# PHASE 3
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# UNIVERSAL TECHNICAL INSTITUTE

## PHASE 3 - AUTOMOTIVE ELECTRICITY

## LIST OF LAB PROJECTS

STUDENT'S NAME______________________

INSTRUCTOR______________________

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | TEST BATTERY WITH HYDROMETER. |
| | | | | | | | | PERFORM LOAD TEST ON BATTERY. |
| | | | | | | | | TEST BATTERY WITH SUN TESTERS. |
| | | | | | | | | CLEAN AND SERVICE BATTERY. |
| | | | | | | | | BUILD AN ELECTRICAL CIRCUIT. |
| | | | | | | | | DIAGNOSE AND REPAIR AN ELECTRICAL CIRCUIT. |
| | | | | | | | | USE AMMETER TO TEST CURRENT FLOW. |
| | | | | | | | | USE OHMMETER TO TEST RESISTANCE. |
| | | | | | | | | USE VOLTMETER TO PERFORM VOLTAGE DROP TESTS. |
| | | | | | | | | TEST ELECTRICAL INSTRUMENT GAUGE CIRCUIT. |
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| | | | | | | | | DIAGNOSE AND REBUILD A STARTER. |
| | | | | | | | | DIAGNOSE AND REBUILD A STARTER SOLENOID. |
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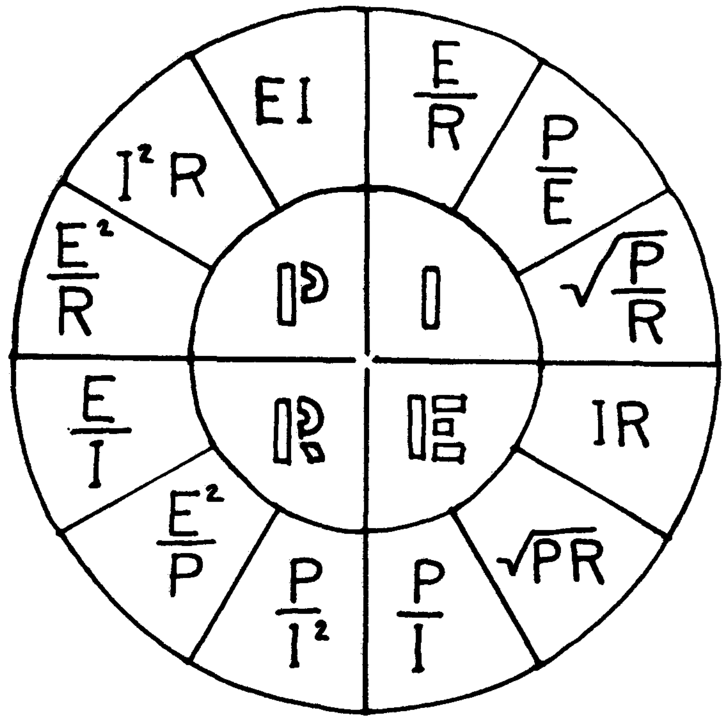
# OHM'S LAW CHART




EVER WONDER HOW MUCH POWER FLOWS THROUGH YOUR TV, AIR CONDITIONER, OR RADIAL-ARM SAW? OR WHAT THE TOTAL POWER LOAD MIGHT BE IF EVERY APPLIANCE AND LIGHT WERE TURNED ON IN YOUR HOME AT THE SAME TIME?

