram of an electric iron.

Evaluation of Results: Since a simple series circuit is used, an open circuit is not difficult to trace. Appreciable contact resistance (from C to E) generates heat due to the I^2R loss and can cause the thermostat to open before the iron comes up to full heat. In such case, clean the contacts or replace the thermostat. Electric irons often have *Calrod* heating elements. (These are basically different from the ribbon *Nichrome* elements used in appliances, such as electric toasters.) A *Calrod* element is enclosed in a sealed metal tube, with an insulating substance around the heater, giving basically a coaxial construction. In case the ohmmeter shows an open circuit (or high resistance) from E to F, the element should generally be replaced instead of attempting a repair. (If an electric iron is plugged into an outlet with other "heavy" appliances on the same line, it may not come up to full heat because of poor line regulation, hence low line voltage.)

NOTE 7

Allow Thermostat to Cycle Several Times When Checking Calibration

An oven thermometer is convenient for checking the operating temperature of appliances in this class. The *average* of the readings when the thermostat closes, and again when it opens, should agree reasonably well with the calibrations on the thermostat dial. If not, adjust the thermostat set-screw as required. However, do not make an adjustment until the thermostat has cycled a few times. From a cold start, the first cycle generates a somewhat abnormal average temperature. The second cycle will give a lower average, and the third or fourth cycles can be properly utilized for a calibration check. If a thermostat does not cycle, it is usually defective; for example, the points may be welded together. However, in some appliances we find a bypass capacitor connected across the points, as shown in Fig. 12. The capacitor is used for reduction of high-frequency interference. A

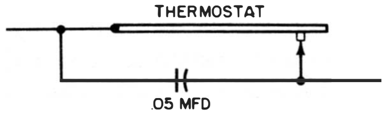


Fig. 12. Bypass capacitor reduces RF interference.

shorted capacitor will occasionally simulate welded contacts. A "thermostatic" heater element in the circuit is sometimes found. In other words, the oven or roaster will not come up to heat, although the thermostat is closed, because the resistance wire in an element has an intermittent contact which opens up when the wire heats.

U10

To Check the Starter in a Fluorescent Lamp

Equipment: None.

Connections Required: Connect the ohmmeter test leads across the starter terminals. The starter commonly consists of a neon-bulb thermostat and a capacitor, as shown in Fig. 13.

Procedure: Observe ohmmeter reading.

Evaluation of Results: The resistance should be infinite. In case a zero or low-resistance reading occurs, the starter is defective. Either the thermostat contacts are welded together or the capacitor is shorted. These defects cause the starting filaments in the lamp to operate continuously and greatly reduce the life of the lamp. In normal operation, application of the 117-volt AC input first causes the neon gas in the thermostat to glow. Heat is generated, which causes the thermostat contacts to close. In turn, the starting filaments light and the neon glow stops. With no heat from the neon, the thermostat contacts open, causing the ballast reactor to generate a high-voltage inductive kickback. This fires the gas in the fluorescent lamp, and the arc drop across the lamp, being too low to fire the

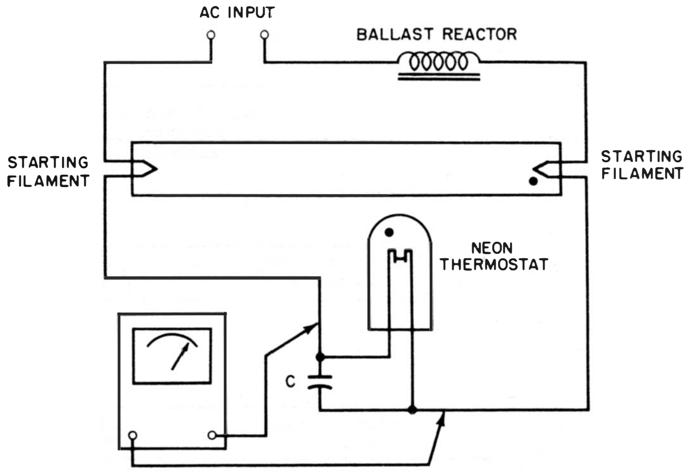


Fig. 13. Fluorescent lamp will not start if thermostat contacts do not close.

neon bulb, keeps the thermostat contacts open as long as the lamp is in operation. The capacitor reduces sparking at the thermostat contacts and also minimizes high-frequency interference voltages. In the starter configuration there is often also a conventional thermostat to protect the fluorescent-lamp filaments in case of welded contacts in the neon thermostat.

U11

To Check the Cause of Strobe Flicker in a Dual Fluorescent-Lamp Unit

Equipment: None.

Connections Required: Disconnect one end of capacitor C (Fig. 14) from its shunt resistor, and connect the capacitor to the ohmmeter test leads.

Procedure: Observe ohmmeter reading. If an infinity reading is obtained, throw the ohmmeter polarity switch or reverse the leads and watch pointer for ballistic throw.

Evaluation of Results: Capacitor C is used to draw a leading current through the leading lamp, and thereby stagger the peaks

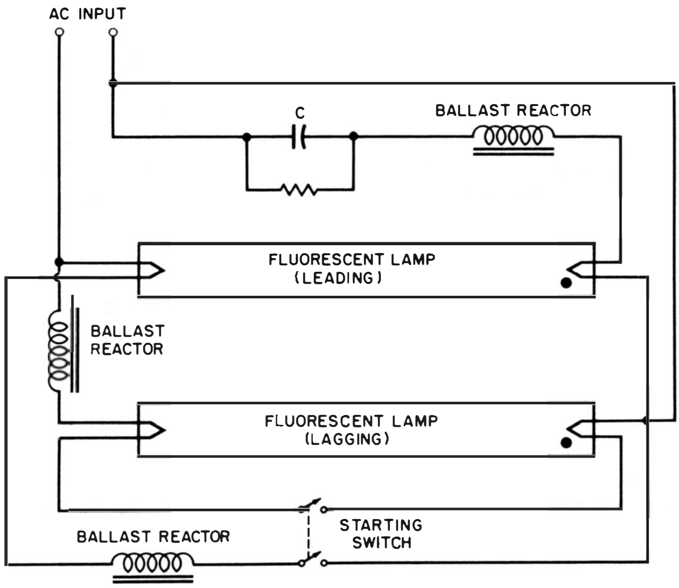


Fig. 14. A shorted lead capacitor will result in strobe flicker in a dual fluorescent lamp.

of light output. This minimizes the annoyance of strobe flicker in the total light output from the two lamps. If C is defective, the staggered output is affected accordingly. Strobe flicker is more annoying when the illumination level is high, and appears as a broken series of images when a moving object is being viewed.

Note the starting-switch arrangement. The user closes the starting switch briefly, which causes current to flow through the starting filaments. The starting switch is then released, resulting in kickback voltages from the ballast reactors which fire the fluorescent lamps. The arcs are self-sustaining from this point, until the AC input is removed.

NOTE 8

Fluorescent Lamps Which Do Not Use Starting Heaters

Some fluorescent lamps do not have starting heaters. These lamps contain a heater structure inside, but the two terminals are shorted together and brought out to a single button on the base of the lamp. Of course, the associated circuitry omits the ordinary heater circuit. In this arrangement a larger ballast, generating a higher inductive kick, is used to start the lamp. The ballast reactor used in the ordinary arrangement will not start this kind of lamp. The newer type of lamp will be found both in conventional and in antistrobe units. Since starting heaters are not used, the circuitry is simpler and correspondingly easier to troubleshoot. If the lamp is in good condition, failure to start will be traced to poor switch contacts, bad connections, sometimes a broken lead in a flexible conductor, or to a defective ballast reactor. Check these possibilities, in turn, with ohmmeter and voltmeter.

U12

To Check for a Defective Solenoid in an Automatic Washer

Equipment: None.

Connections Required: Connect the ohmmeter test leads from the solenoid terminal to ground (such as the solenoid core) as in Fig. 15.

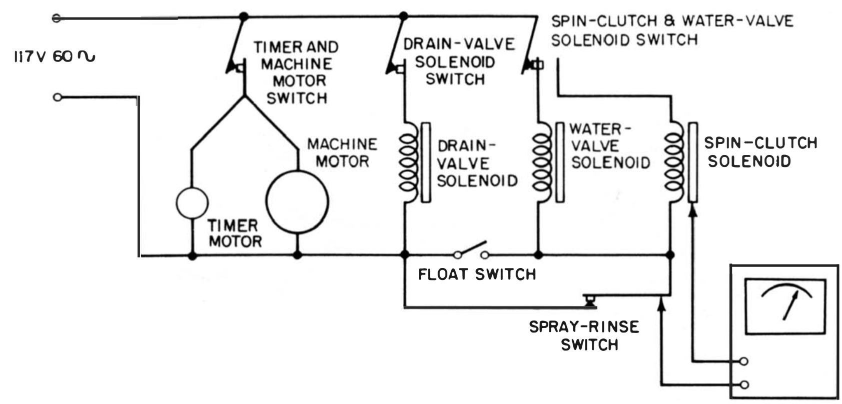


Fig. 15. Wiring diagram of an automatic washer.

Procedure: Note scale reading. (Power plug should be pulled from outlet for test.)

Evaluation of Results: Electrical leakage from the solenoid winding to ground can cause the solenoid to remain activated after the solenoid switch contacts have opened. One side of the power line is grounded, and the washer assembly is also grounded. Note that the cycling of the machine is accomplished by time-control cam switches, as shown in Fig. 16. When the switch is closed, current flows through the solenoid

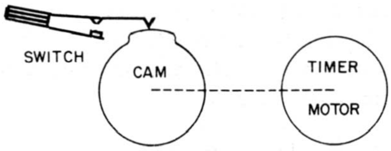


Fig. 16. Time-control cam and switch.

winding, pulling the iron plunger into the coil, and thereby actuating the associated valve, clutch, or motor.

U13

To Check the Voltage Applied to a Refrigerator Motor

Equipment: None.
Connections Required: Connect the VOM test leads across the line terminals on the terminal board of the motor, as shown in Fig. 17.

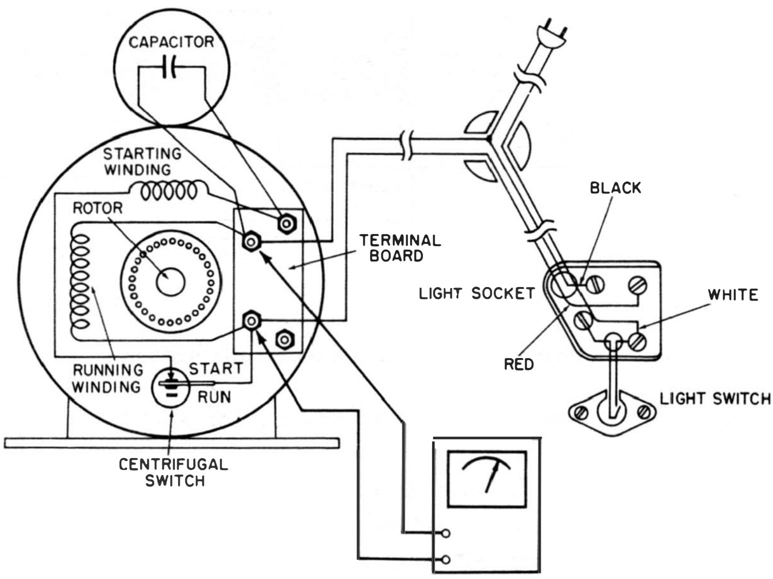


Fig. 17. Checking applied voltage at refrigerator motor.

Procedure: Plug refrigerator power cord into a 117-volt 60-cycle outlet, and note AC-voltage reading on meter.

Evaluation of Results: When the motor does not kick out the starting winding, and the voltage applied to the motor is less than 100 volts, investigate the cause of the low voltage. A defective cord or a poor connection can be responsible. However, if the AC voltage is less than 100 volts at the outlet, notify the power company. Warning: Do not attempt to run the refrigerator motor for extended periods of time if the starting winding does not kick out when the motor reaches a steady speed.

U14

To Check a Centrifugal Starting Switch

Equipment: None.

Connections Required: Connect ohmmeter test leads across terminals of centrifugal starting switch (Fig. 18).

Procedure: Note meter reading.

Evaluation of Results: The contact resistance should be zero. High-resistance or open contacts limit or stop current flow through

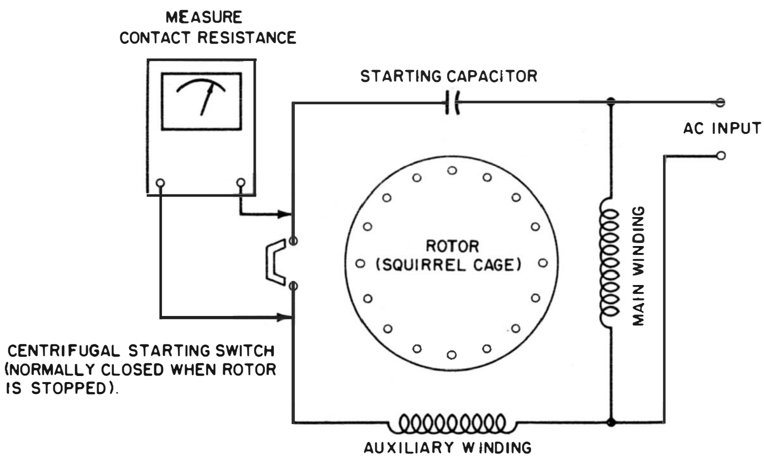


Fig. 18. Motor will not start when switch contacts do not close.

the starting capacitor, resulting in failure of the motor to start. The centrifugal starting switch must be repaired or replaced.

An induction motor such as depicted in Fig. 18 has zero torque when the rotor is stopped and the centrifugal switch is not closed. In this condition only the current flow through the main winding is present, and this single-phase current produces no turning force in the squirrel-cage winding. On the other hand, when the centrifugal switch is closed, current flows through the auxiliary winding also. This is a leading current, due to the reactance of the series capacitor. Thus, the single-phase source is converted to a two-phase source, and a turning force is produced in the squirrel cage from a dead start. As the rotor comes up to speed, counter-emf generated in the moving rotor produces a second phase of current flow in the winding, so that torque is maintained after the centrifugal switch opens.

NOTE 9

Motor-Starting Capacitor Must Be Nonpolarized

Remember that motor-starting capacitors operate on AC. Hence, ordinary filter capacitors as used in power supplies are unsuitable in this application, even when rated at correct voltage and capacitance. All motor-starting capacitors must be of the nonpolarized type. The equivalent of a nonpolarized capacitor can be made from two ordinary polarized units, by connecting them back-to-back (positive-to-positive, or negative-to-negative). This changes the polarized capacitors into a nonpolarized configuration. Of course, the configuration has one-half the capacitance of each individual capacitor (assuming that the two are equal in value). Hence, for satisfactory substitution tests, each capacitor must have twice the rated capacitance value of the series configuration.

To Localize an Open in a Refrigerator Motor Circuit

Equipment: None.

Connections Required: Connect ohmmeter test leads, as shown in Fig. 19, across temperature-control contacts A and B, then across overload contacts C and D, and again across relay contacts E and F.

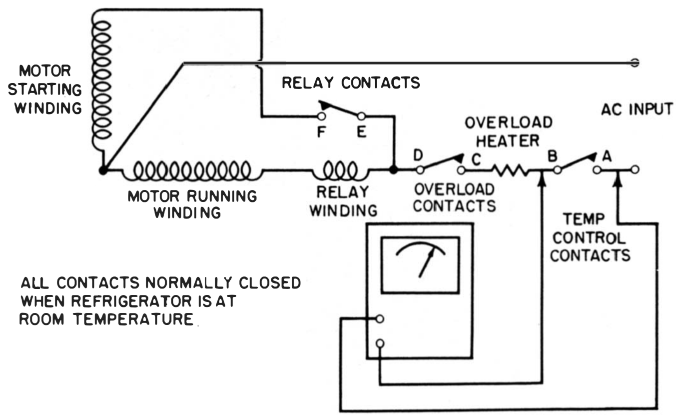


Fig. 19. Wiring diagram of a refrigerator motor circuit.

Procedure: Observe whether continuity is indicated in each of the tests.

Evaluation of Results: The contacts are all normally closed when the refrigerator is at room temperature. If any pair of contacts fails to close or has appreciable contact resistance, the motor will not start. Do not confuse winding resistance with contact resistance when testing from E to F. Although distinction is sometimes difficult with an ordinary ohmmeter, a low-ohms meter (or VOM with low-ohms adapter) clearly distinguishes between the low resistance of the windings and the normally very low contact resistance.

To Check for Coil Defects in an Electric Clock

Equipment: None.

Connections Required: Connect ohmmeter test leads across coil leads. (See Fig. 20.)

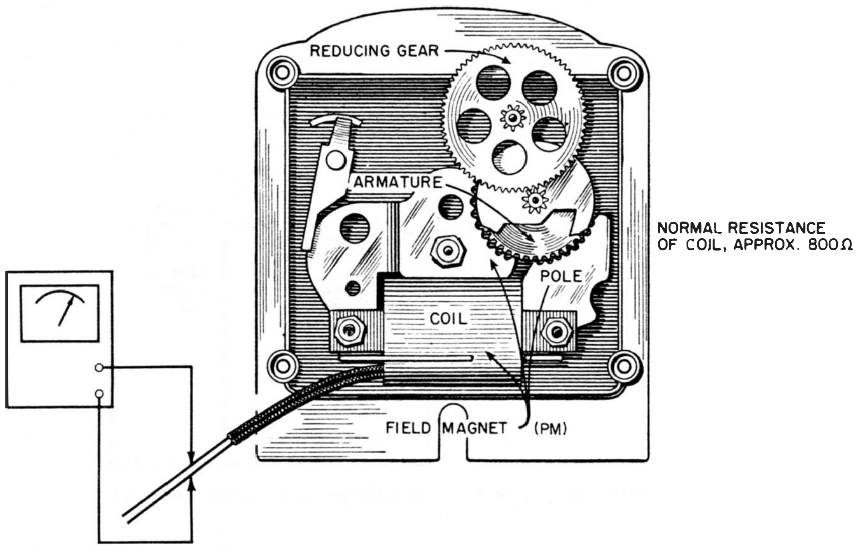


Fig. 20. Configuration of a synchronous motor in an electric clock.

Procedure: Observe meter reading.

Evaluation of Results: An infinite or very high resistance reading indicates an open winding or a poor connection to the coil leads. The normal resistance of a typical coil is 800 ohms. Low resistance readings indicate shorted layers in the coil. Rewinding is easily accomplished in clocks having the construction shown in Fig. 20. On the other hand, disassembly is difficult or impractical in others. Coil defects are usually caused by physical damage or sometimes by operation from a 220-volt outlet.

To Check the Ground Circuit of a 220-Volt, 3-Wire Appliance

Equipment: None.

Connections Required: Connect ohmmeter test leads as shown in Fig. 21.

Procedure: With the appliance turned on for normal operation, observe meter reading.

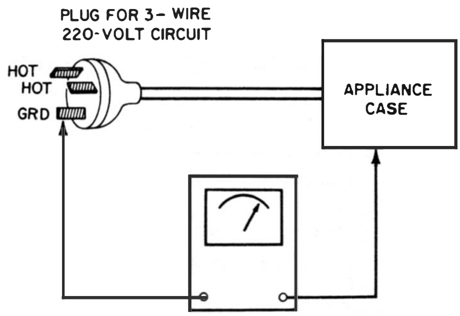


Fig. 21. Checking the ground circuit of an appliance.

Evaluation of Results: The ohmmeter *must* read zero. Otherwise, the ground circuit is open at some point and must be traced down. Unless there is continuity between the "Gnd" terminal of the plug and the appliance case, the normal protection intended for the user is not present. Of course, there must be practically an infinite resistance between either of the two "hot" terminals on the plug and the case of the appliance. The plan of a 3-wire 220-volt supply circuit is shown in

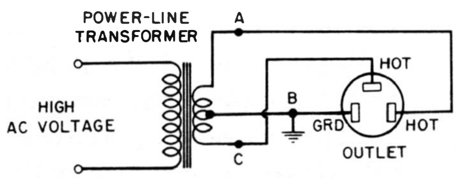


Fig. 22. Wiring diagram of a 3-wire, 220-volt supply.

Fig. 22. The power-line transformer is center-tapped and grounded. Nominally 110 volts is measured from A to B and from C to B, and 220 volts from A to C. This 3-wire arrangement causes the case of the appliance to remain "cold," even though a heater element or motor should become shorted to the case. A fuse will blow or a circuit-breaker will trip, but the user cannot get a shock from the circuit fault.

To Check the Line Filter Capacitors in an Electric Mixer (or Other Appliances)

Equipment: None.

Connections Required: Make preliminary connections in the circuit (Fig. 23). Disconnect capacitors for complete test.

Procedure: Set the VOM to its highest ohmmeter range. Note resistance reading as each capacitor is tested in turn. If all three readings are infinite, proceed to ballistic test: Flip polarity switch on VOM (see U19), watching the ballistic throw of the pointer for each capacitor in turn.

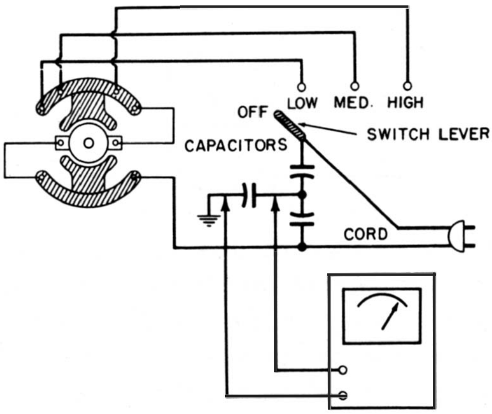


Fig. 23. Checking capacitors in an electric mixer.

Evaluation of Results: If any reading other than infinity is observed, the capacitor is leaky and should be replaced. Leaky capacitors can make the mixer "hot" and are a hazard to the user. If the reading is infinity but there is little or no ballistic throw of the pointer when the ohmmeter polarity switch is flipped, the capacitor is open and should be replaced. An open capacitor permits a high noise level on the line and can cause interference with radio and TV reception. Such capacitors commonly have a value from 0.1 to 0.25 mfd and will cause a substantial ballistic throw when tested with a typical VOM (for example, the Simpson 260) on the R × 10,000 ohmmeter range. (Motor tests are explained elsewhere in this book.)

To Check a Motor-Starting Capacitor

Equipment: None.

Connections Required: Connect VOM test leads to capacitor terminals (Fig. 24).

Procedure: Operate the VOM on its highest ohmmeter range and note scale reading. If a substantially infinite reading is obtained, set the VOM on a lower range, such as R × 100, and make a ballistic test, flipping the polarity-reversing switch, and watching the pointer throw.

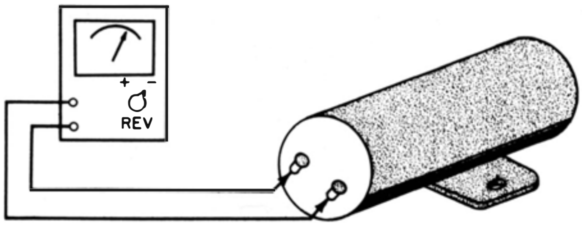


Fig. 24. Checking a motor-starting capacitor.