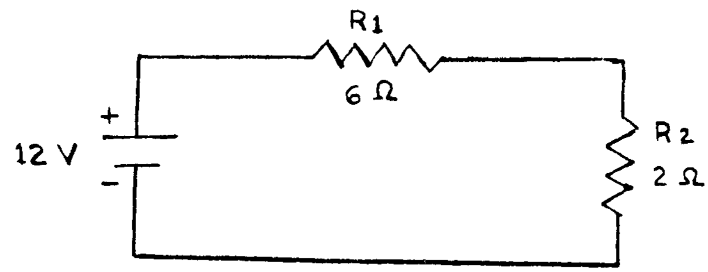
YOU CAN FIND OUT BY USING THE OHM'S LAW CHART ABOVE. IN IT, I STANDS FOR AMPS (INTENSITY), E FOR VOLTS (ELECTROMOTIVE FORCE), R FOR OHMS (RESISTANCE) AND P FOR WATTS (POWER). THUS IT'S EASY TO COMPUTE ANY OF THESE FOUR VALUES BY OHM'S LAW IF YOU KNOW AT LEAST <u>TWO</u> OF THEM. FOR EXAMPLE: YOU BUY A NEW TOASTER RATED AT 1100 WATTS. YOU WANT TO FIND OUT HOW MUCH CURRENT IT USES. USE THE AMPERES SECTION OF THE CHART AND PICK OUT THE FORMULA THAT USES THE TWO ELEMENTS YOU KNOW--WATTAGE (1100) AND VOLTAGE (115). SUBSTITUTING IN THE FORMULA I=P/E YOU GET I=1100/115 OR I=9.5 AMPS. WHERE YOU WANT TO FIND POWER, USE THE WATTS SECTION OF THE CHART AND PICK THE TWO ELEMENTS YOU KNOW, P=E x I.

EVERY ELECTRICAL DEVICE HAS A CLUE TO ITS RATED POWER ON IT. IT IS GIVEN IN WATTS, AMPERES OR HORSEPOWER (1 HP=746 WATTS). USE THE APPROPRIATE FORMULA AND YOU CAN FIGURE THE ELECTRICAL LOAD AT ANY POINT IN YOUR SERVICE.

## OHMS LAW

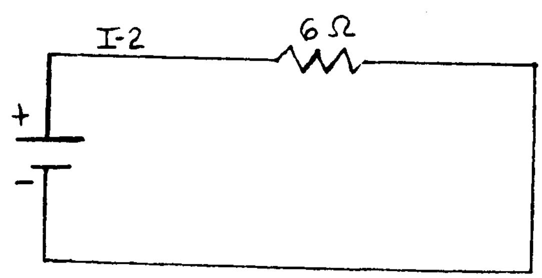
1. AMPERES = VOLTS DIVIDED BY OHMS.

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



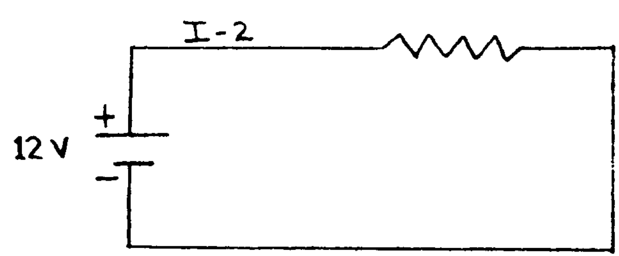

2. VOLTS = AMPERES MULTIPLIED BY OHMS.

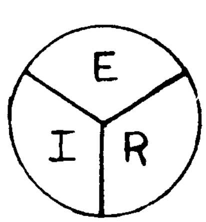
$$E = I \times R$$




3. OHMS = VOLTS DIVIDED BY AMPERES.

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




I - AMPERES
E - VOLTAGE
R - RESISTANCE

# ELECTRICAL FORMULAS

**FORMULAS** WHERE: R is resistence in ohms
E is voltage in volts
I is current in amperes
P is power in watts
C is capacitance in farads

**OHM'S LAW:**

FOR VOLTAGE $E = IR$

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

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

**POWER EQUATION:**

FOR POWER $P = IE$

$P = I^2R = \frac{R^2}{R}$

FOR CURRENT $I = \frac{P}{E}$

FOR VOLTAGE $E = \frac{P}{I}$

**SERIES CIRCUITS:**

FOR VOLTAGE $E_T=E_1 + E_2 + E_3....$

FOR CURRENT $I_T = I_1 = I_2 = I_3...$

FOR RESISTANCE $R_T = R_1 + R_2 + R_3...$

FOR CAPACITANCE $\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} \; ....$

OR $C_T = \frac{C_1 \times C_2}{C_1 + C_2}$ FOR CAPACITORS TWO AT A TIME

**PARALLEL CIRCUITS:**

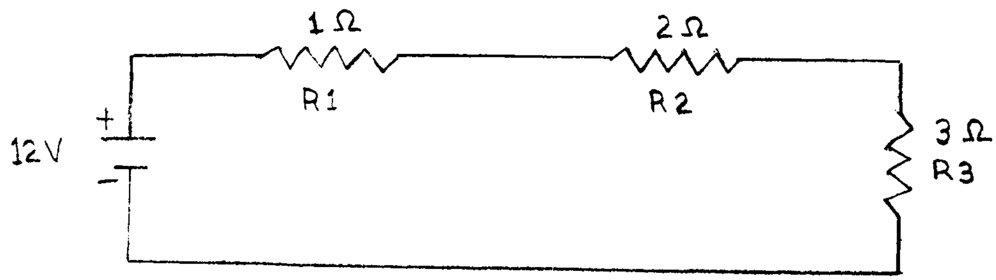
FOR VOLTAGE $E_T = E_1 = E_2 = E_3...$

FOR CURRENT $I_T = I_1 + I_2 + I_3...$

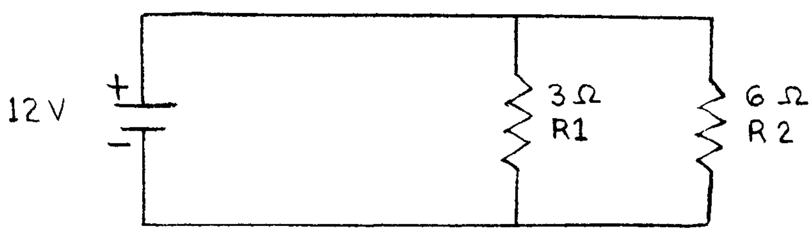
FOR RESISTANCE $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \; ...$

OR $R_T = \frac{R_1 \times R_2}{R_1 + R_2}$ FOR RESISTORS TWO AT A TIME

1. Rt = R1 + R2 + R3 SERIES CIRCUIT

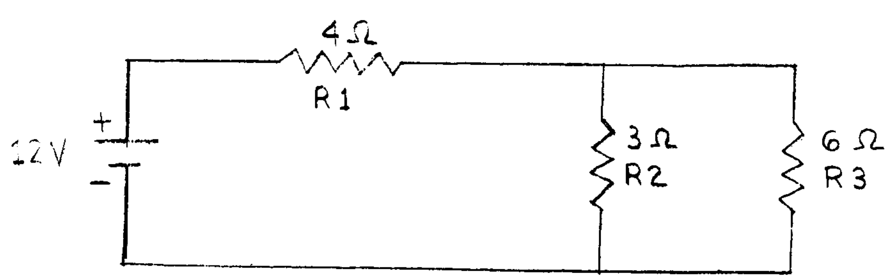



2. $Rt = \frac{R1 \times R2}{R + R2}$ PARALLEL CIRCUIT



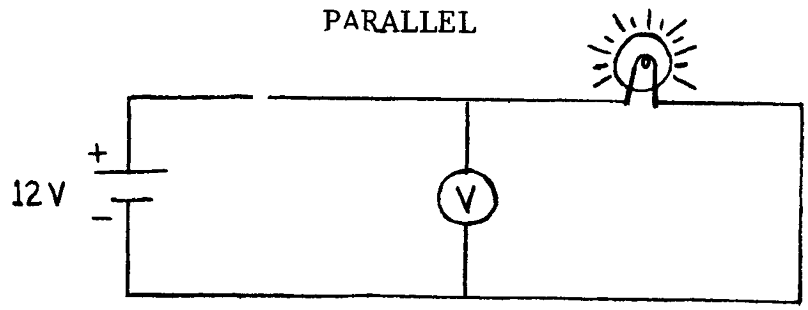

3. $Re = \frac{R2 \times R3}{R2 + R3}$ or $Rt = \frac{1}{\frac{1}{R1} + \frac{1}{R2} + \frac{1}{R3} \text{ etc.}}$ SERIES PARALLEL CIRCUIT