Evaluation of Results: The starting capacitor is a nonpolarized electrolytic unit, hence the polarity of the applied voltage may be either polarity. It is the same as when testing a dual-can electrolytic and connecting the meter leads to the two positive terminals. The leakage resistance should be very high and practically unreadable (infinity) on a VOM. The ballistic throw is a measure of capacitance. An overlay scale can be used on the meter to indicate capacitance values. One of the lower ohmmeter ranges is used for the ballistic test, because the normal capacitance value is comparatively high (such as 40 mfd), and the pointer will throw off-scale if a high ohmmeter range, such as the R × 10,000, is used. The high range is suitable only for measuring smaller capacitance values. Note: If the VOM does not have a polarity switch, an external DPDT switch, such as a polarity-reversing probe, can be used. Or the VOM test leads can be reversed to make the ballistic test.

To Check an Appliance for Insulation Resistance

Equipment: Plug and receptacle, as shown in Fig. 25.
Connections Required: Connect equipment as shown.
Procedure: Operate the VOM on its AC voltage function. Insert the plug into a 117-volt outlet, and observe meter reading (if any).

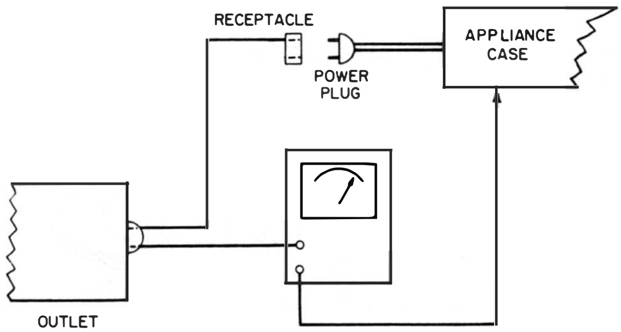


Fig. 25. Checking an appliance for insulation resistance at line voltage.

Evaluation of Results: A voltage indication on the meter results from leakage in the appliance to its case. Defects in insulation resistance usually become more serious with the passage of time, and the user can get a shock if the appliance and a water faucet are touched at the same time, or if the user is standing on a damp floor. Any defects in the insulation resistance *must* be corrected.

U21

To Measure AC With a VOM

Equipment: Suitable current transformer with load resistor (Fig. 26).
Connnections Required: Connect an appropriate pair of primary terminals in series with the lead carrying AC to be measured. Connect the secondary terminals to the test leads of the VOM. (If a VOM adapter is to be used, plug the adapter into the VOM in place of the usual test leads.)

Procedure: Operate the VOM on its AC function and set it to the proper range for the current transformer which is in use. If there is doubt concerning the approximate current value, make the first test on a high-voltage AC range; then reduce the range setting progressively to make sure the pointer will not be slammed. If necessary, use a higher-current pair of primary terminals.

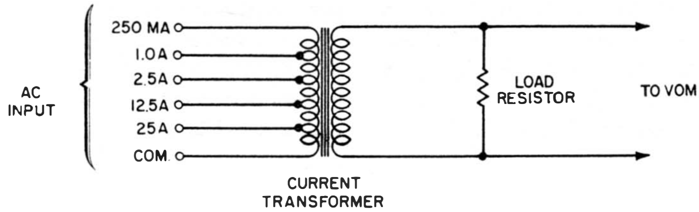


Fig. 26. Current transformer and load resistor converts VOM to AC ammeter.

Evaluation of Results: With the VOM set to the proper range for the current transformer, observe scale reading and multiply by the specified scale factor to obtain the AC reading. Note that, in general, each primary tap is specified with a different scale factor. Suitable current transformers for some commercial VOM's are available as plug-in adapters or as clamp-on probes. Thus, the VOM is made useful to measure the current drawn by a motor, growler, or other AC units.

NOTE 10

DC Saturation of Current Transformer Can Cause Erroneous Reading

Current transformers commonly used to convert a VOM to an AC ammeter have a somewhat limited DC-component capability. In other words, if only AC is passed through the primary, the meter will read correctly. On the other hand, a large DC flow mixed with the AC may cause partial core saturation in the current transformer, resulting in an incorrect reading. For example, an AC measurement from supply line to a motor will give an accurate reading on the instrument. However, if an attempt is made to measure the AC ripple from a DC generator to a load, the reading may be incorrect due to the comparatively large DC component of current flow through the primary winding. The important point is to know the characteristics of the current transformer and to operate it within its rated range.

NOTE 11

AC Can Be Measured With External Shunt for AC Voltmeter

Instead of using a current transformer (such as an AC clamp-on probe) with an AC voltmeter to measure AC, an external shunt, such as that supplied by various meter manufacturers for power applications can be used. These shunts have an appearance similar to the DC shunt in U22. An AC shunt is designed for use with an AC voltmeter having specified characteristics. Unless a suitably designed shunt is used with your meter, it will not indicate correct AC values. In effect, when a shunt is used, the AC circuit is opened and a small-value precision resistor having ample heat-dissipating ability is inserted. The AC voltmeter measures the drop across the shunt, and thereby indicates current values in accordance with Ohm's law. (Also see U22.)

U22

To Measure Heavy DC With a VOM

Equipment: Suitable current shunt (see Fig. 27).

Connections Required: Open the current lead, and connect the ends of the leads to the current input terminals on the shunt. Connect the VOM to the meter terminals on the shunt.

Procedure: Use a suitable DC voltage range of the VOM.

Evaluation of Results: The meter scale may or may not be direct reading, depending on the resistance of the shunt. Use Ohm's law to convert the meter reading to amperes. A wide variety

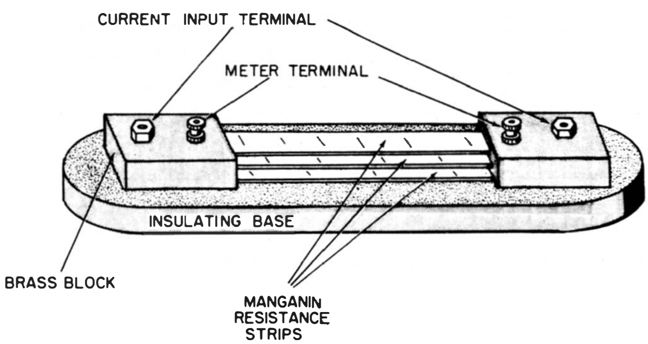


Fig. 27. Typical current shunt for a voltmeter.

of current shunts are available from most meter manufacturers. Some can be plugged into the VOM. Large shunts cannot be designed for plug-in. A shunt for a heavy current has a comparatively low resistance. The shunt is designed for a specified resistance (often stamped on the unit) between the *meter terminals* (not the resistance between the current terminals, which is not of concern to the user). Shunts are constructed to maintain constant resistance in spite of temperature rise, and to avoid errors which could be caused by nonuniform current distribution in the shunt conductors. The meter must *always* be connected between the meter terminals on the shunt.

U23

To Make a DC Check for a Short in an Armature Coil

Equipment: Storage battery and VOM capable of measuring about 20 amperes (the VOM can be used with a current shunt, if necessary).

Connections Required: Disconnect field coils, or make test on isolated armature. Apply a fairly heavy current to the com-

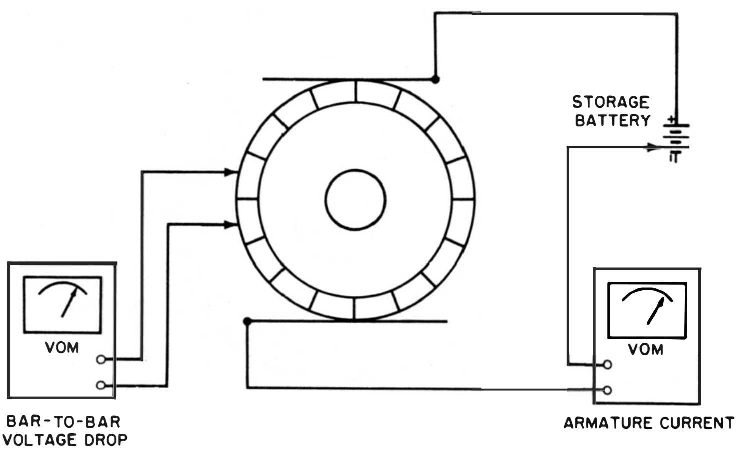


Fig. 28. DC check for shorted turns in an armature coil.

mutator from a storage battery (20 amperes is typical), as shown in Fig. 28.

Procedure: Operate the VOM on its DC-volts function, and make bar-to-bar voltage-drop measurements as illustrated. All tests are made with the VOM leads applied in the same position (rotate armature as required for each test).

Evaluation of Results: Shorted turns in a coil show up as a low- or zero-voltage drop. A low-ohms meter can be used, if available. This meter eliminates the need for a storage battery in the test. Low-ohms adapters are commercially available for some VOM's, or a low-ohms auxiliary circuit can be used with a VOM, as explained in the companion volume, *101 Ways to Use Your VOM and VTVM.*

U24

To Check for an Open Coil in an Armature

Equipment: Growler.

Connections Required: Plug growler into a 117-volt, 60-cycle outlet.

Procedure: Place armature on growler. Operate the VOM on its AC-voltage function and observe readings when test prods

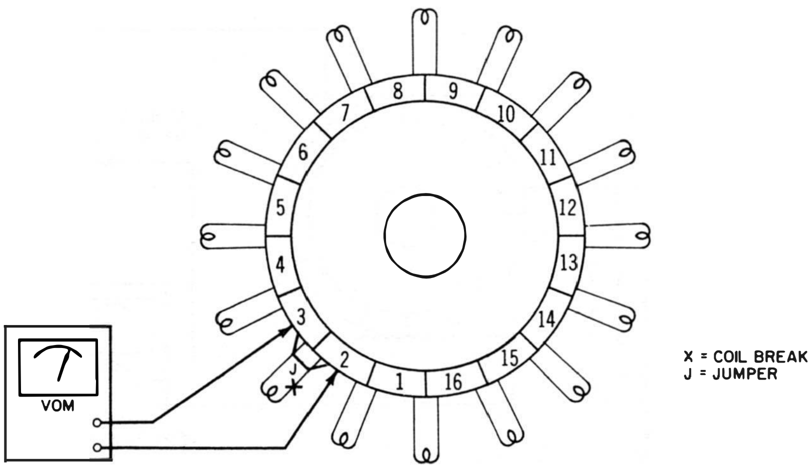


Fig. 29. Checking for open coil, and temporary repair.

are connected to adjacent commutator bars, as shown in Fig. 29. The test position is shown in Fig. 30.

Evaluation of Results: When the test prods are connected between bars 3 and 4, the meter reads zero. Likewise, a zero reading is obtained between bars 1 and 2. On the other hand, a high AC-voltage reading is observed between bars 2 and 3. This

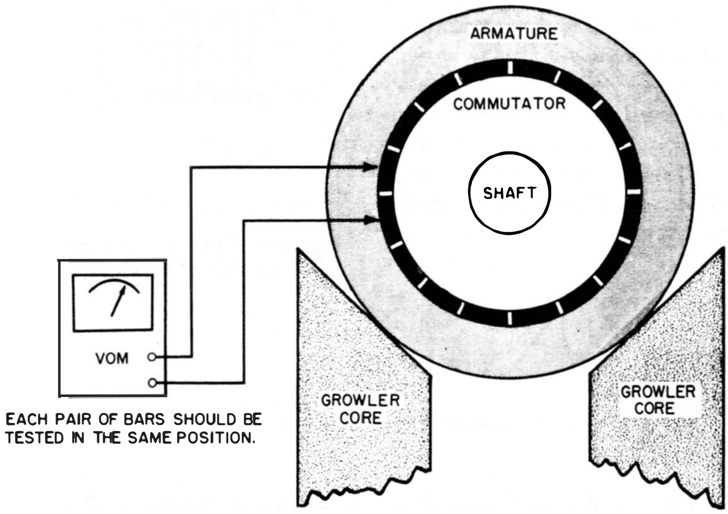


Fig. 30. Test position for armature.

indicates an open circuit in the coil connected between bars 2 and 3. For a temporary repair, in case the break is inaccessible externally, bridge bars 2 and 3 with a jumper (J). This will stop severe sparking at the brushes when the armature is operated. Note: In this instance, an ohmmeter test could be made to localize the open circuit. However, since the growler method is required to determine other types of armature faults, an open circuit will often be discovered when using a growler in general troubleshooting procedures.

NOTE 12

Armature Acts as a Secondary Winding in Magnetic Circuit of Growler

The general plan of a conventional growler is shown in Fig. 31. Laminated iron cores are used, in which the armature under test completes the magnetic circuit. A growler has transformer action, and induces an AC voltage in the armature winding. The coil on the growler operates as the primary of the transformer. About 500 turns of No. 17 wire are used. The coil of some growlers may have two sections of about 250 turns each. The sections are connected either in series or in parallel, to change the voltage induced in the armature windings. A growler is useful in practical work, because it would not be economical to completely assemble a motor for testing after an armature has been wound. Both portable and stationary growlers are used. When a stationary growler is used, the armature is rotated suitably to test each armature element. On the other hand, a portable growler is placed at a chosen test location on the armature.

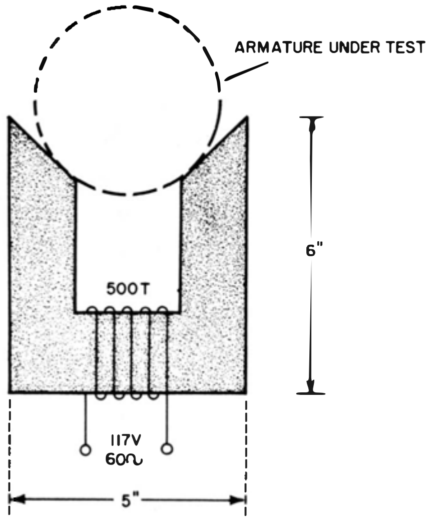


Fig. 31. Plan of laminated core and winding for growler.

U25

To Check for a Short Circuit in an Armature Coil

Equipment: Growler.

Connections Required: Plug growler into a 117-volt, 60-cycle outlet.

Procedure: Place armature on growler. Operate the VOM on its AC-voltage function and observe readings when test prods are connected to adjacent commutator bars, as shown in Fig. 32.

Evaluation of Results: When the test prods of the VOM are connected to the bars terminating the winding with the short, the scale reading will be low or zero. A thin strip of steel will also vibrate when held over armature slots in which the shorted coil is located. Alternatively, a low-ohms meter can be used, eliminating the necessity for a growler. Since the resistance of an armature coil is generally very low, ordinary ohmmeters are not particularly useful in this application.

When there is a short in an armature coil, temporary repair can be made by opening the leads to the faulty coil and bridging the corresponding commutator bars with a jumper.

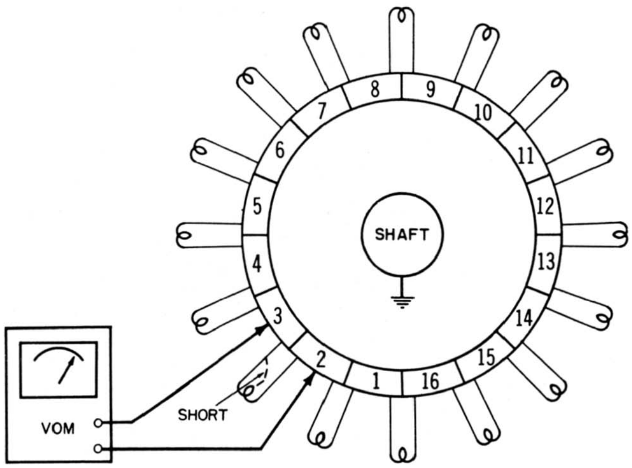


Fig. 32. Checking for short circuit in a coil.

In this manner, the armature can be operated without heavy local current in the coil, which would cause overheating.

U26

To Localize a Grounded Armature Coil

Equipment: Growler.

Connections Required: Plug growler cord into a 117-volt, 60-cycle outlet.

Procedure: Set armature on growler core. Operate the VOM on its AC-voltage function. Connect one VOM lead to the armature shaft and contact a commutator bar with the other test prod. Check from bar to bar, noting readings. (See Fig. 33.)

Evaluation of Results: The AC-voltage reading becomes less and approaches zero as the test prod is contacted nearer to the bar which terminates the grounded coil. This type of test can also be made with a low-ohms meter. Although a grounded coil does not make an armature inoperative, the frame of the motor or generator becomes "hot." On the other hand, if two armature coils become grounded, an effective short exists, which results in excessive heating of the armature. When tested with a growler, such an armature will show two points

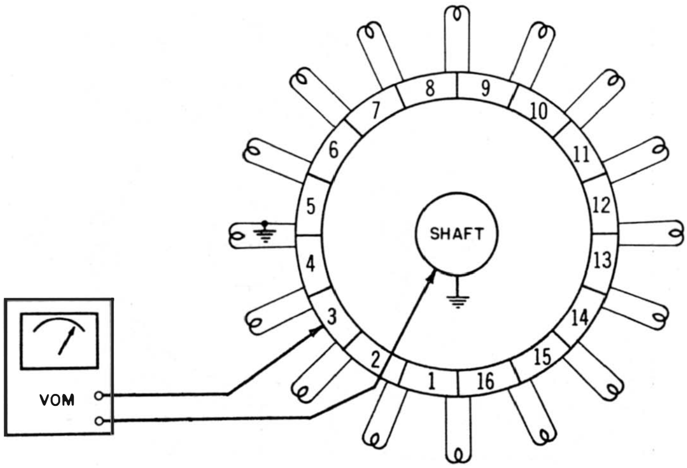


Fig. 33. Checking for a grounded coil.

of minimum reading on the commutator, thereby identifying the defective coils. (See Fig. 34.)

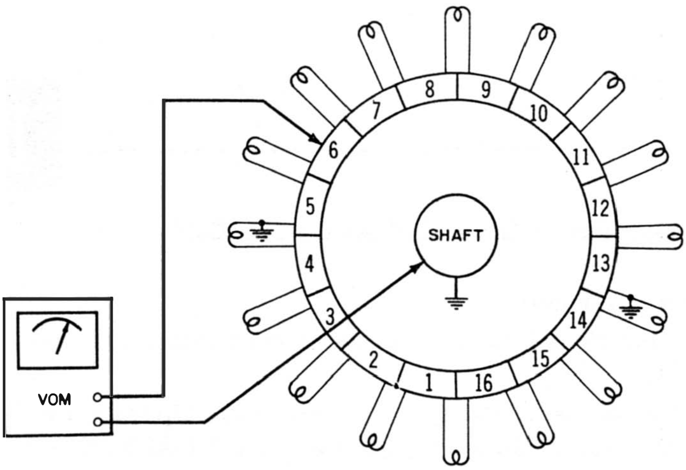


Fig. 34. Localizing two grounded coils.

NOTE 13

Avoidance of False Nulls When Localizing a Grounded Winding

When localizing a grounded winding, it is good practice to make the tests on isolated armature windings, and on isolated field windings, to avoid the possibility of false nulls. Typical development of a false null is illustrated in Fig. 35, in which the ground is in the field winding, and a false null is found in the armature winding, due to the effective bridge circuit which exists. In the same manner, a false null can be found in the field windings, when the ground is actually located in the armature windings. Note further, that a false null can occasionally occur in the system unless *both* ends of the field winding are disconnected for the test. In the latter instance, the occurrence of a false null results from the current drawn by the meter, combined with a fairly high leakage resistance from winding to ground.

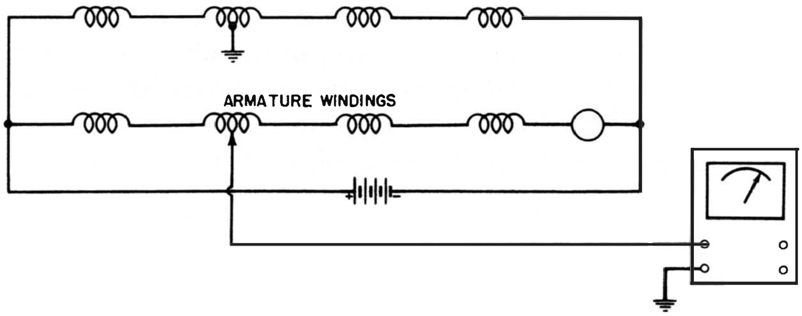


Fig. 35. False null occurs in this configuration when localizing a ground.

U27

To Localize Reversed Coils

Equipment: Growler.
Connections Required: Plug growler cord into a 117-volt, 60-cycle outlet.

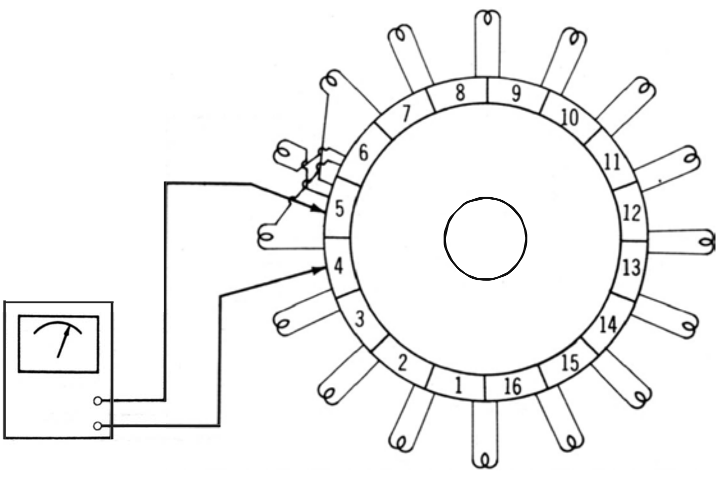


Fig. 36. Reversed coils on rewound armature.

Procedure: Place armature on growler core. Operate the VOM on its AC-voltage function. Check voltages between adjacent commutator bars (Fig. 36).

Evaluation of Results: In the example illustrated, normal reading is obtained between bars 5 and 6, but between bars 4 and 5 and between bars 6 and 7 the reading is twice the normal reading. This is a fault which can occur when an armature is rewound. If an attempt is made to operate the armature, there will be sparking at the brushes, although the sparking will not be so severe as when a coil is open.

U28

To Locate a Coil With Reversed Connections

Equipment: Growler.

Connections Required: Plug growler into 117-volt, 60-cycle outlet.

Procedure: Place armature on growler core. Operate the VOM on its AC-voltage function. Measure voltages between every other pair of commutator bars (e.g., from 11 to 13, as indicated in Fig. 37).

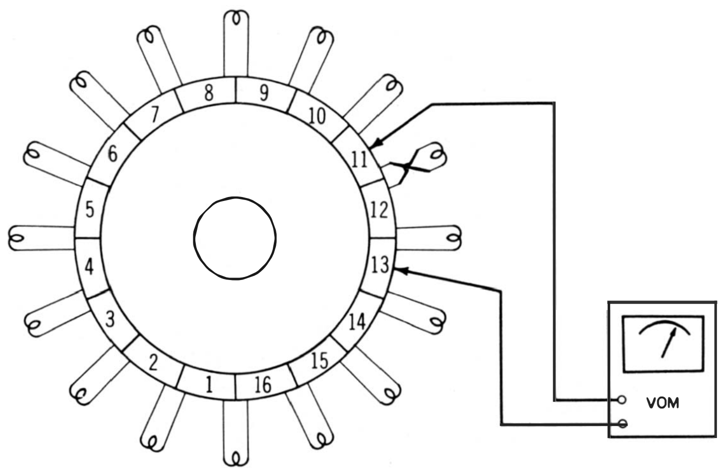


Fig. 37. Meter indicates reversed coil connections.

Evaluation of Results: A zero reading is obtained when one of the test prods is connected to a reversed coil terminal. Thus, in the illustration, a zero reading is found between bars 11 and 13 and between bars 10 and 12. Reversed coil connections sometimes occur when an armature is rewound. Unless corrected, an electrical unbalance exists which can cause the armature to overheat.

U29

To Measure the Resistance of an Armature

Equipment: Lamp bank (or power rheostat) and a current shunt for the VOM.

Connections Required: Connect equipment as shown in Fig. 38. (The same VOM can be used to make both measurements.)

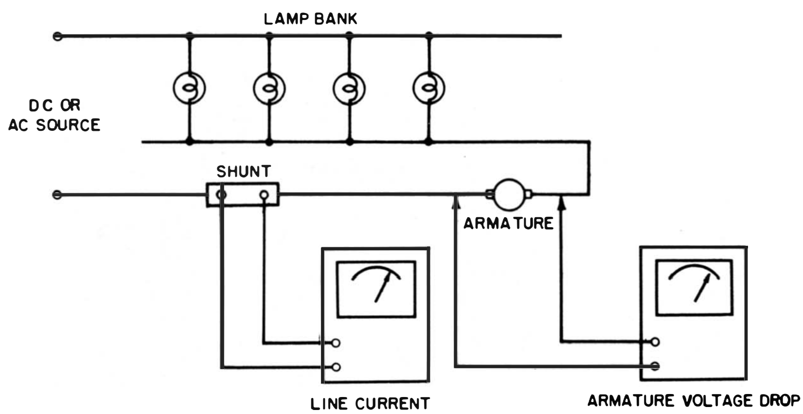


Fig. 38. Test setup to measure armature resistance.

Procedure: Use a sufficient number of lamps in the bank to get a clearly readable voltage drop across the armature. Measure the armature voltage drop and the line current. The test is made on an isolated armature, with the field coils disconnected.

Evaluation of Results: The armature generally has a low resistance, such as 0.3 ohm. The resistance is given by Ohm's law: R = E/I. Note that this measurement can also be made with a low-ohms meter, if available. However, the voltmeter-ammeter method is usually employed. In theory, a DC-voltage source will give a slightly more accurate resistance measurement; however, the reactance of the usual armature is so small that an AC test is quite satisfactory.

U30

To Localize a Short Circuit Between Bars

Equipment: Growler.

Connections Required: Plug growler cord into a 117-volt, 60-cycle outlet.

Procedure: Place armature in growler. Operate the VOM on its AC-voltage function. Check voltages between adjacent bars (Fig. 39).

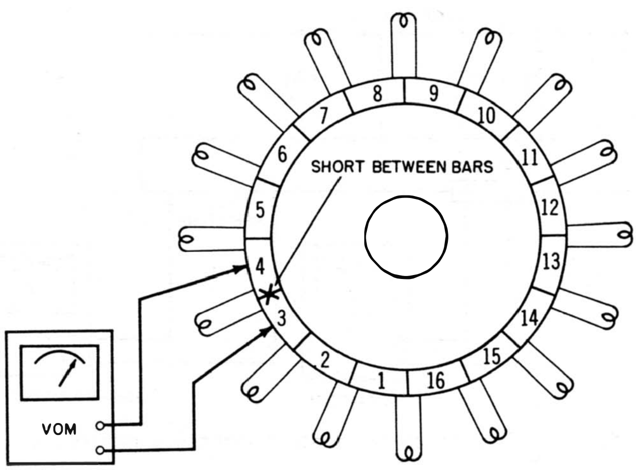


Fig. 39. Localizing a short between bars.

Evaluation of Results: A zero reading is found between bars 3 and 4 in the illustration. In many instances, this defect will cause noticeable sparking at the brushes. Sometimes the defect does not cause a dead short; in such case, a temporary repair can be made by disconnecting the associated coil and bridging a jumper across bars 3 and 4. In any case, the heavy current, which would occur otherwise, must be eliminated.

SPECIAL USES

U31

To Use a VOM as a Clamp-On Ammeter

Equipment: Clamp-on AC probe.

Connections Required: Plug test leads from probe into VOM.

Procedure: Operate VOM on the specified AC-voltage range. Separate jaws of probe and clamp around the wire carrying the AC. Note meter reading.

Evaluation of Results: Even though this method permits measurement of fairly heavy AC only, it is very useful, because the circuit does not have to be opened for the test. The meter reads correctly only when the AC is a sine wave. Thus, the current flow from an AC line to a motor can be accurately measured, but an inaccurate measurement of the current flow to a mercury-vapor tube, thyratron, or ignitron would be obtained.

U32

To Use a VOM as a Low-Ohms Meter

Equipment: Low-ohms adapter for the particular VOM.

Connections Required: Plug the adapter into the VOM in place of the usual test leads.

Procedure: Select the appropriate low-ohms range on the adapter unit. Set the VOM controls as specified in the adapter instruction book. Short circuit the adapter test leads and zero the meter. Then apply the test leads across the commutator bars or other low-resistance circuit to be tested. Observe the scale reading and multiply by the scale factor specified in the adapter instruction book.

Evaluation of Results: The use of a commercial adapter is preferable to a simple low-ohms (high-current) test arrangement, because the contact resistance of the adapter prods to the commutator bars is less likely to cause an error in the reading. A low-ohms probe for the low-ohms indication on a VOM can be constructed as explained in the companion volume, *101 Ways to Use Your VOM and VTVM.*

U33

To Use a VOM as an RF Meter

Equipment: A tuning capacitor, tapped coil, germanium diode, and a .001-mfd fixed capacitor.

Connections Required: Connect equipment as shown in Fig. 40.

Procedure: Select a coil (plug-in coils can be utilized) that covers the desired frequency range. Calibrate the tuning capacitor

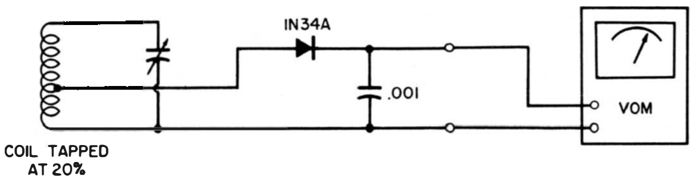


Fig. 40. RF meter configuration.

by link-coupling a signal generator to the coil. If a frosted plastic dial is used on the tuning capacitor, frequency calibrations can be marked on it.

Evaluation of Results: The RF meter is useful to check for RF leaks in dielectric-heating equipment, to neutralize amplifier stages in transmitters, to check local-oscillator frequencies, etc.

To Use a VOM as an S-Meter

Equipment: A triode, resistors, and a potentiometer.

Connections Required: Connect equipment as shown in Fig. 41. The meter posts are mounted on the front panel of the receiver, so that the VOM can be connected, when desired.

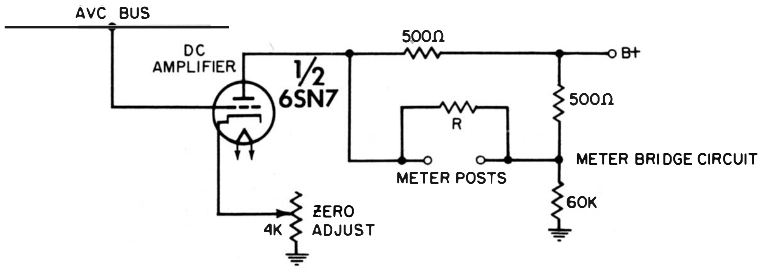


Fig. 41. Arrangement for using the VOM as an S meter.

Procedure: First unplug the DC-amplifier tube. Connect the VOM test leads to the meter posts, and set the VOM to its DC-voltage function and 15-volt range (or approximate range). Try different values for R and select the value that produces a maximum reading on the meter. Next, plug in the DC-amplifier tube, and short its grid to ground. Adjust the cathode resistor for zero reading on the VOM. Finally, remove the short from grid to ground.

Evaluation of Results: The DC amplifier inverts the AVC voltage applied to the grid, so that an increase in negative AVC voltage causes an increase in positive plate voltage, as well as stepping up the grid voltage for increased sensitivity. The VOM deflection is approximately linear with respect to the db of the receiver output, up to the cutoff point of the DC-amplifier tube.

To Use a VOM as an Indicator for a Grid-Dip Meter

Equipment: Grid-dipper circuitry, as typically shown in Fig. 42.

Connections Required: Connect the circuit as shown. An equivalent circuit can be used. The VOM can be connected to pin jacks or binding posts on the panel of the unit, or test leads can be supplied from the unit to plug into the VOM.

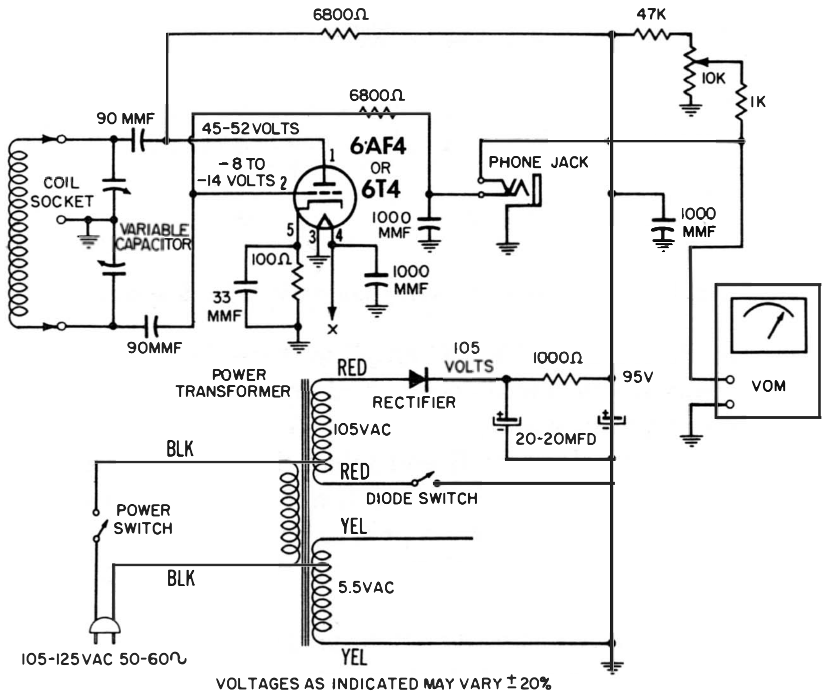


Fig. 42. Typical circuit of a grid-dip meter.

Procedure: Operate the unit as an ordinary grid-dip meter with a built-in indicator. (See the companion volume, *101 Ways to Use Your Ham Test Equipment.*) Operate the VOM on a suitable low DC range, such as 500 ma.

Evaluation of Results: At minimum dip, touch the VOM leads to see if the indication changes. If the stray fields are strong, the meter reading may change. In such case, use a shielded lead from the grid dipper to the VOM.

This application is useful for emergency service in case the meter in a conventional grid dipper is defective. Those who build their own equipment and wish to minimize investment in meters will also find this application attractive.

To Use a VOM as an Indicator for an Antenna-Impedance Meter

Equipment: Antenna Z-meter circuitry, as typically shown in Fig. 43.

Connections Required: Connect the circuit as shown. An equivalent circuit can be used. The VOM can be conveniently connected to pin jacks on the panel of the unit, or test leads can be supplied from the unit to plug into the VOM.

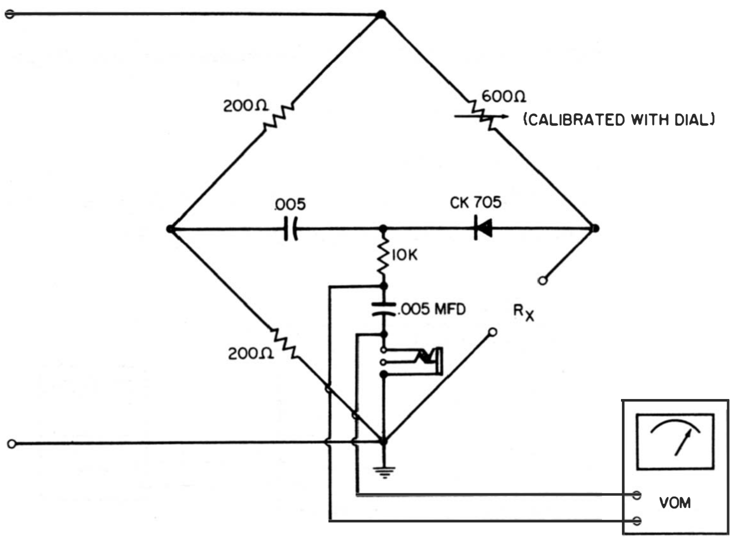


Fig. 43. Typical antenna Z-meter circuit.

Procedure: Operate the unit as an ordinary antenna Z meter with a built-in indicator. (See the companion volume, *101 Ways to Use Your Ham Test Equipment.*) Operate the VOM on a suitable DC range, such as 100μa. Beginners should note that very short leads are necessary in RF circuitry; however, the VOM circuit carries only DC, and short leads to the meter are not required.

Evaluation of Results: This is basically a resistive bridge arrangement, which gives a zero or null reading when the 600-ohm potentiometer is adjusted to a suitable point. A zero reading is not obtained unless R_x is purely resistive, as it should be in an ideal antenna installation. The .005-mfd capacitor shunted across the VOM input leads normally keeps stray

RF fields from being picked up by the leads. However, if stray fields are quite strong and the null indication changes when the meter leads are touched, use a shielded cable from the unit to the VOM.

U37

To Use a VOM as an External Detector for an Impedance Bridge

Equipment: Impedance bridge.

Connections Required: Connect VOM test leads to external detector posts of the bridge, as shown in Fig. 44.

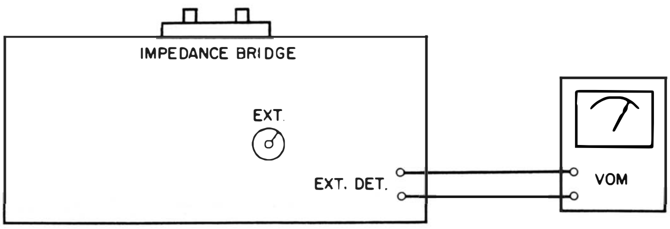


Fig. 44. Test setup of impedance bridge and VOM.

Procedure: Switch the bridge to the external detector position. Operate bridge in the usual manner. (See the companion volume, *101 Ways to Use Your Ham Test Equipment.*)

Evaluation of Results: The most sensitive null indication is obtained when the VOM is operated on its lowest DC range. However, always start on a high DC range (to avoid pointer slamming) until the bridge is adjusted for approximate balance. Then operate the VOM on lower DC ranges for a more sensitive null indication. Since typical bridges use a built-in 200-microampere meter, an external VOM can give considerably greater indication sensitivity.

To Use a DC Voltmeter as an Indicator for a UHF Wavemeter

Equipment: None.

Connections Required: Connect meter test leads to output terminals of the detector in the wavemeter (Fig. 45). Energize the wavemeter in the usual manner.

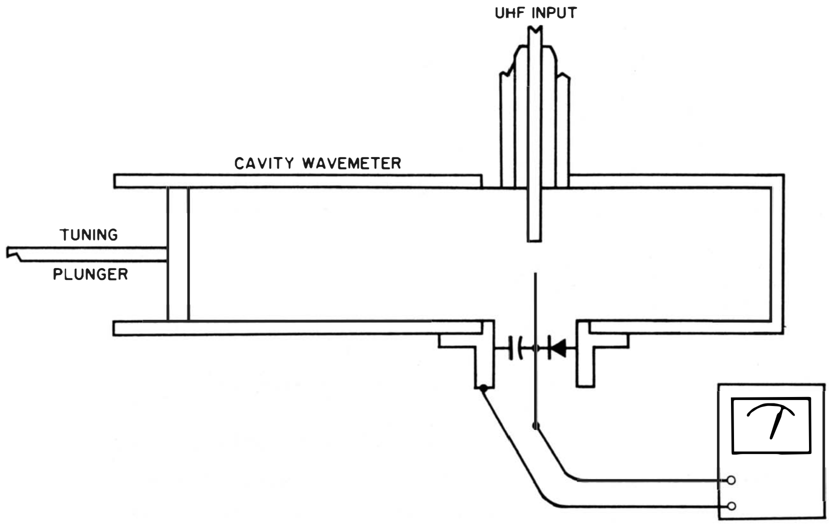


Fig. 45. DC voltmeter as an indicator for a cavity wavemeter.

Procedure: Adjust the tuning plunger in the wavemeter for a maximum reading on the DC voltmeter.

Evaluation of Results: The reading on the wavemeter scale indicates the wavelength of the applied UHF signal.

To Use a VOM as a Tachometer

Equipment: Components illustrated in Fig. 46. (A scope is needed for calibration.)

Connections Required: Connect equipment as shown.

Procedure: To calibrate the meter, the scale is converted to RPM. Use 5400 RPM for full-scale deflection. (An overlay scale can be drawn, if desired.) Equally divide the scale into divisions of 900, 1800, 2700, 3600, 4500, and 5400. Set the horizontal-sweep rate of a scope to lock in a 60-cycle signal applied to the vertical input. The scope then sweeps 3600 times a minute. Connect the scope's vertical input and the tachometer input to the 6- or 12-volt ignition supply voltage where it connects to

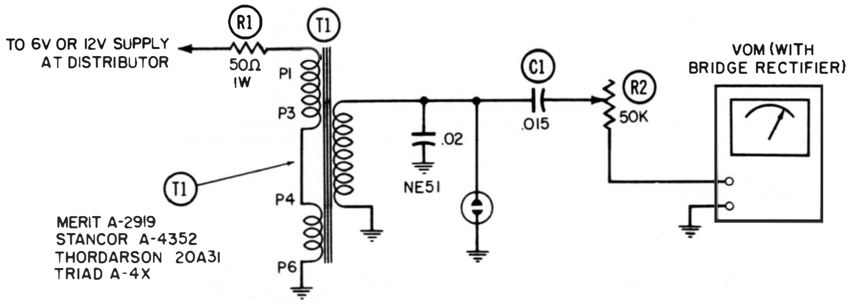


Fig. 46. Electric tachometer arrangement.

the distributor, and start the engine. At little more than idling speed, one pip will appear on the screen; this is a speed of 900 RPM. Increase engine speed for two pips, or 1800 RPM, and adjust R2 for an 1800-RPM scale reading on the VOM. The neon lamp should glow steadily at speeds over 1500 RPM; if it flickers at higher speeds, change R1 to a lower value. Use the scope to check the meter reading at 900 and 2700 RPM (one and three pips). If the readings are high, increase C1 and readjust R2 at 1800 RPM. If readings are low at 900 and 2700 RPM, reduce C1 and recalibrate.

Evaluation of Results: The calibration procedure described is for an eight-cylinder engine. If the electrical system of the engine used for calibrating the meter is correctly tuned, the tachometer can be used to check any eight-cylinder engine which is also correctly tuned.

To Use a VOM as a Field-Strength Meter for a Mobile Transmitter

Equipment: A simple dipole antenna and a crystal diode (Fig. 47).
Connections Required: Connect equipment as shown.
Procedure: Place the dipole at a predetermined distance from the transmitting antenna, with the dipole rods in the same plane. Turn the transmitter on and observe meter reading.

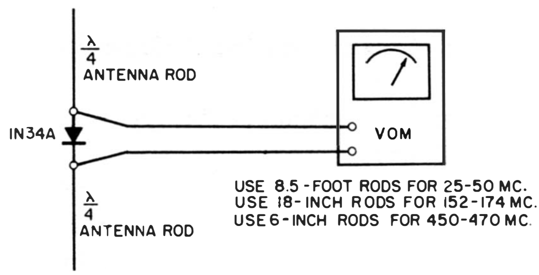


Fig. 47. Simple field-strength meter for checking a mobile transmitter.

Evaluation of Results: This arrangement gives a relative field-strength indication, which must be observed with respect to a reference reading corresponding to the normal field strength.

TEST-EQUIPMENT CHECKS

U41

To Measure the Input Capacitance of a VTVM AC Probe

Equipment: Impedance bridge (or capacitance bridge operating at 1 kc).

Connections Required: Connect probe and ground lead to terminals of bridge as shown in Fig. 48.

Procedure: Do not plug VTVM into power outlet. Operate the bridge as if an ordinary capacitor were under test. Note reading of the capacitance dial at the null point.

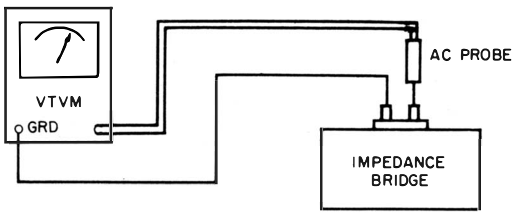


Fig. 48. Measuring the input capacitance of a VTVM on its AC-voltage function.

Evaluation of Results: A typical input capacitance value is 150 mmf. This means that when the VTVM is operated on its AC-voltage function, it shunts 150 mmf across the circuit under test, or it imposes this amount of capacitive loading on the circuit. A complete null on the bridge indicator may not be obtained, as is the case when an ordinary capacitor is under test. This is due to the stray 60-cycle hum voltage picked up by the VTVM. The hum voltage tends to unbalance the bridge; however, the bridge circuit is considerably more responsive to 1-kc voltage than to 60-cycle voltage, so a reasonably good null is obtained. On the other hand, this measurement is grossly in error if attempted on a 60-cycle capacitance bridge. There are two reasons for the large error. First, the stray hum voltage tends to unbalance the bridge, and the indicator makes no distinction between the bridge-driving voltage and the spurious voltage. Second, a 60-cycle bridge often has no provision for balancing the resistive component of the input capacitance, which also causes an erroneous reading on the capacitance dial.

U42

To Measure the Input Capacitance to the Ground Terminal of a VTVM

Equipment: Capacitance bridge.

Connections Required: Connect one terminal of the capacitance bridge to the ground terminal of the VTVM and the other to the power plug of the VTVM. (See Fig. 49.)

Procedure: Turn on VTVM power switch so that the input capacitance is measured with the VTVM circuit completed. Measure the input capacitance on the bridge in the same manner as if a capacitor were under test.

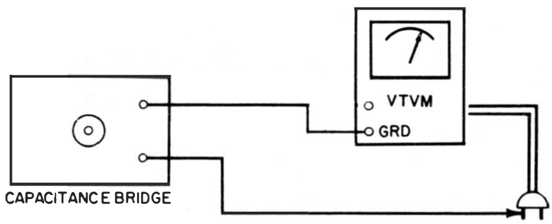


Fig. 49. Measuring the input capacitance to the ground terminal of a VTVM.