Rt = R1 + Re

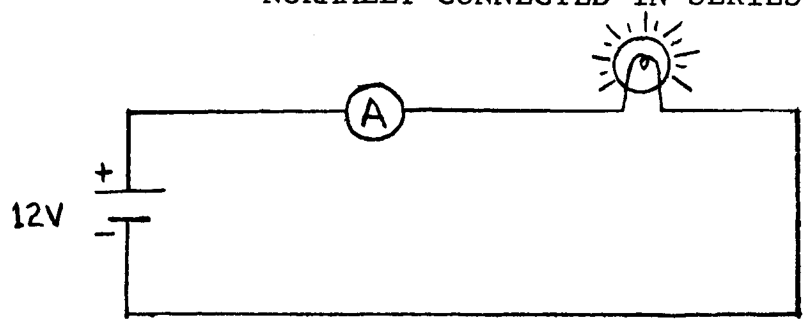


METERS

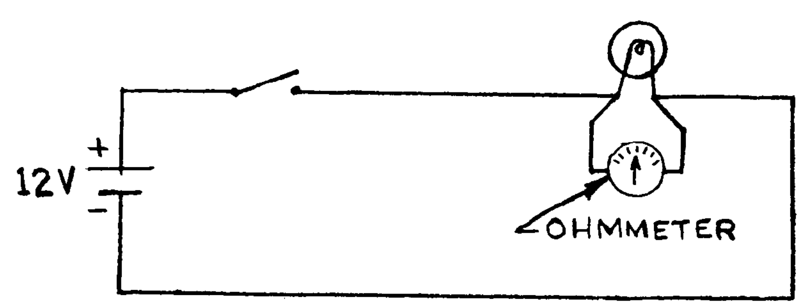
1. VOLT METER - USED TO MEASURE VOLTAGE IN A CIRCUIT. CONNECTED IN PARALLEL




2. AMMETER - USED TO MEASURE CURRENT FLOW (AMPERAGE) IN A CIRCUIT. NORMALLY CONNECTED IN SERIES




3. OHMMETER - USED TO MEASURE RESISTANCE, IN OHMS, IN AN ELECTRICAL COMPONENT. CONNECTED ACROSS THE UNIT BEING TESTED.



# RESISTOR COLOR CODES

| COLOR | | VALUE BAND A | VALUE BAND B | NO. OF ZEROS OR MULTIPLIER BAND C | TOLERANCE BAND D | FAILURE PER 1000Hrs. BAND E |
|---|---|---|---|---|---|---|
| BLACK | BK | 0 | 0 | - | - | - |
| BROWN | BR | 1 | 1 | 0 | - | 1.% |
| RED | R | 2 | 2 | 00 | - | .1% |
| ORANGE | O | 3 | 3 | 000 | - | .01% |
| YELLOW | Y | 4 | 4 | 0000 | - | .001% |
| GREEN | GR | 5 | 5 | 00000 | - | - |
| BLUE | BL | 6 | 6 | 000000 | - | - |
| VIOLET | V | 7 | 7 | 0000000 | - | - |
| GREY | GY | 8 | 8 | - | - | - |
| WHITE | W | 9 | 9 | - | - | - |
| GOLD | G | - | - | .1 | ± 5% | - |
| SILVER | S | - | - | .01 | ±10% | - |
| NONE | - | - | - | - | ±20% | - |

The first band (A) shows the first figure of the resistor value.

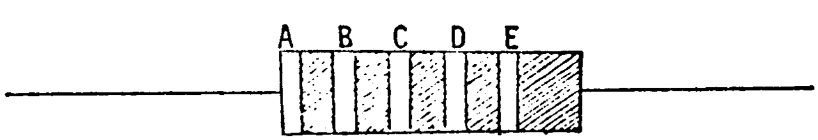
The second band (B) shows the second figure.

The third band (C) indicates the number of zeros to add, or the percentage of the first two bands if the third band is Gold or Silver.

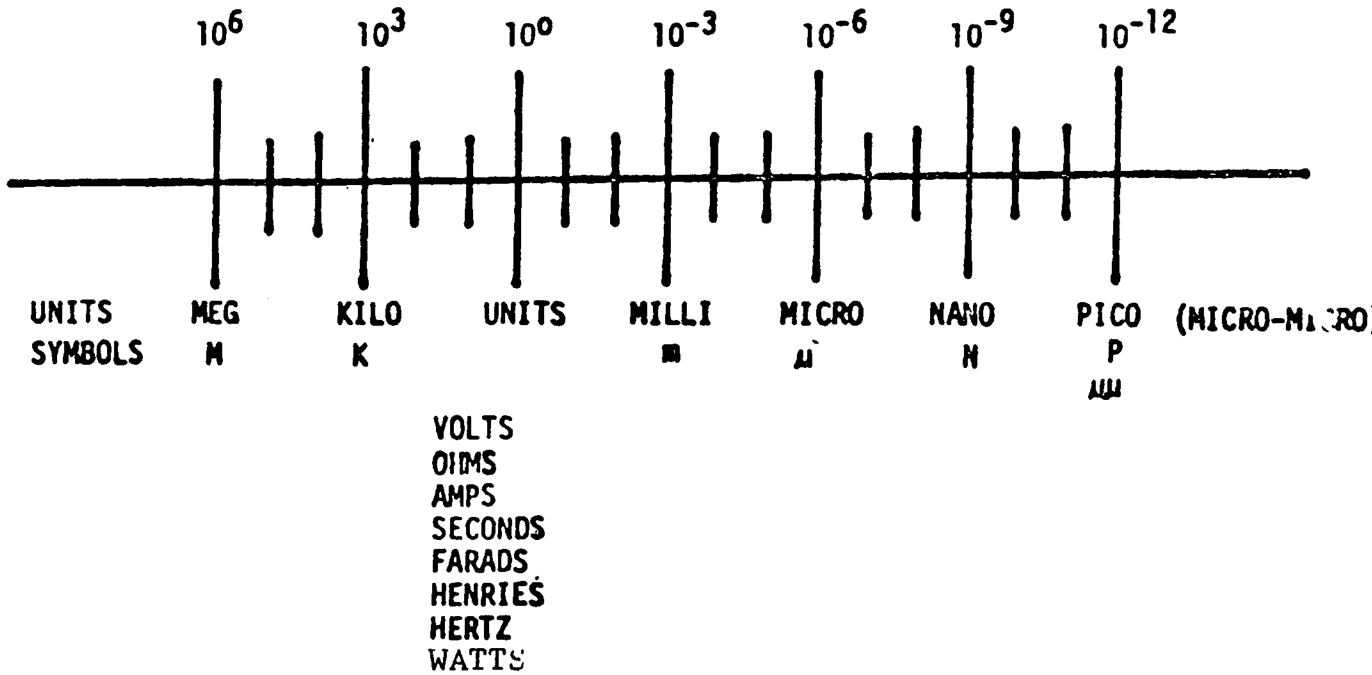
The fourth band (D) which is not included on all resistors indicates tolerance.

The fifth band (E) indicates the fauilure % for 1000 Hrs. of operation.

| BAND A 1st FIGURE | BAND B 2nd FIGURE | BAND C NUMBER OF ZEROS | BAND D TOLERANCE | RESISTOR VALUE IS |
|---|---|---|---|---|
| Brown = 1 | Black = 0 | Black = none | Silver = ± 10% | 10 ohms ± 10% |
| Orange = 3 | White = 9 | Brown = 0 | Gold = ± 5% | 390 ohms ± 5% |
| Yellow = 4 | Violet = 7 | Silver (÷100) | None = ± 20% | .47 ohms ± 20% |
| Brown = 1 | Black = 0 | Green = 00000 | Silver = ± 10% | 1 megohm ± 10% |



# METRIC UNITS CONVERSION GRAPH



# TEST EQUIPMENT

The use of test equipment is often necessary in performing diagnosis. In fact, test equipment and the wiring diagrams are your best tools. This section describes commonly used test equipment and explains how to put it to best use in diagnosis.

## JUMPER WIRES

Jumper wires are simple, yet extremely valuable, pieces of test equipment. Jumper wires, as shown in Figure 76, are merely wires that are used to bypass or "jump" sections of a circuit. The simplest type of jumper wire is merely a length of multistrand wire with an alligator clip at each end. Generally, electrical service technicians fabricate their own jumper wires. The well-equipped technician will have several different styles of jumper wires in several different lengths.