Evaluation of Results: A ground-input capacitance of 250 mmf is typical. This capacitance limits the application of a VTVM in above-ground tests. For example, Fig. 50 shows an RC circuit driven by an audio oscillator. A test of the AC-voltage drop across C is often in error, because the ground terminal of the VTVM effectively shunts 250 mmf across R. The error increases at high frequencies, and for larger values of R.

A VOM eliminates this particular difficulty, because both VOM terminals are above ground. On the other hand, unless the VOM has a high sensitivity rating, such as 100,000 ohms per volt, its current drain will be very much greater than a VTVM and this drain in turn may load a circuit objection-

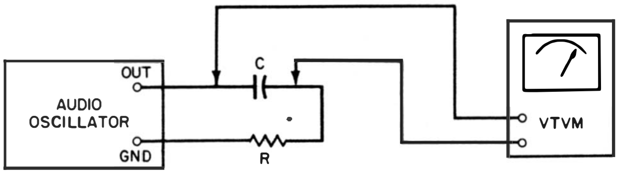


Fig. 50. Voltage measurement across C is often in error, because of VTVM "ground" capacitance.

ably. Some manufacturers offer hybrid VOM/VTVM's which are battery-operated, and thereby meet both requirements. Likewise, one manufacturer has a VTVM adapter for a VOM which is also battery-operated, permitting above-ground tests without objectionable errors from excessive capacitance or current loading.

U43

To Determine the Input Capacitance of a DC Probe for a VTVM

Equipment: FM (or other high-frequency) receiver and several small-value fixed capacitors with 1% tolerance.

Connections Required: Tune the receiver to a heterodyne beat note (such beat notes are occasionally available as spurious receiver responses). If necessary, use a signal generator to develop a heterodyne beat against a station signal. Then connect the DC probe across the oscillator coil (Fig. 51) and retune the receiver to the zero beat. Finally, disconnect the probe and connect trial capacitors across the oscillator coil to restore the zero beat.

Procedure: Continue connecting capacitors across the oscillator coil until the zero beat is found. Remember that capacitors

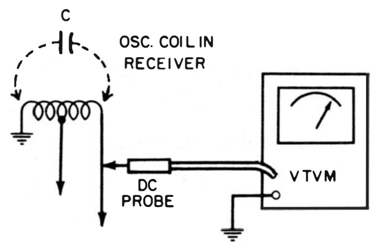


Fig. 51. Determining the input capacitance of a VTVM DC probe.

can be connected in series or parallel to get new values. A large capacitor connected in series with a small capacitor will change the total value slowly as the larger unit ranges through wide values. Thus, exact values of small capacitance can be made up with comparatively little difficulty.

$$(C_{total} = \frac{C_1 \times C_2}{C_1 + C_2})$$

Evaluation of Results: The capacitance value which restores the zero beat is the input capacitance value of the DC probe. It is normally small, such as 1 or 2 mmf. If a clip is used on the probe tip, the input capacitance will be found to increase considerably. Note that the input capacitance of a DC probe cannot be measured unless an RF bridge is at hand. Hence, the simple substitution method outlined above is generally used.

U44

To Check the Calibration of an Audio Oscillator at 60 Cycles

Equipment: Source of 60-cycle line voltage (such as a heater transformer).

Connections Required: Connect equipment as shown in Fig. 52. Note that the AC function of the voltmeter can be used instead of the probe, if desired.

Procedure: Set the audio oscillator for several volts output (if available) and tune to the vicinity of 60 cycles, watching the meter response.

Evaluation of Results: As the audio oscillator approaches 60 cycles, the pointer will oscillate. The oscillation becomes slower as the zero beat is approached, and the pointer comes to rest when the frequencies are identical. The clearest indication is obtained when the two input voltages are approximately equal. The power-line frequency is reasonably accurate, but not completely so. Power companies maintain the 60-cycle frequency quite accurately over an extended time, so that electric clocks, for example, keep good time; however, the instantaneous frequency is subject to minor tolerances. Thus, for highest accuracy of calibration, repeat the procedure at hourly intervals several times, and take the average zero-beat point.

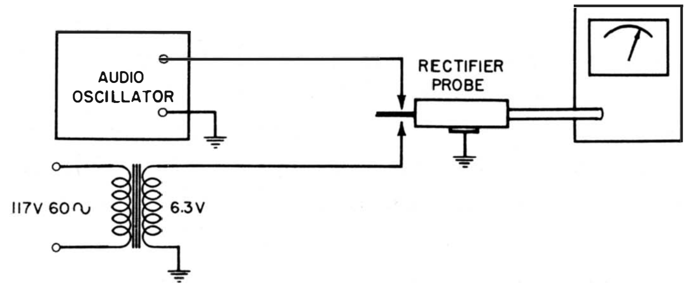


Fig. 52. Setup used to check the calibration of an audio oscillator at 60 cycles.

U45

To Measure the Output From a Square-Wave Generator With a VOM

Equipment: None.

Connections Required: Connect VOM test leads to the output terminals of the square-wave generator.

Procedure: Operate the VOM on its output function.

Evaluation of Results: The output function of the VOM is used to avoid the possibility of a false reading in case there is DC voltage in the square-wave output. This occurs, for example, when the generator output stage is a cathode follower without a blocking capacitor. The peak-to-peak output voltage of the square-wave generator is represented by 1.8 times the scale reading on the VOM. The reading must be multiplied by 1.8 because the meter movement responds to the average value of the rectified square wave, which is one half of peak for a full-wave instrument rectifier, or one quarter of peak for a half-wave instrument rectifier. The VOM scale is calibrated to indicate rms values of a sine wave, and the scale reading is 1.11 times the average value for a full-wave instrument, or 2.22 times the average value for a half-wave instrument. In other words, a VOM *indicates* 1.11 times peak for a square-wave input. Hence, to convert from indicated to peak-to-peak voltage multiply the scale reading by 1.8, which is 2 divided by 1.11 (or 4 divided by 2.22 for a half-wave instrument).

NOTE 14

Response of Various Meters to Basic Complex Waveforms Differs

In service work, meters with one or more of the following responses to AC waveform voltages are commonly used:

1. Peak-to-peak response.
2. Positive-peak response. (Turnover occurs if even harmonics are present.)
3. Negative-peak response. (Turnover occurs if even harmonics are present.)
4. Half-wave average response, positive. (Turnover.)
5. Half-wave average response, negative. (Turnover.)
6. Full-wave average response.

With respect to the basic complex waveforms illustrated in Fig. 53, the total amplitude, or peak-to-peak voltage, is of most interest. If a voltmeter with a peak-to-peak response is used, this value is indicated directly. On the other hand, suppose an RF probe which contains a half-wave rectifier is used. The DC scales of the VTVM then indicate the peak voltage of a complex waveform. If the probe contains a positively-polarized rectifier, the positive-peak voltage is indicated; if a negatively-polarized rectifier, the negative-peak voltage is indicated. Thus, if the complex waveform contains even harmonics (has different positive- and negative-peak voltages), the scale reading changes when the probe is "turned over." Again, a VOM may have a half-wave or full-wave instrument rectifier which responds to the average value of the rectified voltage, while the scale is calibrated in rms values. Hence, a VOM gives a different reading on a complex waveform. The chief points are summarized in Fig. 53.

Note: "A" is the peak amplitude of the waveform.

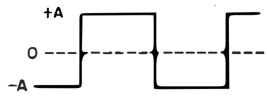
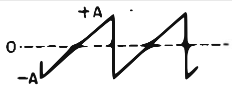
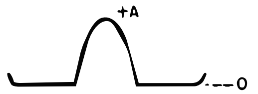
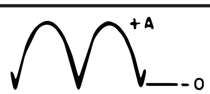
Waveform	Meter Response	Scale Reading
 SQUARE WAVE	Peak	0.707A
	½ Wave Average	1.11A
	Full-Wave Average	1.11A
 SAWTOOTH WAVE	Peak	0.707A
	½ Wave Average	0.555A
	Full-Wave Average	0.555A
 ½ RECTIFIED SINE WAVE	+Peak	0.707A
	+½ Wave Average	0.707A
	Full-Wave Average	0.354A
 FULL RECTIFIED SINE WAVE	Peak	0.707A
	+½ Wave Average	1.414A
	Full-Wave Average	0.707A

Fig. 53. Response of common meters to basic waveforms.

U46

To Determine the Internal Resistance of a DC Milliammeter or Ammeter

Equipment: Auxiliary DC voltmeter, battery, and appropriate potentiometer.

Connections Required: Connect equipment as shown in Fig. 54.

Procedure: Adjust the potentiometer for a current flow of half-scale to three-quarter scale on the milliammeter (or ammeter). Note current and DC voltmeter readings.

Evaluation of Results: The internal resistance of the milliammeter (or ammeter) is given by Ohm's law. For example, a typical VOM, operating on its DC function, shows a 0.28-volt drop across its terminals when the current is 100 ma. Thus, the internal resistance is equal to 0.28/0.1, or 2.8 ohms. In general, the lower-current ranges of a VOM have higher internal resistances. In some tests, this internal resistance may impose technical limitations. When using a VOM to measure current, the amount of series resistance added to the circuit by

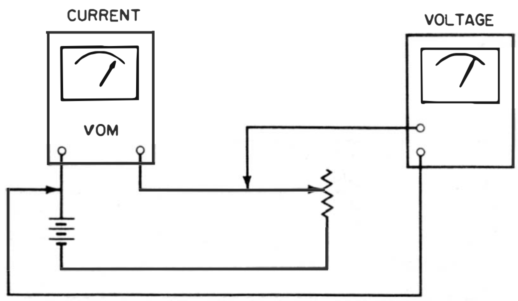


Fig. 54. Determining the internal resistance of a milliammeter or ammeter.

the VOM should be known. For example, a VOM that has an internal resistance of 240 ohms on the 1-ma range acts as a 240-ohm resistor when connected into a circuit and operated on this range.

NOTE 15

Apparent Errors in Current Readings on Different VOM Ranges

When different readings are obtained on adjacent DC ranges of a VOM, a false conclusion that the instrument is defective might be reached. However, *the internal resistance of the VOM is part of the circuit.* When switching from the 1-ma range to the 5-ma range, for example the internal resistance is smaller. The total circuit resistance is then less, and more current flows. Thus, the meter reads a larger value when switched to the 5-ma range. This is a very practical point to keep in mind when checking meter accuracy by comparing readings on adjacent ranges. This situation of apparent error becomes negligible only when the circuit resistance is much greater than the internal resistance of the instrument. With a high circuit resistance, a constant-current source is approximated because the varying resistance from one range to another on the meter then represents a comparatively small fraction of the total circuit resistance.

U47

To Determine the Internal Resistance of a Meter Movement

Equipment: Dry cell and two potentiometers (see Fig. 55). R2 must have a value greater than the internal resistance of the meter, and R1 must limit the current to full-scale value. Otherwise, the meter movement may be damaged. Thus, if a 10-microampere movement is under test, R1 must have a value of at least 150,000 ohms.

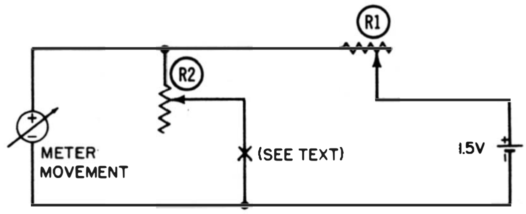


Fig. 55. Determination of the internal resistance of a meter movement.

Connections Required: Make connections as shown in Fig. 55, leaving R2 disconnected.

Procedure: Adjust R1 for full-scale reading on the meter movement. Then connect R2 into the circuit and adjust it for half-scale indication on the meter movement.

Evaluation of Results: Disconnect R2 and measure its resistance with an ohmmeter or a resistance bridge. The resistance of R2 is equal to the internal resistance of the meter movement. *Warning:* Never try to measure the internal resistance of a meter movement directly with an ohmmeter, as the voltage applied by the ohmmeter will very likely burn out the movement.

U48

To Determine the Scale Factor for a VOM on its Output Function

Equipment: Sources of 60-cycle and 120-cycle sine-wave voltages (such as an audio oscillator) and a 40-mfd motor-starting capacitor.

Connections Required: Connect equipment as shown in Fig. 56.

Procedure: Operate the VOM first on its AC-voltage function and note reading. Next, switch the VOM to its output function and again note scale reading. This pair of readings is made with the source operating at 60 cycles. Finally, repeat the procedure with the source operating at 120 cycles.

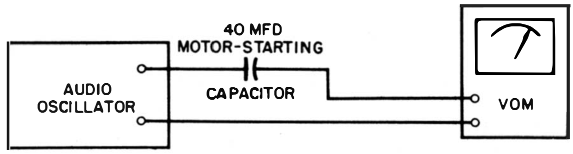


Fig. 56. Determination of scale factor for the output function of the VOM.

Evaluation of Results: If the reading is lower on the output function, a scale factor is required for the given test frequency. For example, suppose the audio oscillator is set to 60 cycles and 5 volts is read on the AC-voltage function but only 3 volts on the output function. A scale factor of 5/3 will then be required in order for the true voltage reading to be obtained on the output function at 60 cycles. Likewise, if the audio oscillator is set to 120 cycles and 5 volts is read on the AC-voltage function but only 4 volts on the output function, then a scale factor of 4/3 will be required before a true voltage reading can be obtained on the output function at 120 cycles. Note that output-function scale factors are often required at low frequencies because the small-value series blocking capacitor in the VOM develops appreciable reactance at low frequencies. Note also that if there is no measurable DC voltage at the terminals of the audio oscillator, the motor-starting (nonpolarized) capacitor shown in Fig. 56 can be omitted.

NOTE 16

Ordinary VOM's and VTVM's Do Not Read RMS Voltages of Complex Waves

Ordinary VOM's and VTVM's do not indicate the correct rms voltage when a complex wave is applied. However, a peak-to-peak VTVM indicates the correct peak-to-peak voltage of a complex wave. A service-type VOM has either a half-wave or full-wave instrument rectifier, and is calibrated to read rms voltages of sine waves. The meter action in a half-wave VOM is illustrated in Fig. 57, and the meter action in a full-wave VOM is seen in Fig. 58. It can be seen that the meter movement responds to the average value of the waveform, which in turn divides the wave into equal areas above and below the average level. Hence, if the waveform changes, the average level changes. The actual rms values are given in Fig. 59. To measure the rms value of a complex waveform directly, a special type of VTVM called a square-law voltmeter must be used. Why is the rms voltage of a complex waveform of any importance? It is occasionally important because a complex waveform is

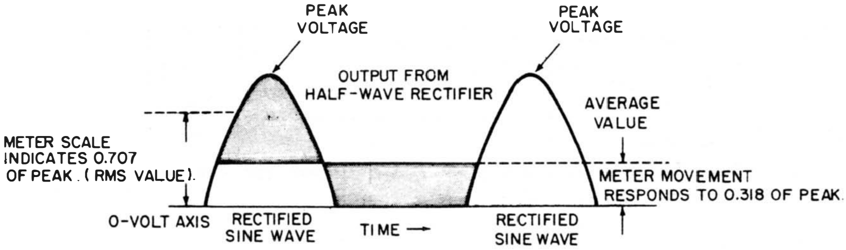


Fig. 57. An ordinary VOM has this current waveform flowing through the movement of the meter.

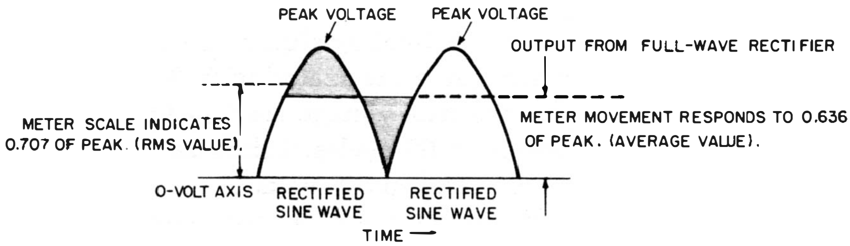


Fig. 58. If the VOM has a full-wave instrument rectifier, this current waveform flows through the meter movement.

used to heat the filament of a high-voltage rectifier, for example. Also a complex waveform from an inverter is used to power the heaters and B+ section in various types of electronic equipment. Since the heating action of a current is given by its rms value, it is necessary to know this value in such applications.

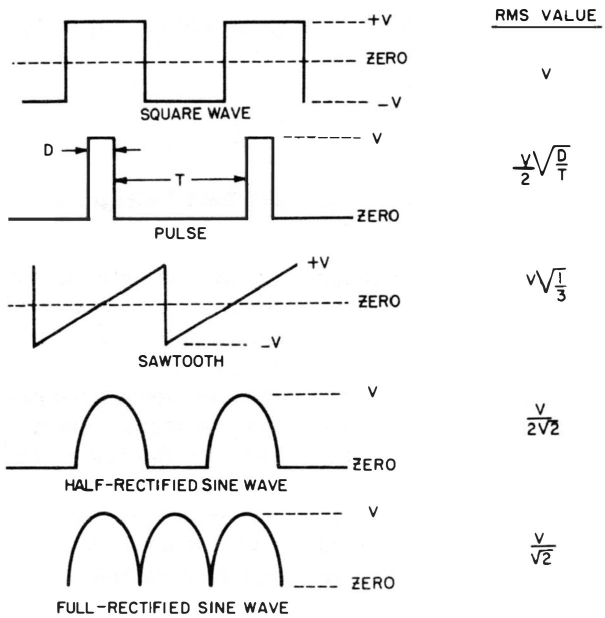


Fig. 59. RMS values of common waveforms.

U49

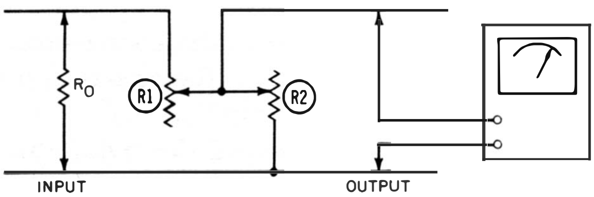
To Check the Input and Output Impedances of an L-Pad

Equipment: Resistors having values equal to the source impedance and the load impedance for the L-pad.

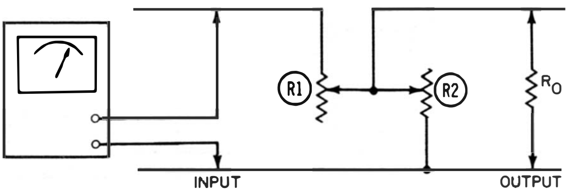
Connections Required: Connect the ohmmeter and resistors as shown in Fig. 60.

Procedure: Vary the L-pad control through its range while observing the scale reading.

Evaluation of Results: The output impedance of the configuration in Fig. 60A changes as the setting is varied. This test shows the value of the output impedance at any setting. On the other



(A) Output impedance.



(B) Input impedance.

Fig. 60. Hookups for checking the input and output impedances of an L-pad.

hand, the input impedance (Fig. 60B) normally remains constant as the setting is varied. The test shows whether the input impedance changes with the setting. Note that the output impedance can be made constant by reversing the input and output connections to the pad, but the input impedance then changes with the setting. To put it another way, a normally operating L-pad keeps either the input impedance or the output impedance, but not both, constant. Some pads have wide tolerances, because it is expensive to manufacture potentiometers to close limits. This test gives information concerning only the low-frequency performance of the pad—low frequencies at which the characteristic impedance is essentially a DC resistance. It does not indicate how the pad "looks" to high frequencies which "see" stray capacitances in the pad assembly.

U50

To Check the Impedances of a T-Pad

Equipment: Resistors having values equal to the rated input and output impedances of the T-pad.

Connections Required: Fig. 61 shows the connections for testing the output impedance of the pad. (Reverse the ohmmeter and R_o positions to test the input impedance.)

Procedure: Vary the control of the pad through its range, watching the ohmmeter reading.

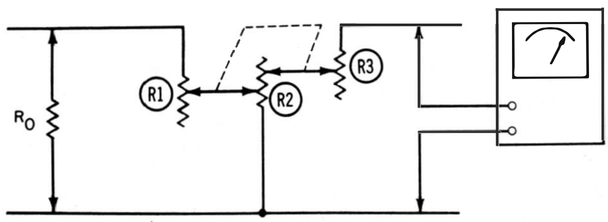


Fig. 61. To check the output impedance of a T-pad.

Evaluation of Results: The reading should remain constant as the control is turned through its range (within the rated tolerance of the pad). Note that the output impedance ("looking back" into the pad) may or may not have the same value as the input impedance ("looking forward" into the pad), depending on the pad design. In either case, however, the input and output impedances normally remain essentially constant throughout the control range. Some pads have fairly wide tolerances, because close-tolerance potentiometers are expensive. Since this test is made with DC, it does not indicate the impedance of the pad at higher frequencies, where stray capacitances may become significant. Note also that it is essential to have resistor R_o connected to the pad during the test; otherwise, the meter reading will not give the desired information.

NOTE 17

Why Impedances Are Generally Matched in Audio-Frequency Work

Impedances are usually kept reasonably well matched when lines, loads, pads, amplifiers, and utilization devices are connected into a system. There are several technical reasons for so doing. First, maximum power transfer may be of interest; that is, as much power in the load as possible must be realized. Maximum power transfer occurs with matched impedances, although efficiency is only 50%. In audio work, maximum power transfer is often of more concern than system efficiency. Second, minimum distortion may be of interest; quite a few amplifiers develop increased distortion when working into other than their rated load impedance. Third, many speakers develop increased distortion when working out of a source impedance other than rated. Fourth, when working on very long lines, such as from a studio to a remote transmitter, mismatched impedances can cause reflections, or electrical echoes, which impair the fidelity of the transmission. On most audio lines, which are electrically short, reflections are not apparent to the ear. Thus, in the 70-volt audio system, the amplifier is treated as a constant-voltage source, and various speakers are switched in without regard for changing load impedances. To put it another way, the circuits in a 70-volt audio system are considered from the same standpoint as the circuits in a 117-volt, 60-cycle power system.

U51

To Check a T-Pad for Reactive Response

Equipment: An audio oscillator, a resistor with a value equal to the rated input impedance of the pad, and a resistor with a value equal to the rated output impedance of the pad.

Connections Required: Connect equipment as shown in Fig. 62.

Procedure: Operate the meter on its AC-voltage function. Vary the generator frequency through the audio-frequency range (or higher, if desired) and observe any variation in meter reading.

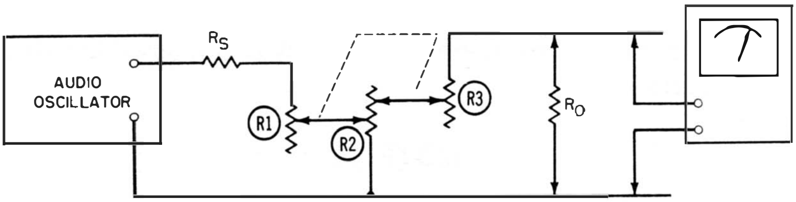


Fig. 62. Checking a T-pad for reactive response.

Evaluation of Results: At some upper frequency, the meter reading begins to change. This is the frequency at which the stray capacitances of the pad bypass some of the AC voltage around the potentiometers, causing the branch impedances to have lower values than the resistive components alone. Note that, in general, pads with lower characteristic impedances (input and output) perform better at higher frequencies. If the pad has a very low input impedance, the most accurate test is obtained by taking the internal impedance of the audio oscillator into account, and making the sum of this internal impedance and R_S equal to the rated input impedance of the pad.

U52

To Check the Frequency Characteristic of an Equalizer

Equipment: An audio oscillator; resistors to provide correct source and load impedances.

Connections Required: Connect equipment as shown in Fig. 63. If the equalizer is intended to work into a high-impedance grid circuit, omit R_L. On the other hand, if the equalizer is intended to work into a 600-ohm line, for example, use a

600-ohm resistor for R_L. Most equalizers work out of a low- or medium-source impedance; a few work out of a high-source impedance. Hence, select R_S to equal the intended source impedance.

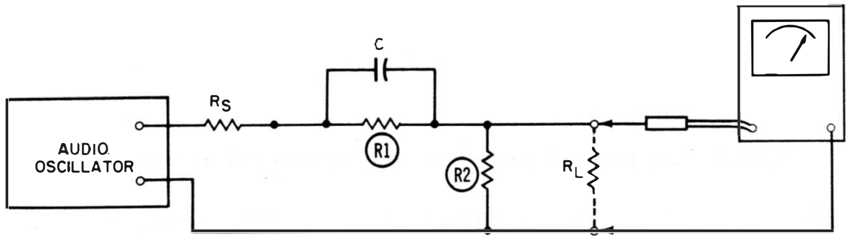


Fig. 63. Test setup to check the frequency characteristic of an equalizer.

Procedure: Operate the VTVM on its AC-voltage function. Vary the audio-oscillator frequency through the normal operating range of the equalizer, noting the meter readings at suitable frequency intervals.

Evaluation of Results: The equalizer illustrated in Fig. 63 gives a high-frequency boost. This is perhaps the most commonly encountered form of equalizer. Its frequency response depends on the values of all four resistors and capacitor C.

U53

To Determine the Power Sensitivity of an Amplifier

Equipment: Audio oscillator and optional output load resistor for amplifier (or audio-wattmeter adapter for VOM).

Connections Required: Connect equipment as shown in Fig. 64. The same AC voltmeter can be used for both measurements.

Procedure: Set the audio oscillator for a 400-cycle output and drive the amplifier to its maximum rated power output. Note rms input voltage. Also observe voltage across load resistor. (If audio-wattmeter adapter is used, note the milliwatts of power in the load.)

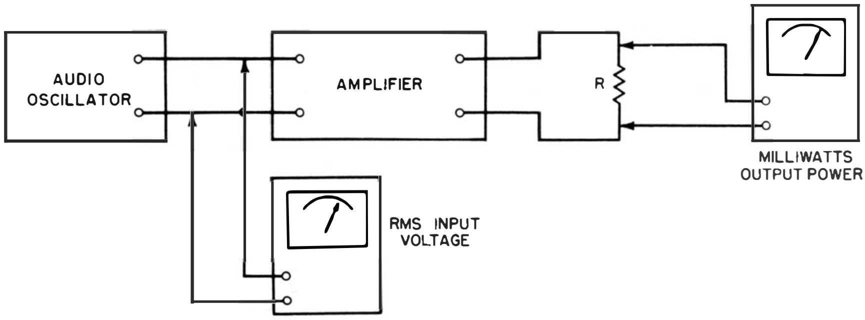


Fig. 64. Test setup to determine the sensitivity of an amplifier.

Evaluation of Results: The amplifier sensitivity is given by

$$\frac{\sqrt{\text{power output in milliwatts}}}{\text{rms grid voltage}}$$

Triode amplifiers have less power sensitivity than pentode or beam-power amplifiers.

U54

To Check a Schmitt Phase Inverter for Balance

Equipment: Audio oscillator.
Connections Required: Connect equipment as shown in Fig. 65.

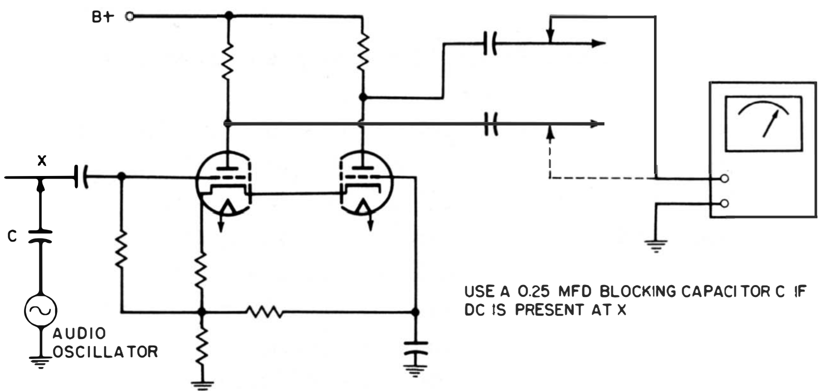


Fig. 65. Checking a Schmitt phase inverter for balance.

Procedure: Drive the phase inverter to its maximum rated output at 400 cycles. Operate the VOM on its output function and measure the AC voltage across each plate-load resistor in turn.

Evaluation of Results: The two voltage values should be equal. If they are not, tube selection may improve the balance. Otherwise, it is indicated that the plate-load resistances do not have the correct ratio (one resistor or both may have drifted in value). Defective capacitors can also cause unbalance. A balanced push-pull output requires a somewhat lower value of plate-load resistance in the driven section, compared to the plate-load resistance in the follower section.

U55

To Measure the Frequency Response of a Phase Inverter

Equipment: Audio oscillator.

Connections Required: Connect equipment the same as for the balance check. (Fig. 65 is typical.)

Procedure: If a blocking capacitor (C in Fig. 65) is required, use a larger value (such as 1 mfd) in this test to avoid the possibility of attenuating the low-frequency drive voltage. Operate the VOM on its output function. As the audio oscillator is advanced in steps from low to high frequencies, measure the AC voltage across each plate-load resistor in turn.

Evaluation of Results: The operating limits of the phase inverter occur at the low- and high-frequency ends of the response range when (1) the outputs become unbalanced or (2) the output voltages drop substantially. Wider variations of response are permissible in commercial sound systems, for example, than in high-fidelity equipment.

To Adjust a Cathamplifier for Balance

Equipment: An audio oscillator and a suitable load resistor.

Connections Required: Connect the output from the audio oscillator to the input terminals of the amplifier. Connect the VTVM across the cathode bias resistor. (See Fig. 66.)

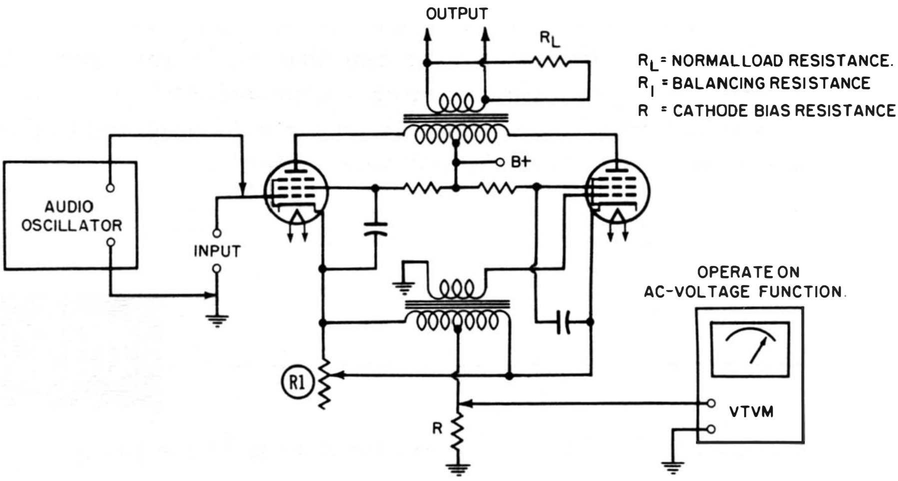


Fig. 66. Adjusting a cathamplifier for balance.

Procedure: Drive the amplifier to its maximum rated power output. Operate the VTVM on its AC-voltage function. (If a VOM is used, operate it on its output function.) Adjust R1 for minimum reading across R.

Evaluation of Results: When the amplifier is balanced, the AC cathode currents are equal and opposite and add to zero across R. Complete balance can be obtained at only one frequency (if at all), due to lack of perfect transformer action.

To Check the Feedback Branches in a Push-Pull Output Stage

Equipment: Audio oscillator; load resistor, if speaker is not used.

Connections Required: Connect the output from the audio oscillator to the input terminals of the amplifier. Connect the VOM, in turn, across the feedback network components (Fig. 67).

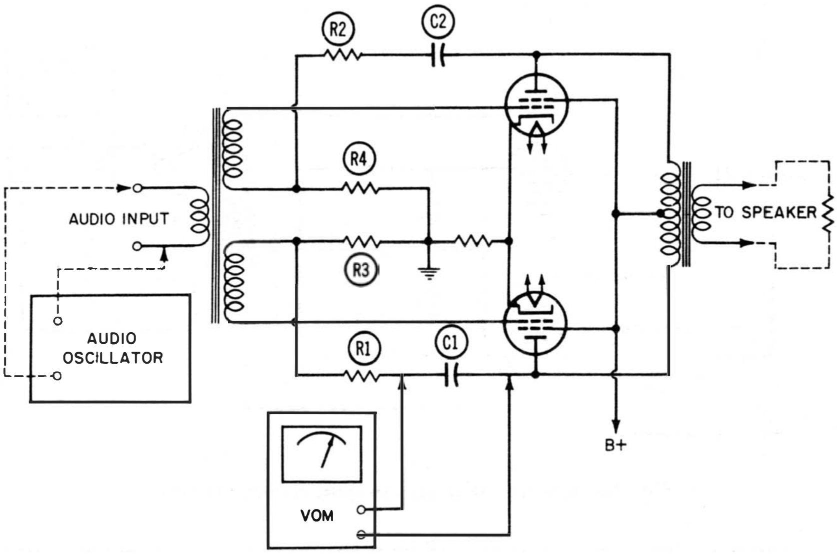


Fig. 67. Checking the feedback branches in a push-pull output stage.

Procedure: Drive the output stage preferably to its maximum rated output. Operate the VOM on its output function. Make comparative readings across symmetrical components, such as C1 and C2, R1 and R2, and R3 and R4.

Evaluation of Results: Approximately equal readings should be observed across each pair of symmetrical components. Otherwise, a component is defective. In such case, check out each component individually for the correct value.

To Adjust a Screen-Grid Phase Splitter for Maximum Dynamic Range

Equipment: Audio oscillator; load resistor (if desired) for transformer secondary.

Connections Required: Connect the output leads from the audio oscillator between input grid and ground. Connect the VTVM with a half-wave probe across the output-transformer secondary (Fig. 68).

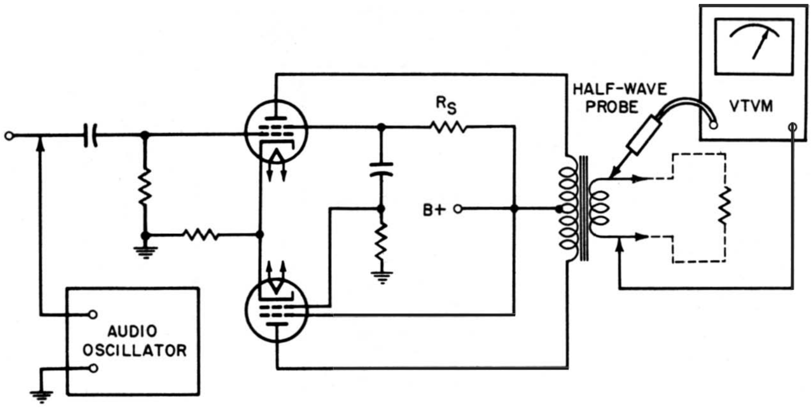


Fig. 68. Circuit of a screen-grid phase splitter.

Procedure: Drive the phase splitter to its maximum rated output with the audio oscillator set to 400 cycles. Observe VTVM reading. Then reverse probe and ground connections of the VTVM and again observe the VTVM reading.

Evaluation of Results: The two readings will differ because of even-harmonic generation and turnover. The difference can be minimized by selecting the value of screen resistor R_S. This operating condition provides maximum dynamic range with minimum distortion.

To Check a Transistorized Audio-Output Stage for Balance

Equipment: None.
Connections Required: Connect the voltmeter as shown in Fig. 69.
Procedure: Operate the meter on its DC-voltage function. Observe scale reading.

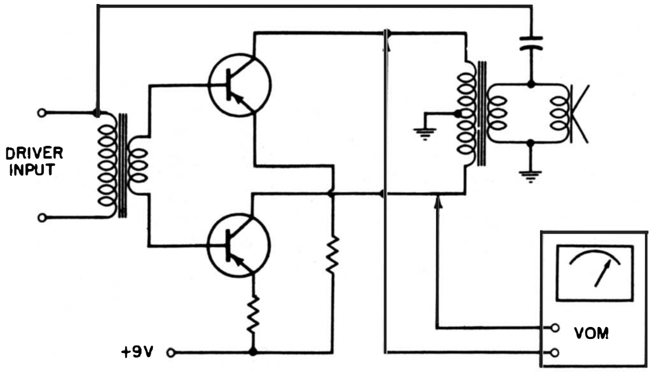


Fig. 69. Checking a transistorized audio-output stage for correct balance.

Evaluation of Results: Ideally, the meter should read zero under both quiescent and maximum rated-output conditions. In practice, some DC unbalance generally occurs, due to tolerances on transistors and circuit components. Unbalance results in increased distortion. Severe unbalance generally indicates unmatched transistors or a defective transistor.

U60

To Adjust a Paging Amplifier for Maximum Dynamic Range

Equipment: Audio oscillator; load resistor (if desired) to substitute for the speaker.
Connections Required: Connect output from audio oscillator to primary of microphone transformer; connect the VTVM with a half-wave probe across the output-transformer secondary (Fig. 70).
Procedure: Drive the amplifier to its maximum rated output, with the audio oscillator set to 400 cycles. Observe VTVM reading.

Then reverse probe and ground-return leads to the output-transformer secondary and observe VTVM reading again.

Evaluation of Results: Ideally, the two readings should be the same; in practice, the readings differ. This is called the turnover error. It is not really an erroneous pair of measurements, but simply indicates that the single-ended amplifier is gen-

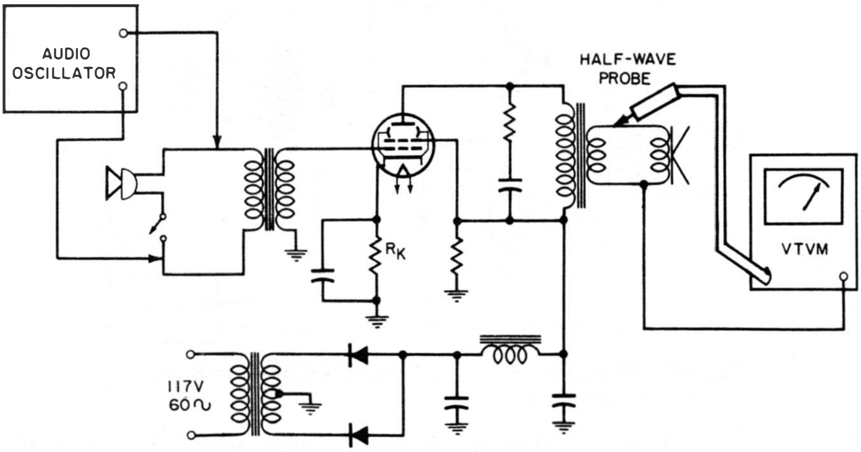


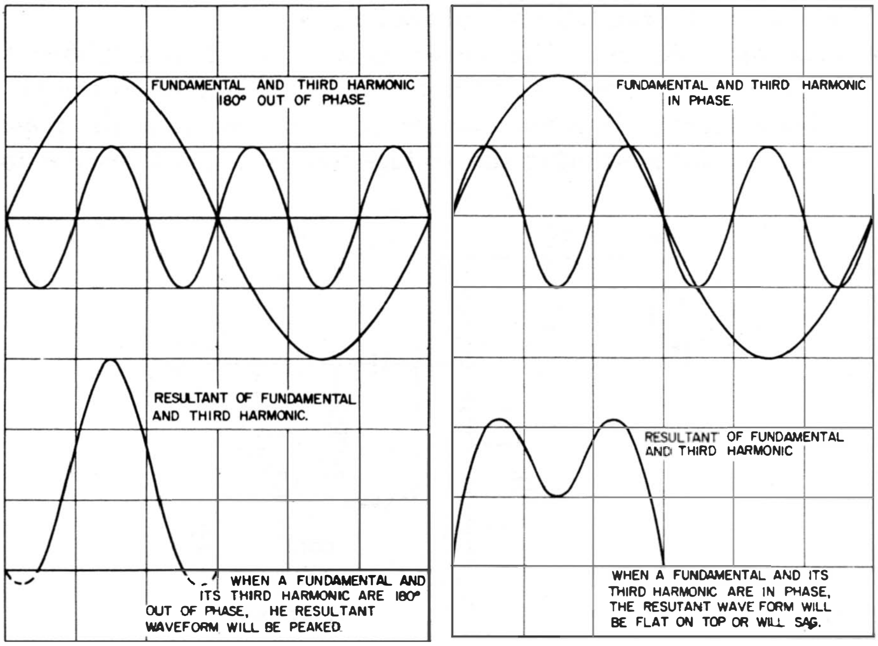
Fig. 70. Simple one-stage paging amplifier.

erating even harmonics. To adjust the amplifier for minimum turnover error, select an optimum value for cathode resistor R_K. This gives the maximum dynamic range at minimum distortion. Note that this adjustment cannot be made with a peak-to-peak VTVM, because the full-wave rectifier will average out the even-harmonic distortion, and no turnover error will be found.

Note 18

Average Half-Cycle Value of Waveform Changes With Phase of Harmonics

It might be supposed that the mixture of a fundamental and a third harmonic would have the same average half-cycle value regardless of phase. However, this is not so. Fig. 71 shows a fundamental mixed with a third harmonic in the same phase, and also 180° out of phase. It can be seen from the resultant waveforms that the peak voltage is different in each case. The peak voltage of the resultant in Fig. 71A is considerably higher than that of Fig. 71B. Likewise, the average values (to which a VOM responds on its AC-voltage function) are different. On the other hand, the rms values of both waveforms are the same, be-



(A) Fundamental and its third harmonic 180° out of phase.

(B) Fundamental and its third harmonic in phase.

Fig. 71. Phase relationships between the fundamental and third-harmonic frequencies, and their resultants.

cause the power in the fundamental adds arithmetically to the power in the third harmonic. The power in a waveform refers to its energy in a linear circuit, such as a resistive load or speaker. In a linear circuit, the fundamental and the harmonic develop their power independently of each other. The average half-cycle value of a waveform refers to the shape of the rectified wave and is the level in the rectified wave which divides it into equal areas. Since the waveshape depends on the phase of the harmonic, the average value, in turn, changes with phase.

U61

To Measure the Power Input to a Final Amplifier

Equipment: None.

Connections Required: Connect voltmeter test leads from A to B to determine the DC plate current, and then from C to ground to measure the DC plate voltage. (See Fig. 72.)

Procedure: Observe DC voltage readings.

Evaluation of Results: The power input to the final amplifier is given by the product of the DC plate voltage times the DC plate current. It is common practice to determine the plate current by measuring the voltage across a series resistor in

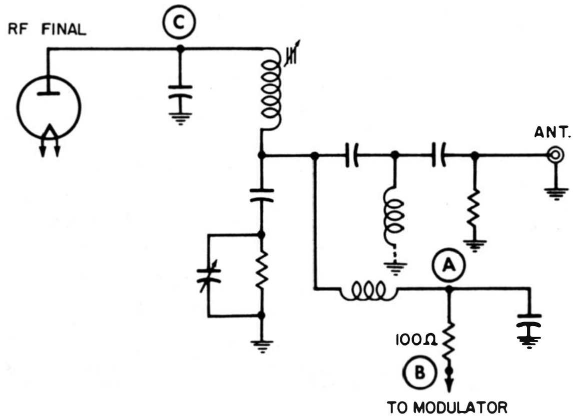


Fig. 72. Measurements of DC voltages from A to B, and at C indicate power input.

the plate-return lead (100 ohms in Fig. 72). If 20 volts is measured from A to B, the current flow is 200 ma by Ohm's law. Note that AM transmitters for use in Class-B or -D Citizens radio stations are limited by FCC regulations to five watts of power input to the final amplifier.

U62

To Determine the Plate Efficiency of an Amplifier Tube

Equipment: Load resistor, if required.

Connections Required: See Fig. 73.

Procedure: Note the DC plate voltage of the tube and the AC-voltage drop across the load resistor with the amplifier driven to its maximum rated output (or to maximum output within a selected limit of percentage distortion). Also measure the DC plate current of the tube.

Evaluation of Results: The AC output power is given by E^2/R, where E is the rms AC voltage across the load resistor. The DC power to the plate is given by E_1I, where E_1 is the DC

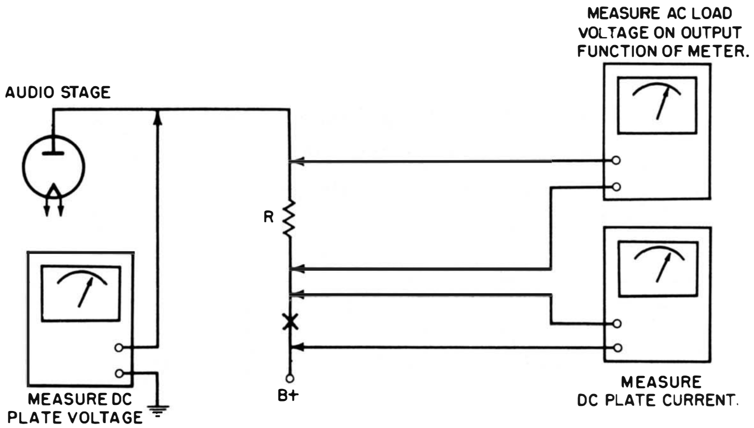


Fig. 73. Checking plate efficiency of an amplifier.

plate voltage, and I is the DC plate current. Use the following formula to determine plate efficiency:

$$\text{Plate Efficiency} = \frac{\text{AC Output Power}}{\text{DC Power to Plate}}$$

The plate efficiency is maximum when the dynamic operating range of the tube is optimum. This requires suitable operating voltages on each of the tube electrodes and varies somewhat from one tube to another because of tolerances. The current in the plate circuit can be determined by measuring the DC-voltage drop across the plate-load resistor and using Ohm's law: $I = E/R$. Also note that the AC-voltage drop across the load resistor must be measured on the *output* function of a VOM, to avoid error from presence of a DC component.

To Measure the Sensitivity of an FM Mobile Receiver

Equipment: Calibrated signal generator. (Dummy load resistor can be used in place of the speaker, if desired.)

Connections Required: Connect equipment as shown in Fig. 74.

Procedure: Disable the squelch circuit, so that it remains open with no input signal. Operate the voltmeter on its AC-voltage function. Note noise-voltage reading. Apply a CW signal at the frequency to which the receiver is tuned and advance the output until the noise voltage drops 20 db.

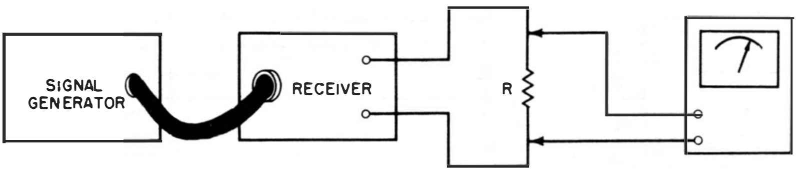


Fig. 74. Measuring the sensitivity of a receiver.

Evaluation of Results: The number of microvolts input which saturates the limiter sufficiently to drop the noise output voltage by 20 db is a measure of receiver sensitivity. Note that most VOM's and VTVM's have db scales which give a direct reading (although it may be necessary to add a range factor). If the meter does not have a db scale, a 20-db drop occurs when the original reading falls to 10%.

U64

To Check the Control Voltage in a Mobile 2-Wire Remote System

Equipment: None.

Connections Required: Connect meter test leads across coil terminals of the line relay (Fig. 75).

Procedure: Operate the meter on its DC-voltage function. With the press-to-talk relay closed, observe meter reading.

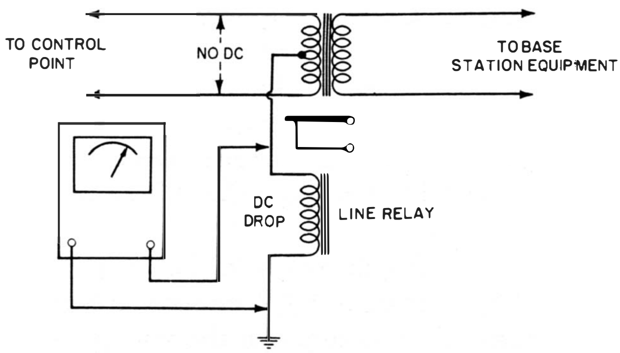


Fig. 75. Control-voltage check at line relay.

Evaluation of Results: If the DC control voltage at the line relay is low or absent, the transmitter will not switch on. If normal control voltage is present, check the voltage across the line-relay coil at the station end of the circuit. A poor ground or spurious ground currents at either end can result in low or no control voltage.

U65

To Check the Dynamotor Unit of a Mobile System

Equipment: Three SPST switches, a storage battery, a fuse of suitable rating, a load resistance to match the output rating of the dynamotor, and a fixed capacitor approximately equal to the filter capacitor used in equipment.

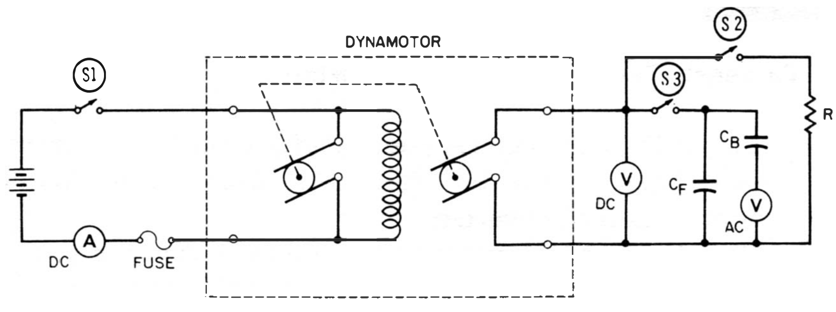


Fig. 76. Test setup for checking a dynamotor.

Connections Required: Connect equipment as in Fig. 76. One VOM can be connected, in turn, into the three test points.

Procedure: First the DC output voltage is measured with S2 open and S1 closed. Next, S2 is closed, and the decrease in voltage noted. Observe also the DC current drawn from the battery while S2 is closed. Finally, note the AC ripple voltage, with S2 closed.

Evaluation of Results: The decrease in DC output voltage when R is switched into the circuit (S2 closed) gives the regulation of the dynamotor. For example, if the voltage decreases from 360 volts to 300 volts, the output-voltage regulation is 20%. The regulation varies with the value of R, which is chosen by Ohm's law to draw the maximum rated current from the dynamotor at its rated output voltage. Resistor R must also be able to dissipate a power equal to the product of this voltage and current. The ripple voltage is measured on the output function of the VOM which provides a built-in blocking capacitor C_B. Capacitor C_F takes the place of the normal filter capacitor in the mobile equipment. The three measurements are compared with specified values in the equipment manual, or with a similar dynamotor in good operating condition. Excessive input current, poor regulation, or high ripple voltage indicate the dynamotor is in need of service. The fuse should not be omitted; it protects both the meter and the dynamotor from possible damage.

U66

To Bench-Test a DC-to-AC Converter

Equipment: A DC bench power supply, a fuse rated for converter current input, and a load resistor to draw normal output current from the converter.

Connections Required: Connect equipment as shown in Fig. 77.

Procedure: Observe the output-voltage variation from the converter as the input voltage from the DC source is varied from

5.75 to 7.5 volts for a 6-volt system, or from 11.5 to 15 volts for a 12-volt system.

Evaluation of Results: The output voltage should not rise above 125 volts, nor drop below 110 volts. In case greater variation occurs, the associated motor-generator, rotary converter, or

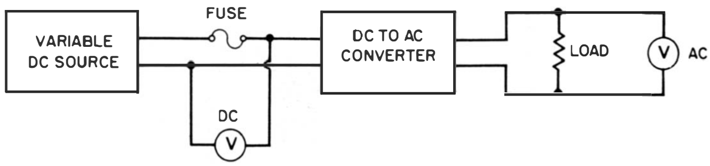


Fig. 77. Test setup for checking a DC-to-AC converter.

vibrator mechanism must be checked. Unlike a vibrator supply, motor generators and rotary converters draw several times their normal input current until they come up to speed. Hence, unless the bench power supply provides adequate starting current, it may be falsely concluded that the rotary unit is defective.

U67

To Check a Regulated Screen-Grid Supply Circuit

Equipment: Audio oscillator.

Connections Required: Connect the audio-oscillator output to the amplifier input. Connect the DC voltmeter from the regulated screen-supply bus to ground (Fig. 78).

Procedure: With zero output from the audio oscillator, observe meter reading. Advance audio oscillator for maximum rated amplifier output and again observe meter reading.

Evaluation of Results: There is normally little variation in screen-grid supply voltage from zero to maximum rated output. In case of much variation, check the front-to-back ratio of the bias rectifier and the values of circuit capacitors and resistors. It is assumed, of course, that the tubes have been checked. The regulation limits of the circuit may be exceeded in case an amplifier defect imposes excessive current demand on the screen supply. In such case, of course, attention is directed to the amplifier components.

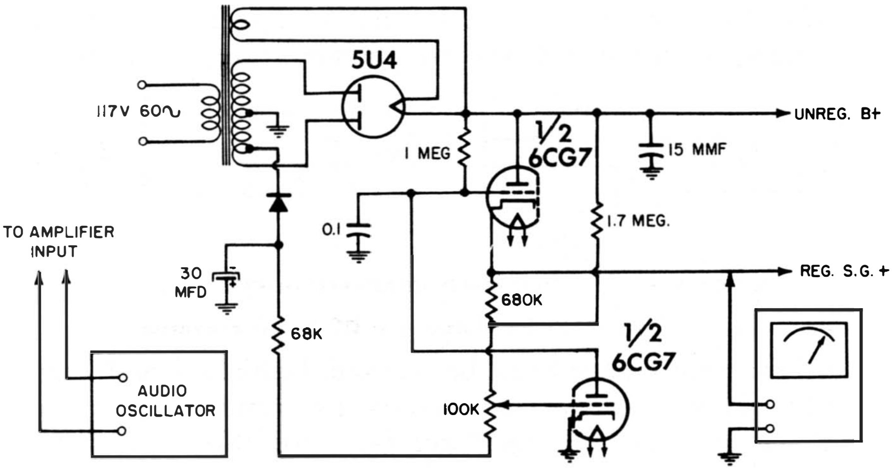


Fig. 78. Typical regulated screen-grid supply.

U68

To Measure the Regulation of a Power Supply

Equipment: None.

Connections Required: Connect VOM (or VTVM) across the power-supply output, as shown in Fig. 79.

Procedure: Operate the meter on its DC-voltage function. First measure the voltage with the load disconnected, then measure the voltage with the load connected.

Evaluation of Results: The regulation is given by the difference between the two voltages, divided by the full-load voltage.

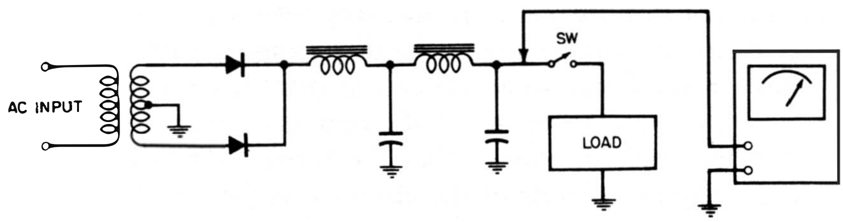


Fig. 79. Checking the regulation of a power supply.

A low percentage regulation means the power-supply voltage changes little as the current demand varies. The regulation is low when the internal resistance of the power supply is low.

U69

To Determine the Internal Resistance of a Power Supply

Equipment: None.

Connections Required: Connect equipment as shown in Fig. 80. The same VOM can be used to make both measurements.

Procedure: Measure the no-load output voltage from the power supply. Next measure the output voltage with the load connected. Measure also the current through the load.

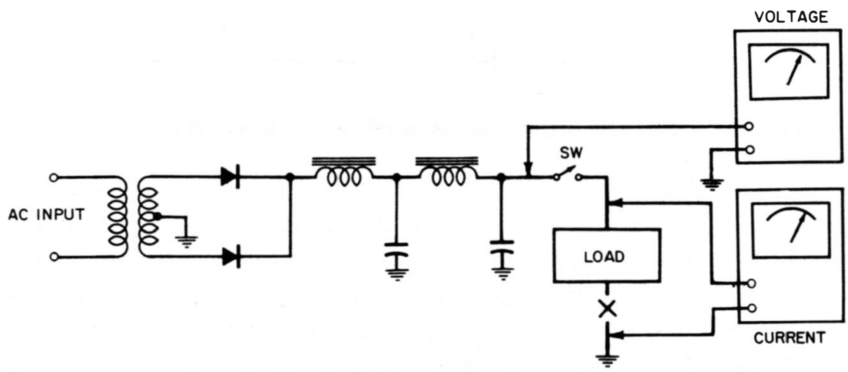


Fig. 80. Determining the internal resistance of a power supply.

Evaluation of Results: The internal resistance of the power supply is determined by Ohm's law. Divide the difference between the two voltage values by the current flow; that is:

$$R = \frac{E_{\text{no load}} - E_{\text{full load}}}{\text{current in amperes}}$$

For example, if 300 volts under no load and 250 volts under a load of 100 milliamperes are measured, the internal resistance of the power supply is 50/0.1, or 500 ohms.

To Check Speaker Lines in a Commercial Sound System

Equipment: Heater transformer.

Connections Required: Disconnect the amplifier from the line input terminal block and connect the 6.3-volt secondary as shown in Fig. 81. Connect the AC voltmeter at suitable points, as shown.

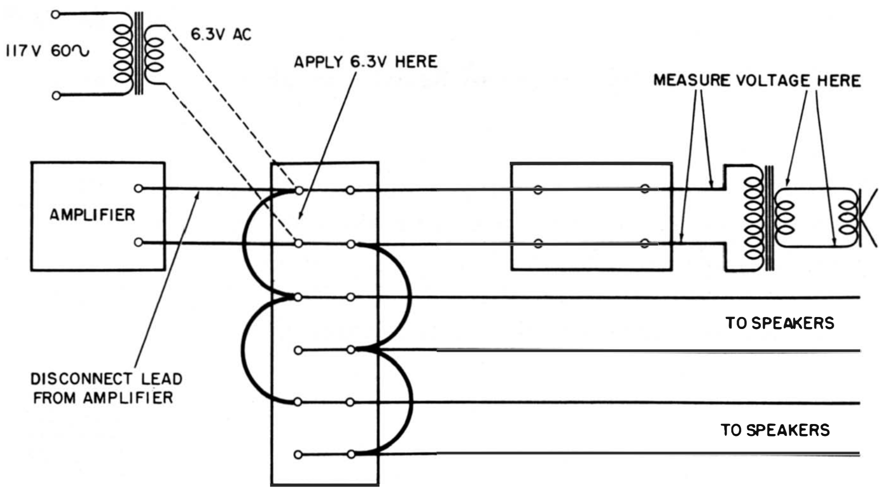


Fig. 81. A 60-cycle signal can be used to check out speaker lines.

Procedure: Observe the scale reading for low or no indication.

Evaluation of Results: This is basically a signal-tracing method to close in on the open circuit, poor contact, or short which is causing the faulty operation. The 6.3-volt source is convenient, because it provides a constant voltage during the testing. Note that low-impedance lines handle correspondingly heavy currents, and hence an appreciably attenuated output from a long line can be expected. For a conductor of a given size, the line attenuation (IR drop) is directly proportional to the load impedance value. Beginners can become confused if they overlook the normal IR drop in a commercial line.

To Check the Grid Drive to a Transmitting Tube

Equipment: None.

Connections Required: Connect voltmeter test leads at the test point in the grid-leak circuit of the transmitter (Fig. 82).

Procedure: Operate the voltmeter on its DC-voltage function and observe scale reading.

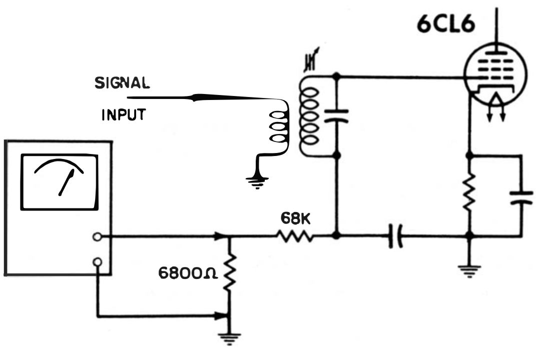


Fig. 82. Checking grid drive to a transmitter tripler.

Evaluation of Results: Compare the voltage reading with the value specified in the transmitter operating manual. If the reading is too low, increase coupling to the grid tank, and vice versa. The grid-cathode circuit operates as a rectifier diode, since the grid normally draws current. For the typical tripler input circuit shown in Fig. 82, using a 6CL6 tube, normal grid drive gives a reading of 0.7 volt DC.

U72

To Check for Feedthrough in a Neutralized RF Amplifier

Equipment: Coupling link, twisted-pair conductor, germanium diode, and .002-mfd bypass capacitor.

Connections Required: Connect equipment as shown in Fig. 83.

Procedure: Unplug the tube from the neutralized stage under test. Operate the driver stage in the normal manner. Couple the link of the RF field indicator to the output tank inductor. Rotate tank tuning capacitor and observe indication on VOM.

Evaluation of Results: Ideally, there should be no feedthrough. In practice, some RF leakage is present, which should be

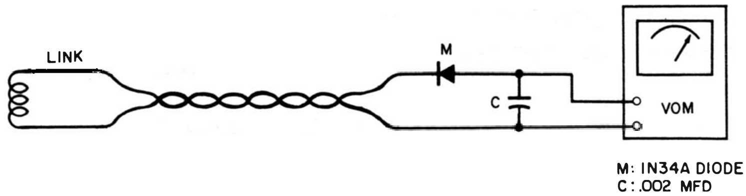


Fig. 83. RF field indicator.

minimized. If leakage is excessive, check bonding of shielding between input and output of the stage. Check condition of RF grounds. Excessive leakage results in operating instability and radiation of spurious frequencies.

U73

To Check the Condition of a Radio "A" or "B" Battery

Equipment: None (or, for out-of-set test, use a battery-tester adapter for the VOM).

Connections Required: Connect VOM test leads across the battery.

Procedure: Operate the VOM on its DC-voltage function. Place battery under normal load (turn the receiver on, or set the adapter to a suitable position).

Evaluation of Results: Note reading on meter scale. A dry radio "A" battery is considered weak when its voltage under normal load drops to 70% of the rated value. A hearing-aid "A" battery is weak when its load voltage drops to 60% of the rated value. A "B" battery is also considered weak when its load voltage drops to 60% of the rated value. Unless the battery is under normal load, the meter reading is practically meaningless. A very weak battery may measure nearly normal when checked with no load.

U74

To Check the Condition of a Storage Battery

Equipment: Charger and hydrometer.

Connections Required: Connect voltmeter test leads, in turn, across each cell of the battery.

Procedure: Note the voltage reading for each cell after the battery has been fully charged. With the hydrometer, observe the specific gravity of the acid solution in each cell.

Evaluation of Results: A normal cell reads 2.1 volts with a specific gravity between 1.28 and 1.30 after it has been fully charged. A voltage reading of 2.2 volts and a specific gravity of 1.23, for example, indicates the battery has lost acid (possibly due to overflowing with distilled water or a leak in the container). For another example, if the specific gravity is normal (1.28 to 1.30 after fully charged) but the cell voltage reads 1.8 volts, it indicates there is too much acid in the cell. Thus, an evaluation of voltage readings against specific-gravity readings gives a meaningful indication of battery condition. The VOM must have good accuracy, since a voltage difference of 0.1 volt is significant. In case the available voltmeter is not sufficiently accurate, comparison measurements can be made against batteries known to be good.

U75

To Check a Storage Battery Under High Load

Equipment: None.

Connections Required: Connect voltmeter test leads, in turn, across each cell of the battery.

Procedure: Measure the voltage of each cell while the starter is cranking the engine. (See Fig. 84.)

Evaluation of Results: The voltage of an individual cell should not be below 1.75 volts during the high-load test. A lower voltage

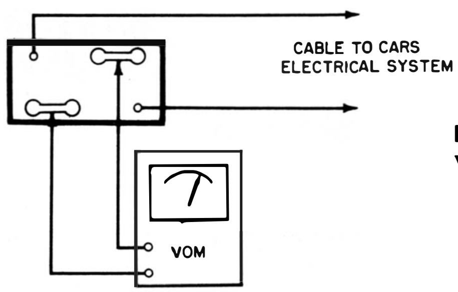


Fig. 84. Battery cells can be checked while engine is cranking.

indicates a defective cell which should be investigated for weak acid solution or other fault. If the battery checks out all right, weak cranking force may be occasioned by a poor contact or defective cable which causes the voltage to drop before it powers the starter motor. Check the voltage across the motor terminals; if proper voltage is maintained here, the brushes or armature require attention.

U76

To Measure the Hot Resistance of a Component

Equipment: Voltage source of a suitable value.

Connections Required: Make connections as shown in Fig. 85. A single VOM can be used for both measurements.

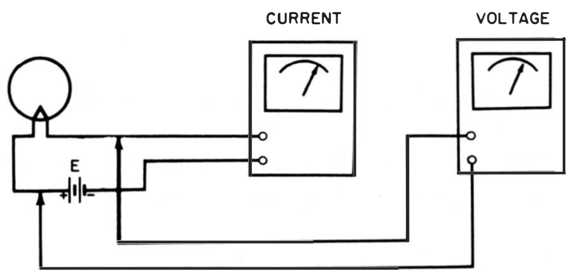


Fig. 85. Determination of hot-resistance value.

Procedure: After the component has warmed up to normal operating temperature, note the current and voltage readings.

Evaluation of Results: The hot resistance is found by using Ohm's law: $R = E/I$. The hot resistance is sometimes much different from the cold resistance. For example, a tube heater having a cold resistance of 3 ohms may show a hot resistance of 24 ohms.

U77

To Check the Globar Resistor in an Intercom Heater String

Equipment: None.

Connections Required: Connect voltmeter test leads across heater terminals of a tube in the series string (typical configuration is shown in Fig. 86).

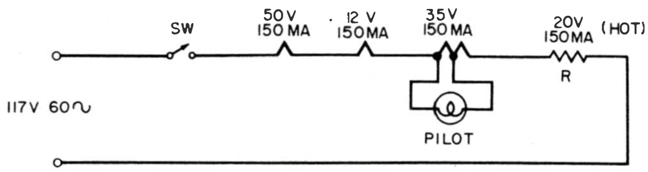


Fig. 86. Globar resistor must be checked hot.

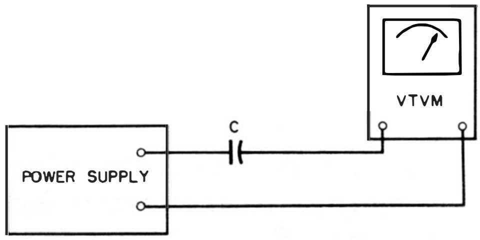
Procedure: Operate the voltmeter on its AC-voltage function. Note scale reading. (Adequate warm-up time must be allowed.)

Evaluation of Results: If the heater voltage is low, an excessive voltage drop across the globar resistor will probably be found. Surge resistors sometimes develop a high "hot" resistance after extended service. To determine the proper "hot" resistance for the resistor in Fig. 86, use Ohm's law, and divide 0.15 amps into 20 volts to obtain a rating of approximately 135 ohms. The cold resistance will be from 8 to 10 times the hot resistance.

To Determine Whether Two Capacitors Are Suitable for Series Connection

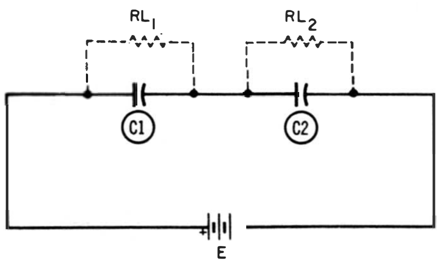
Equipment: Power supply.
Connections Required: Connect equipment as shown in Fig. 87.
Procedure: Operate the VTVM on its DC-voltage function. Advance the output voltage of the power supply to one half the value which will be impressed across the pair of capacitors in their series connection. Observe scale reading. Then repeat the test with the other capacitor to be used in the series connection.

Fig. 87. Test setup.



Evaluation of Results: If the VTVM reads nearly the same on both tests, the two capacitors may be connected in series without possible breakdown. Fig. 88 shows the factors involved. Suppose two 0.25-mfd, 200-volt capacitors in series are to be used to operate as a 0.125-mfd capacitor which will withstand a stress of 400 volts. The method is valid only in case the two capacitors have the same insulation resistance. For example, if R_{L1} is 200 megohms, and R_{L2} is 1000 megohms, the DC-voltage stress across C1 will be 66 volts, and across C2 will be 333 volts, approximately. The likelihood that C2

Fig. 88. If R_{L1} is much lower than R_{L2}, most of E is impressed across C2.



will fail is very great. To insure that such a series connection is valid, check each capacitor at its intended working voltage and get a sensitive test of insulation resistance by feeding the small leakage current into a VTVM, which can be operated on its low ranges to get comparative measurements of high insulation resistances. Note carefully that although DC voltages drop across series capacitors in proportion to their insulation resistances, AC voltages, on the other hand, drop across series capacitors in inverse proportion to their capacitance values. Thus, a small capacitor in series with a large capacitor drops most of the AC voltage.

U79

To Measure the Q of a Tuned Circuit

Equipment: A resistor with value selected for the intended application, a signal generator, and an RF probe for the VTVM.

Connections Required: Connect equipment as shown in Fig. 89.

Procedure: Tune the signal generator for maximum reading on the VTVM and note resonant frequency f_0. Then tune the generator for 0.707 of maximum reading and note frequencies f_1 and f_2.

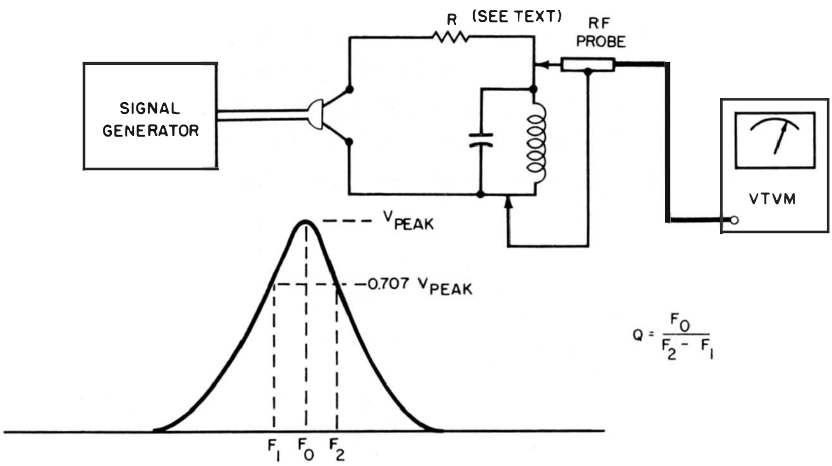


Fig. 89. Test setup for measuring the Q of a tuned circuit.

Evaluation of Results: The Q of the tuned circuit (in combination with source resistance R) is given by $Q = f_0/(f_2 - f_1)$. Choose the value of R to equal the source resistance in the intended application. The source resistance might be the plate resistance of a pentode, the effective resistance of a crystal diode, the output resistance of a transistor, or the internal resistance of another tuned or untuned circuit. Or it might be the characteristic impedance of a transmission line, the coupled impedance of an adjacent coil, or the cathode resistance of a tube. In any case, an accurate measurement of Q requires that the value of R be suitably chosen, because the Q becomes less as R is reduced in value. Thus, the same tuned circuit is more selective when driven from the plate of a pentode, rather than from the plate of a triode. Again, the circuit is more selective when driven from the plate of a triode instead of the collector of a transistor.

U80

To Determine the Approximate Resonant Frequency of a Quartz Crystal

Equipment: Signal generator.
Connections Required: Connect equipment as shown in Fig. 90.
Procedure: Operate the VTVM on its AC-voltage function. Tune the signal generator for maximum deflection on the VTVM.

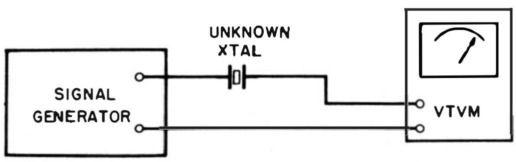


Fig. 90. Determination of the approximate resonant frequency of a quartz crystal.

Evaluation of Results: The frequency indicated on the generator dial is the same as the resonant frequency of the crystal, within the accuracy of the generator.

To Measure the Negative Resistance of a Crystal Diode

Equipment: DC voltmeter and DC milliammeter (the same VOM may be used, though it is less convenient), variable power supply, 1-ma fuse, and a 50K resistor.

Connections Required: Connect equipment as shown in Fig. 91.

Procedure: Advance output from the variable power supply until the reading of the DC voltmeter starts to fall. Note reading of milliammeter. Then advance the output from the power supply in several small steps, noting the current flow for each voltage step.

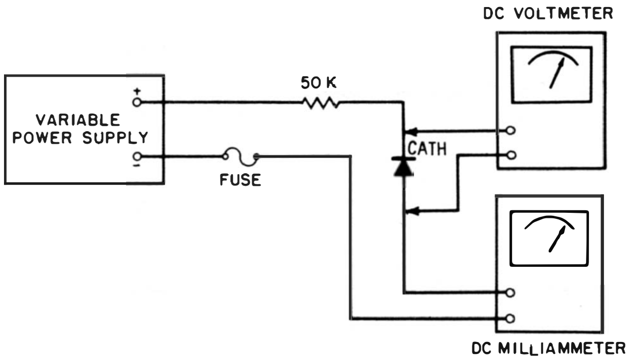


Fig. 91. Test setup to measure negative resistance.

Evaluation of Results: When the voltage across the crystal diode starts to fall (at about 80 or 90 volts for a 1N34, for example), the negative-resistance region of the diode characteristic is reached. As the power-supply voltage is further increased, the current flow in the circuit increases, but the voltage drop across the diode decreases. Or less voltage across the diode causes more current to flow through it. This is the definition of negative resistance. The amount of negative resistance is found from Ohm's law. Thus,

$$\frac{\text{Decrease in volts across diode}}{\text{Increase in amps through diode}} = -\text{R in ohms}$$

Note: Be sure to convert the milliampere reading to ampere units. Do not run the diode very far into its negative-resistance region, or it will be destroyed by the heat generated internally.

To Check the Characteristic of a Ballast Resistor

Equipment: A variable power supply, a DC voltmeter, and a DC ammeter (the same VOM may be used, although it is less convenient).

Connections Required: Connect equipment as shown in Fig. 92.

Procedure: Advance output voltage from power supply until the current starts to "level off." Then increase output voltage in steps, noting the small current increase at each step. (Do not exceed the maximum rated current of the ballast resistor.)

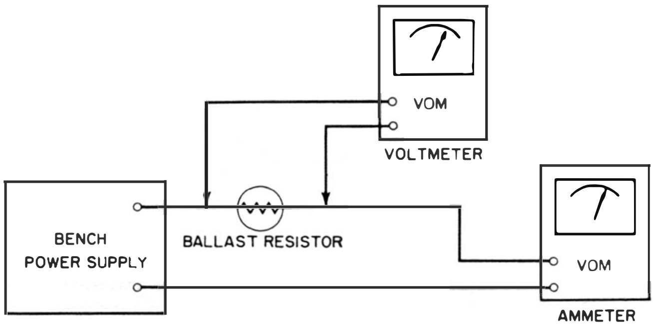


Fig. 92. Test setup for checking the characteristic of a ballast resistor.

Evaluation of Results: An ideal ballast resistor would keep the current flow entirely constant over its rated operating range, but in practice constant current flow is only approximated. If sufficient voltage is available, two ballast resistors can be connected in series to improve the regulation. A ballast resistance is wound with a special alloy wire that increases in resistance as its temperature increases.

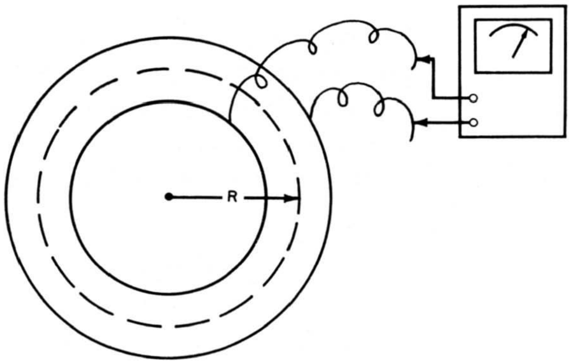
U83

To Find the Number of Turns in a Coil

Equipment: Machinist's rule with wire gauge.

Connections Required: Connect ohmmeter to coil terminals. (See Fig. 93.)

Procedure: Observe the resistance of the winding. Use the rule to measure the gauge of the wire and the mean radius of the coil.



Size B&S Gauge	Diameter in Mils	Resistance (Ohms) per 1000 feet at 60° F.
26	15.94	40.75
25	17.90	32.21
24	20.10	25.60
23	22.57	20.30
22	25.35	16.12
21	28.46	12.78
20	31.96	10.14
19	35.89	8.04

Fig. 93. To find the number of turns in a coil.

Evaluation of Results: Determine the mean circumference by multiplying the mean radius times 2 pi. From the resistance table in Fig. 93, determine the resistance of a turn having a length equal to the mean circumference. Finally, divide the resistance of one turn into the resistance of the winding to determine the number of turns in the coil. Note that 1 mil = .001 inch.

To Check the Phase of a Transformer

Equipment: None.

Connections Required: Connect the VOM in series with one secondary lead, as shown in Fig. 94.

Procedure: Operate the VOM on a suitable AC-voltage range, having a top reading of at least double the secondary voltage of one transformer.

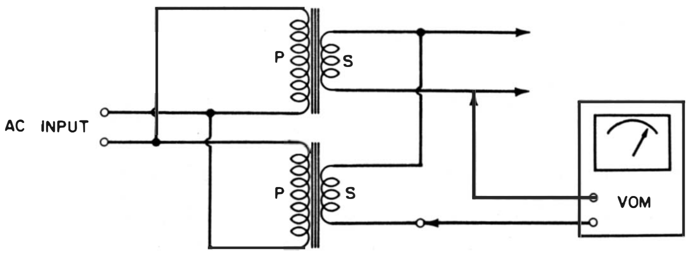


Fig. 94. Checking transformer phase for safe parallel connection of the windings.

Evaluation of Results: If the meter reading is zero, or very nearly zero, the phase is correct for parallel operation. If the meter reading is double the voltage of one secondary output, the leads from one transformer must be reversed. If the two secondaries do not have the same voltage output (within fairly close limits), a wasteful local current will flow in the windings even when correctly phased. Both transformers should have similar construction, so that their load drops (regulation) will be equal. Otherwise, an unsuspected and even damaging local current can appear in the windings when substantial current is drawn from the paralleled secondaries.

U85

To Check the Polarity Markings on a Transformer

Equipment: None.

Connections Required: Make test connections as shown in Fig. 95.

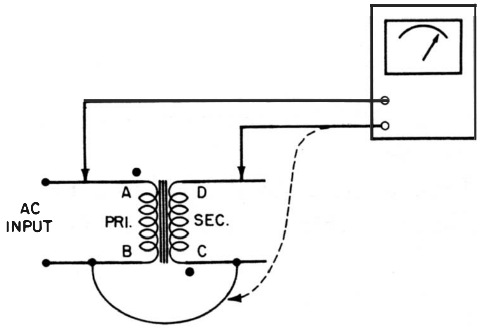


Fig. 95. Checking polarity markings on AC devices.

Procedure: Measure the AC voltage from A to D, then from A to C.

Evaluation of Results: If the voltage reading from A to D is greater than the reading from A to C, the polarity markings are correct as shown. (The meaning of polarity markings on AC devices is shown in Fig. 96.) Electron flow into the

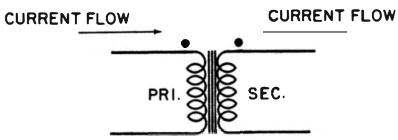


Fig. 96. Meaning of polarity markings on AC devices.

marked terminal of the primary causes electron flow out of the marked terminal of the secondary. In other words, polarity markings establish relative AC phases.

U86

To Determine the Consistency of Polarity Markings

Equipment: None.

Connections Required: Make test connections as shown in Fig. 97.

Procedure: Observe voltmeter reading.

Evaluation of Results: If the meter reading is zero, the polarity markings on the unknown are consistent with the polarity

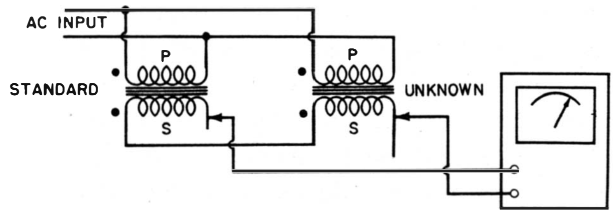


Fig. 97. Determining consistency of polarity markings.

markings on the standard. However, in case a double-output reading occurs, the polarity markings on the unknown are inconsistent and should be transferred to the other primary and secondary leads.

U87

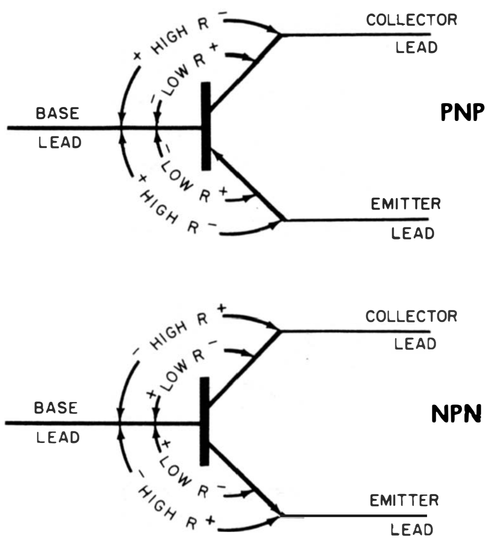
To Make an Ohmmeter Test of a Low-Power Transistor

Equipment: None.

Connections Required: Connect ohmmeter leads to obtain the resistance readings indicated in Fig. 98.

Procedure: Note the resistance readings in each test. If possible, use the same ohmmeter range for each test.

Fig. 98. Comparative ohmmeter readings for low-power PNP and NPN transistors.



Evaluation of Results: Comparatively high and low readings should be observed, as noted in Fig. 98. If both forward and back resistance values are low in either the collector or the emitter test, the transistor is shorted and should be discarded. If both forward and back resistance values are high, the transistor is open and should be discarded. The forward-back resistance ratios for good transistors range from 25-to-1 up to 100-to-1, depending on the transistor brand and the type of ohmmeter used. Forward resistances are typically less than 500 ohms, and back resistances are from 10K to 50K, or sometimes much higher, depending on the ohmmeter range and battery voltage in the instrument. If both forward and back resistances measure about equal medium-resistance values, the transistor is defective. To avoid possible damage to a transistor, use an ohmmeter with a comparatively low battery voltage and try to avoid using the R × 1 range.

U88

To Make an Ohmmeter Test of a High-Power Transistor

Equipment: None.
Connections Required: See Fig. 99.
Procedure: Note the six resistance readings depicted in Fig. 99.

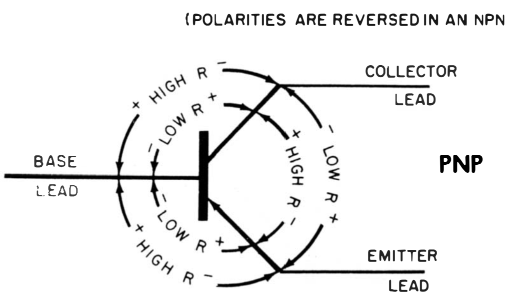


Fig. 99. Comparative ohmmeter readings for high-power PNP and NPN transistors.

Evaluation of Results: The data are evaluated in the same general manner as described in U90, except that an additional pair of resistance measurements is made between collector and emitter. In case a small front-to-back ratio is found between collector and emitter in a power transistor, reject the unit.

U89

To Test a Phototube With an Ohmmeter

Equipment: None.

Connections Required: Connect meter test leads to the phototube terminals with the positive ohmmeter lead to the anode. (Fig. 100.)

Procedure: Operate the ohmmeter on its highest resistance range. Shine a light beam into the phototube. Do not exceed the light level specified in the tube data. Note meter reading.

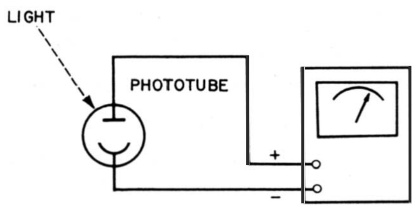


Fig. 100. Testing a phototube.

Evaluation of Results: A phototube does not convert light energy into electricity, but develops a finite plate resistance when exposed to light. This plate resistance can be measured with an ohmmeter, which, incidentally, applies an accelerating voltage between cathode and anode. Since the applied voltage is comparatively low, the normal plate resistance may not be available in tube data and it may be necessary to make a comparison test against a good tube of the same type.

U90

To Test the Condition of a Photovoltaic Cell

Equipment: None.

Connections Required: Connect VOM test lead to cell terminals. (Fig. 101.)

Procedure: Operate the VOM on its DC function. Shine a strong light beam, such as sunlight, into the face of the cell. Note meter reading.

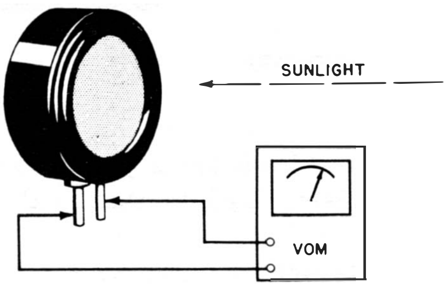


Fig. 101. Testing the condition of a photovoltaic cell.

Evaluation of Results: A photovoltaic cell generates electricity by converting light energy into electrical energy. Hence, no external voltage source is required for the test. Various brands of cells have different outputs, and the manufacturer's specifications should be checked in case of doubt. A typical cell has an output of 750 microamperes (.75 milliampere) when energized by direct sunlight.

U91

To Measure the High-Frequency Voltage Drop Across a Coupling Capacitor

Equipment: High-frequency probe for the VTVM.

Connections Required: See Fig. 102.

Procedure: Measure the high-frequency voltage at the input end of capacitor C, then repeat the measurement at the output end of the capacitor.

Evaluation of Results: Subtract the two readings. The difference is the IX drop across the coupling capacitor. Note that it is necessary to make a pair of measurements, because both ends

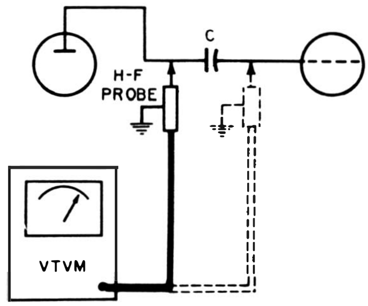


Fig. 102. Measuring the high-frequency voltage drop developed across a coupling capacitor.

of the capacitor are above AC ground. The ground terminal of the VTVM has appreciable input capacitance (typically 250 mmf) which will often load an above-ground point excessively.

MISCELLANEOUS TESTS

U92

To Measure the Average Value of a Pulsating DC Voltage

Equipment: None.

Connections Required: Connect VOM across a circuit component carrying the pulsating DC component. (For an example, see Fig. 103.)

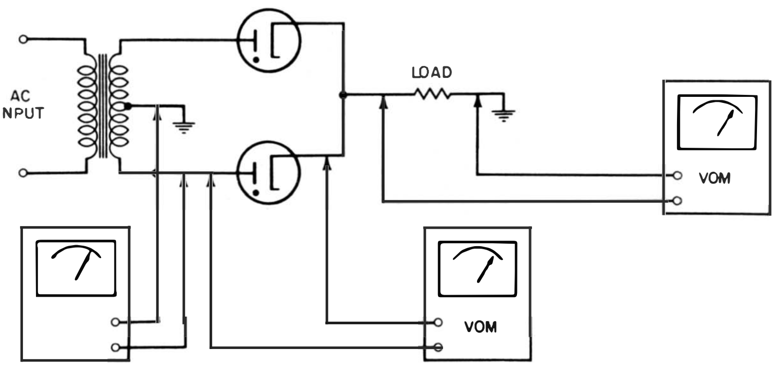


Fig. 103. Measurement of average DC voltages.

Procedure: Operate the VOM on its DC-voltage function. Note scale reading.

Evaluation of Results: The meter reading is the average DC drop across the component. The AC component is canceled by the meter movement. The sum of the average DC voltages around any complete circuit is equal to zero, by Kirchhoff's law. This fact is useful in case the terminals for one of the components in an electronic device are inaccessible. The voltage drop across the inaccessible component can be calculated by making use of Kirchhoff's law. A simple example is shown in Fig. 104. A battery has an internal resistance R_{in} associated with its electromotive force E. For all practical purposes, the value of E is obtained by measuring the open-circuit voltage of the battery with a 20,000 ohms-per-volt meter. Next, when load resistor R is connected across the battery, a lower load voltage reading is obtained. Where has the difference voltage

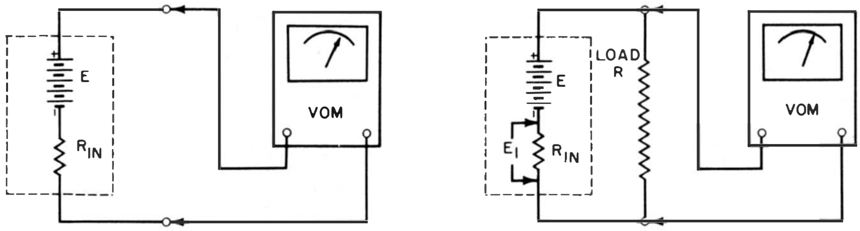


Fig. 104. Kirchhoff's law gives the internal voltage drop, E_I.

disappeared to? It is the voltage E_I dropped across the battery's internal resistance. Or, by Kirchhoff's law, $E_I = E - E_{load}$.

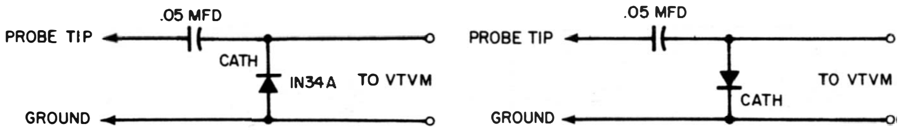
NOTE 19

Average Value of a Pulsating DC Voltage Does Not Indicate Power in the Load

When working with a steady DC voltage which is dropped across a load, the value of power can be found by multiplying this steady DC voltage by the current through the load. On the other hand, if a pulsating DC voltage is being dropped across the load, a multiplication of average voltage times the current does not, in general, give the true value of the power. In order to use the voltmeter-ammeter method of determining power, it is necessary to use instruments having square-law response. Square-law instruments are commonly used only in laboratories. Unless the load is resistive, even square-law measurements of voltage and current values do not give the true power directly, because of the power factor. To measure true power in a load when the voltage is pulsating DC, as well as when the pulsating DC is applied to reactive loads, an electro-dynamic wattmeter is usually preferable. Such wattmeters designed for use in service applications are not unduly expensive.

To Find the Crest and Trough Values of a Pulsating DC Voltage

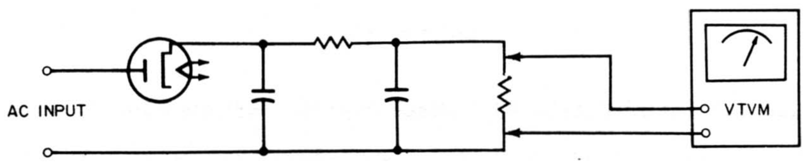
Equipment: Half-wave rectifier probes, one with positive response and one with negative response. (See Fig. 105.)



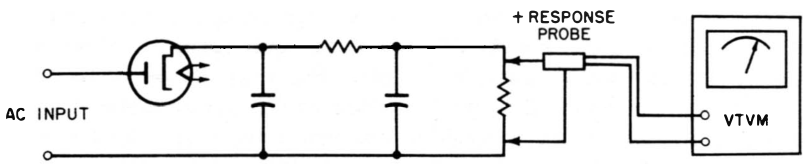
(A) Positive-response probe. (B) Negative-response probe.

Fig. 105. Half-wave rectifier probes.

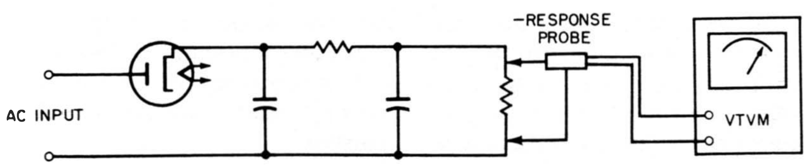
Connections Required: Connect the probes, in turn, to the VTVM and apply across the source of pulsating DC voltage (Fig. 106). Also connect the regular DC probe to the VTVM and make a DC voltage measurement across the pulsating DC source, as in Fig. 106.



(A) Measure DC voltage.



(B) Measure AC voltage with positive-response probe.



(C) Measure AC voltage with negative-response probe.

Fig. 106. Finding the crest and trough values of a pulsating DC voltage.

Procedure: Note voltage readings with all three probes, using the DC-voltage function of the VTVM.

Evaluation of Results: The crest value is given by the sum of the DC-probe and positive-rectifier probe readings. The trough value is given by the difference between the DC-probe and negative-rectifier probe readings. The DC-probe reading by itself is, of course, the average value of the pulsating DC voltage. This is easily understood by reference to Fig. 107. A pulsating DC voltage is one which does not cross the zero-volt level, and has a DC component (its average value) with

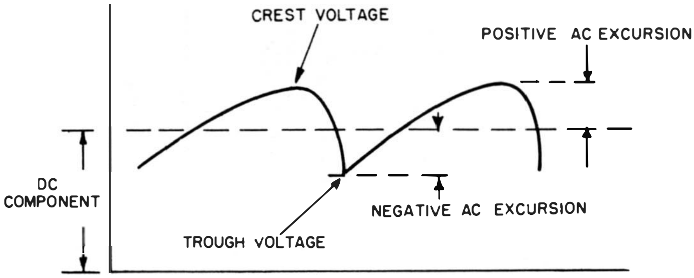


Fig. 107. Pulsating DC voltage, with principal values.

a superimposed AC voltage. The AC voltage may be a complex wave or a sine wave. Troughs may or may not touch the zero-volt line. However, with a pulsating DC voltage, the trough never crosses the zero-volt line. If a trough does cross the zero-volt level, an AC voltage that may or may not have a DC component is present.

U94

To Find the Phase Angle Between Two AC Voltages

Equipment: Audio oscillator.

Connection Required: Connect VOM to measure each phase voltage by itself, and then to measure the sum of the phase voltages, as in Fig. 108.

Procedure: The amplifier must be energized. Note each phase voltage and the sum of the phase voltages.

Evaluation of Results: Represent each voltage by a line length, and combine the lines into a triangle, as shown in Fig. 108. The angles of the triangle show the phase angles between the voltages. Note carefully that the phase angle θ between V_1 and V_2 is customarily specified by the projection of the line for V_1, as shown. In other words, the phase angle is greater than 90° but less than 180°. The phase angle between V_1 and V_2 changes with frequency, and changes faster at very

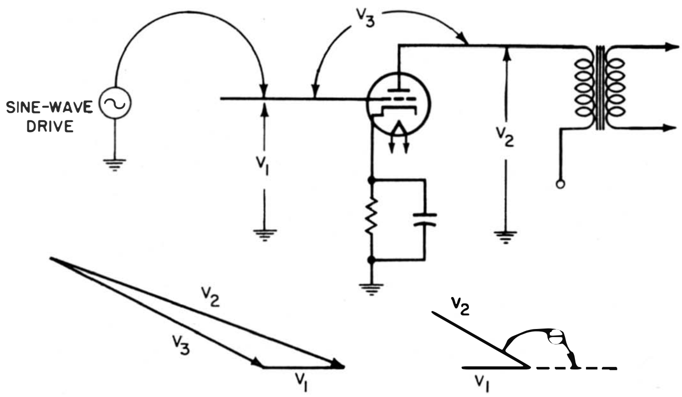


Fig. 108. Finding the phase angle between two AC voltages.

low and at very high frequencies. This is a consideration of great importance when troubleshooting negative-feedback amplifiers. Ideally, the feedback circuits should operate to apply a voltage from the output to the input of the amplifier which is exactly 180° out of phase at any frequency within the response limits of the amplifier.

U95

To Measure the Phase and Line Voltages in a Three-Phase System

Equipment: None.

Connections Required: Connect the VOM test leads across one winding of a star to measure the phase voltage. Connect the test leads across one pair of lines to measure the line voltage. (See Fig. 109.)

Procedure: Operate the VOM on its AC-voltage function. Note each of the three phase-voltage readings and each of the three line-voltage readings.

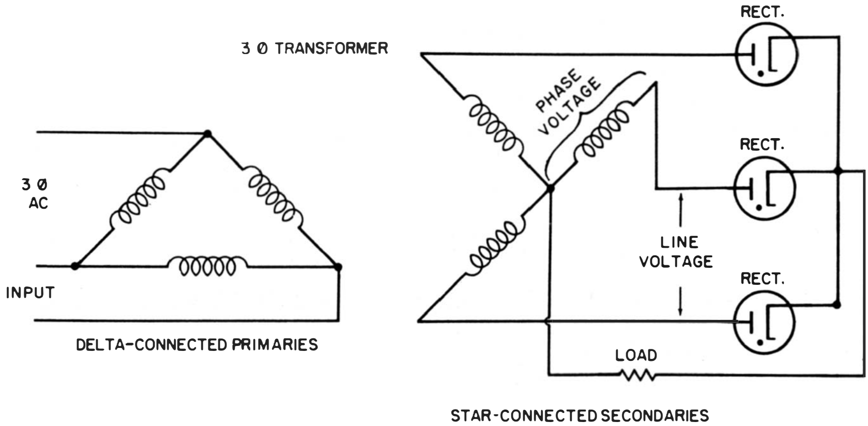


Fig. 109. Points of phase- and line-voltage measurements.

Evaluation of Results: If any one of the phase or line voltages is zero, there is an open circuit in the associated winding of the transformer. The three phase voltages (and the three line voltages) are about equal in normal operation. Each line voltage is normally 1.73 times the phase voltage. If any of the voltages are low, there is an abnormal load on the associated phase. For example, there could be shorted turns

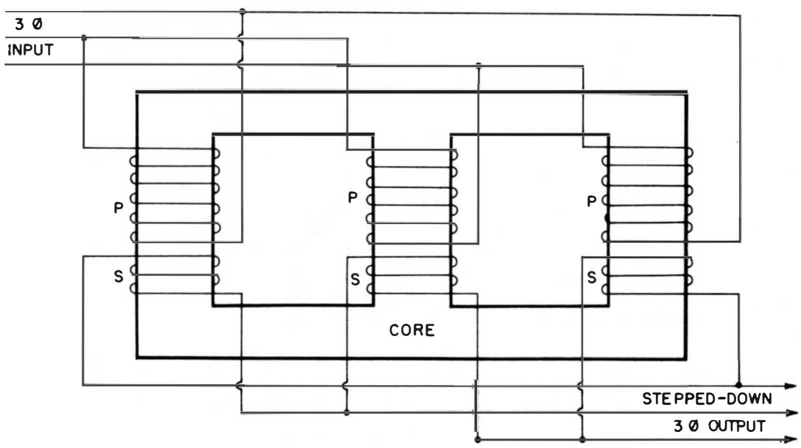


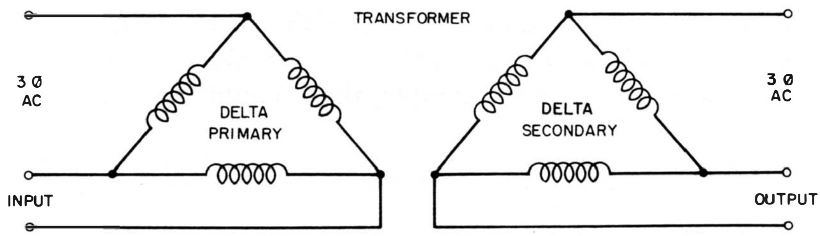
Fig. 110. Plan of a three-phase transformer.

in a phase winding, or a fault in a branch of the load circuit. Phase voltage is also called a star voltage. In the case of a delta connection, of course, we can check only the line voltages; the voltages across the individual coils are necessarily the same as the line voltage. Any line voltage in a three-phase system is a single-phase voltage, and is often so used to power single-phase utilization devices. Approximately 85% of all motors used in industry are three-phase motors. (See Fig. 110 for the plan of a three-phase transformer.)

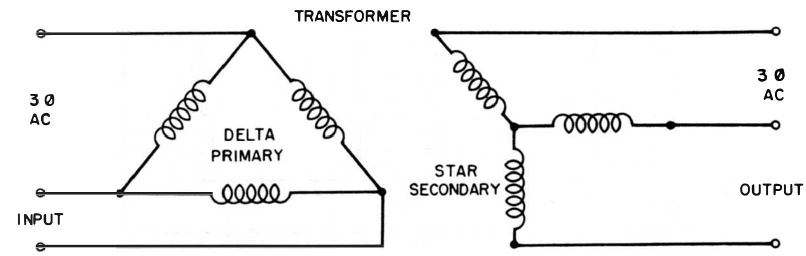
NOTE 20

Transformer Secondary Voltage Changed from Delta to Star Connection

The line voltage and the phase voltage are the same for a delta-connected three-phase winding; but for a star-connected three-phase winding the line voltage is 1.73 times greater than the phase voltage. Fig. 111 shows a transformer with primary and secondary both delta-connected. If we change the secondary to a star connection, the output voltage becomes 1.73 times greater. Fig. 112 shows that if a delta-delta transformer is reconnected to a star-delta configuration, the output voltage drops to 0.58 of the first value. Three-phase industrial equipment is sometimes provided with switches to provide a choice of star or delta connections.

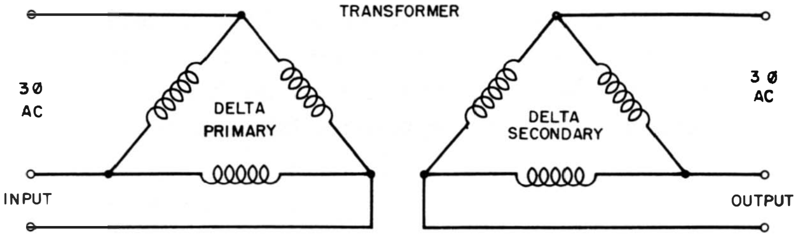


(A) Delta-connected primary and secondary.

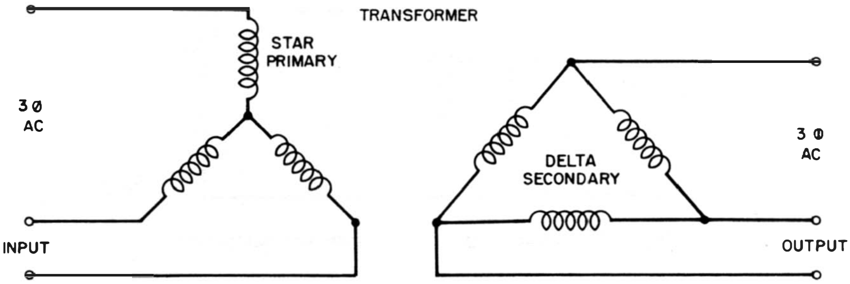


(B) Delta-connected primary; star-connected secondary.

Fig. 111. Changing primary connections from delta to star lowers the output line voltage to 0.58 of its initial value.



(A) Delta-connected primary and secondary.



(B) Star-connected primary; delta-connected secondary.

Fig. 112. Changing secondary connections from delta to star raises output line voltage 1.73 times.

U96

To Check the Line Voltage for Harmonics

Equipment: Three fixed capacitors and three resistors. (See Fig. 113.)

Connections Required: Connect capacitors and resistors into a parallel-T network, as shown. Connect input of the network to the line, the output to the meter.

Procedure: Operate the voltmeter on its AC-voltage function. Switch to the low range and observe scale reading, if any.

Evaluation of Results: If there are no harmonics in the line voltage, the voltmeter will read zero, even on its lowest range. The network must be constructed accurately, or some of the 60-cycle fundamental will get through. Since the values are somewhat critical, it is often advisable to use two potentiometers in place of R_0 and R_1. Thus, if C_1 and C_2 are 0.25 mfd, and R_2 is 15K, 25K pots can be used for R_0 and R_1. Adjust the two pots for minimum or zero reading on the meter, as the case may be. If a zero reading cannot be obtained, there are harmonics in the line voltage. Sometimes there is inter-

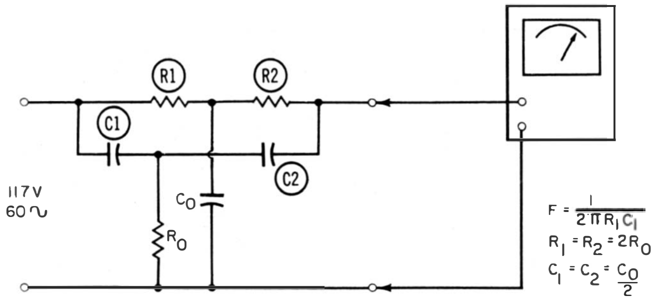


Fig. 113. Checking line voltage for harmonics.

ference on the line, which is not a harmonic of 60 cycles. In such case, the interference voltage is also indicated on the meter.

U97

To Check an Insect Electrocuter

Equipment: None.

Connections Required: Connect VTVM leads across the grid-screen terminals as shown in Fig. 114.

Procedure: Operate the VTVM on its AC-voltage function. Observe meter reading.

Evaluation of Results: The meter reading should be approximately 600 volts. If low or no voltage is measured, check the grid screen for shorts (or excessive leakage resistance). In case the grid screen is functioning properly, check the limiting resistance for an open or excessively high value. The transformer secondary can become open if it has been dead shorted for any reason. Note: Fluorescent lamp tests are described elsewhere in this book.

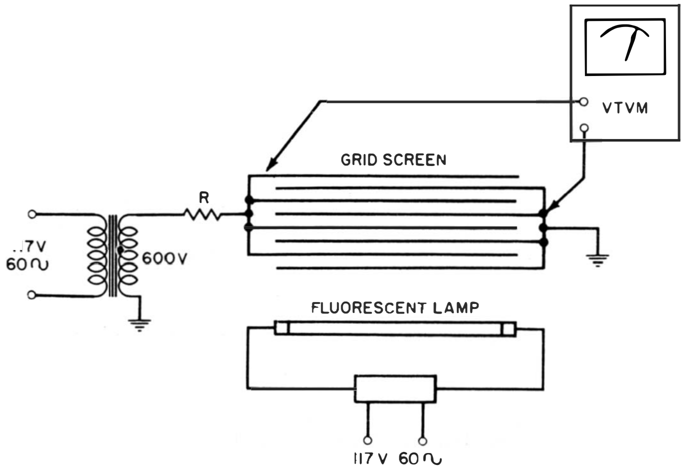


Fig. 114. Typical hookup for an insect electrocuter.

U98

To Check a Fuel-Gauge System

Equipment: None.

Connections Required: Connect the DC voltmeter, in turn, to points A, B, C, and D, as shown in Fig. 115.

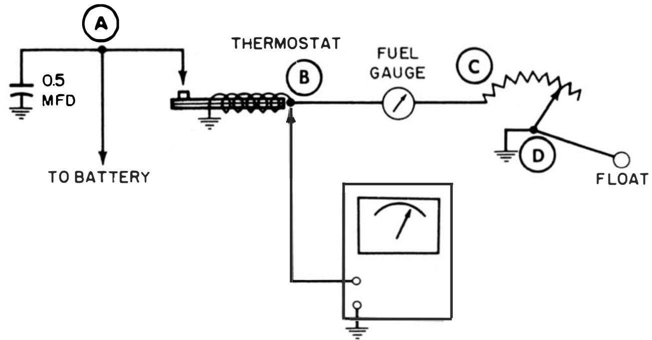


Fig. 115. Typical fuel-gauge hookup.

Procedure: Operate the VOM on its DC-voltage function. Observe readings as the test lead is moved from point A to D.

Evaluation of Results: A progressive drop in voltage from 6 (or 12) volts to zero is normally found. This procedure of voltage tracing will indicate whether the trouble is in the supply voltage, the thermostat, fuel-gauge meter, sensing resistor, or circuit connections.

U99

To Check a Capacitance Proximity-Type Burglar Alarm

Equipment: None.

Connections Required: Connect the VTVM test leads between grid and ground of the oscillator tube, as shown in Fig. 116. Connect the leads next from grid to ground of the control tube.

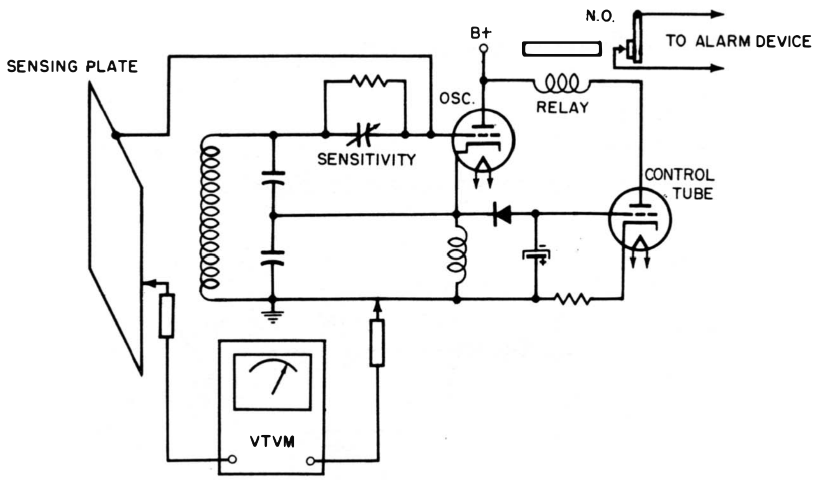


Fig. 116. Test setup of a proximity-type burglar alarm.

Procedure: Operate the VTVM on its DC-voltage function. Observe scale reading.

Evaluation of Results: If the RF oscillator is operating, a negative voltage appears between the grid terminal and ground. If the B+ voltage falls slightly below a critical value, the oscillator will stop abruptly. The control tube normally has a high negative bias on its grid, which cuts the tube off unless the oscillator stops (normally due to approach of an object near the sensing plate). If the control-tube bias is low or zero, check the rectifier diode.

U100

To Check the Output Voltage of a Photoelectric Burglar Alarm

Equipment: None.

Connections Required: Connect voltmeter test leads across relay winding terminals, as shown in Fig. 117.

Procedure: Operate the voltmeter on its AC-voltage function. Place your hand in front of the photocell to interrupt the light beam. Note change in meter reading.

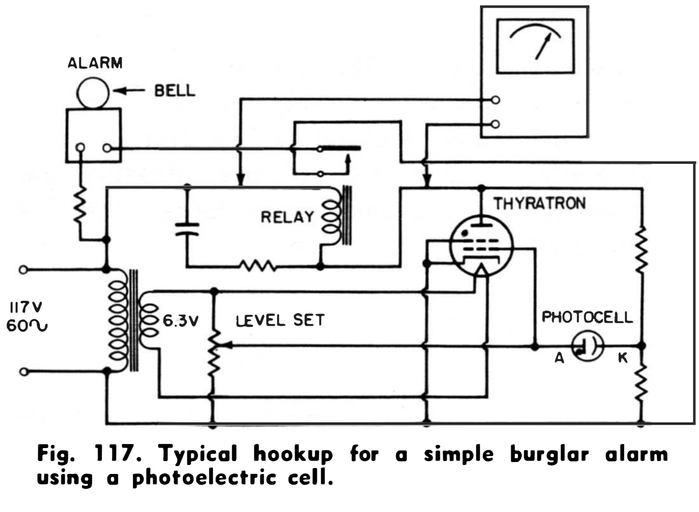


Fig. 117. Typical hookup for a simple burglar alarm using a photoelectric cell.

Evaluation of Results: The meter should indicate a very small voltage drop across the relay coil while light is entering the photocell. If the reading is high, look for an open circuit in the relay winding. When the photocell light is blocked, the meter should read practically full line voltage. If the voltage drop is considerably less than line voltage, check the thyratron tube. If there is no response when the light beam is interrupted, check the photocell (see U89). The level-set control is normally advanced somewhat past the point at which the relay drops out when light is admitted to the photocell. As a result, the AC voltage from the level control (which is 180° out of phase with the anode voltage) drives the grid of the thyratron sufficiently negative to prevent firing. Next, when the light beam to the photocell is interrupted, the negative DC bias previously supplied to the grid falls to zero, and the level-control voltage peaks now extend past the conduction level. The thyratron conducts and actuates the relay. The relay is sometimes a lock-in type, which continues to ring the alarm until manually tripped.

U101

To Measure the Impedance of a Pair of Earphones

Equipment: Audio oscillator; 1K resistor.

Connections Required: Connect equipment as shown in Fig. 118.

Procedure: Set the audio oscillator to 1 kc and advance the output for average sound from phones. Measure the voltage drop across the phones, then across the resistor. Operate the VOM on its AC-voltage function.

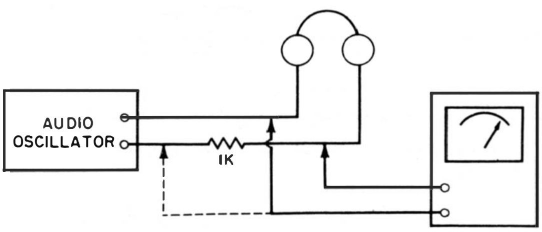


Fig. 118. Measuring earphone impedance.

Evaluation of Results: The AC impedance of the phones will be considerably higher than the DC resistance. The AC impedance is the actual load imposed by the phones in a receiving circuit. The AC impedance is given by Ohm's law (I = E/Z), where I is the current flowing through the phones and E is the voltage across the phones. Measure the voltage across the phones directly. Determine the current indirectly, by measuring the voltage across the 1K resistor and using Ohm's law—I = E/1000. Remember that I is given in amperes by the formula, and a milliampere is .001 ampere. Knowing I in amperes, Z = E/I. Note that the measured impedance will vary with frequency; 1000 cycles is standard for this test. In case the phones have very high impedance and it becomes difficult to measure the voltage drop across the 1K resistor, use a 10K resistor instead. A precision resistor gives the most accurate measurement.

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101 MORE ways to use your VOM and VTVM

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