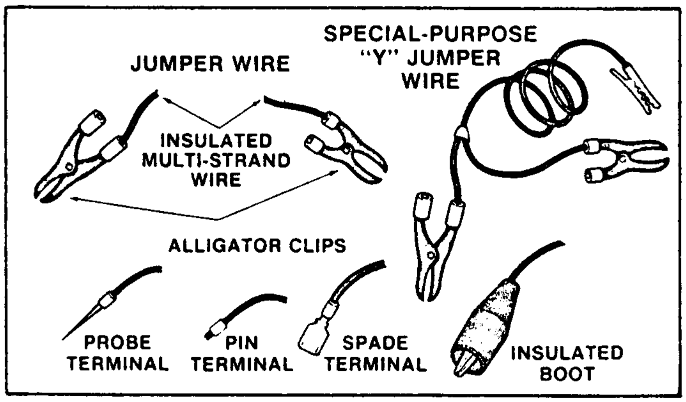



FIGURE 76. TYPES OF JUMPER WIRES

Some jumper wires are made with three or more terminals coming from a common splice for special-purpose testing. In cramped, hard-to-reach areas it is advisable to have insulated boots over the jumper wire terminals in order to prevent accidental grounding, sparks, and possible fire.

## USES OF JUMPER WIRES

Jumper wires are used primarily to locate open circuits, on either the ground side of the circuit or on the hot side. Refer to Figure 77. If the lamp fails to operate, connect the jumper wire as shown, between the lamp and a good ground. If the lamp operates only with the jumper installed, the lamp ground circuit is open. If the lamp ground circuit is good, but the lamp does not operate, the circuit between the battery and lamp is open. You can then

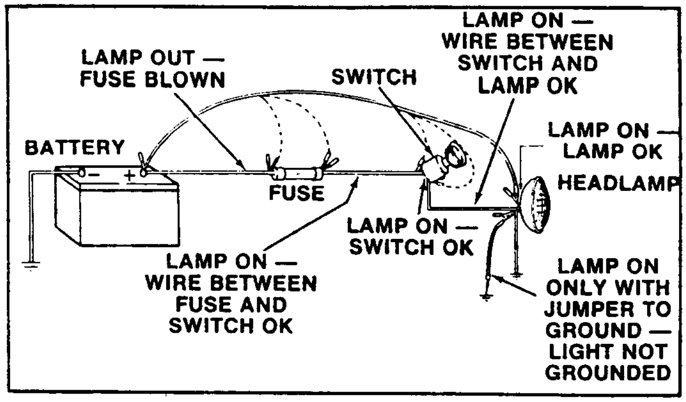



FIGURE 77. USING JUMPER WIRE TO ISOLATE AN OPEN CIRCUIT

connect the jumper wire directly from the battery to the hot terminal of the lamp. If both the battery and lamp are OK, the lamp will light. By moving the jumper wire, then, successively back from the lamp toward the battery until the lamp goes out, you can isolate the area of the circuit where the open is located. When the lamp goes out, the open is in the segment of circuit between the jumper wire and the point previously tested. With one terminal of the jumper wire connected to the battery positive terminal, and the second terminal of the jumper wire at point A, the entire circuit is bypassed and the lamp will light. With the second terminal at point B, the wire between the switch and lamp is proved to be sound, if the headlamp lights. With the jumper moved to point C, the switch is proved good, if the lamp lights. At point D, the wiring between the fuse and switch is checked; it's OK if the lamp lights. Then, with the jumper wire moved to point E, the lamp off, we know that the open is between point E and the point previously tested — point D. Obviously, the fuse is blown. This, of course, is not the recommended way to check for a blown fuse (it's much easier just to look at it), but the method illustrates how a simple tool like a jumper wire can pinpoint opens in a circuit.

**CAUTION:**

Never use jumpers made from wire that is of lighter gauge than used in the circuit under test. If the jumper wire is of too small a gauge, it may overheat and possibly melt.

Never use jumpers to bypass high-resistance loads (such as motors) in a circuit. Bypassing resistances, in effect, creates a short circuit which may, in turn, cause damage and fire.

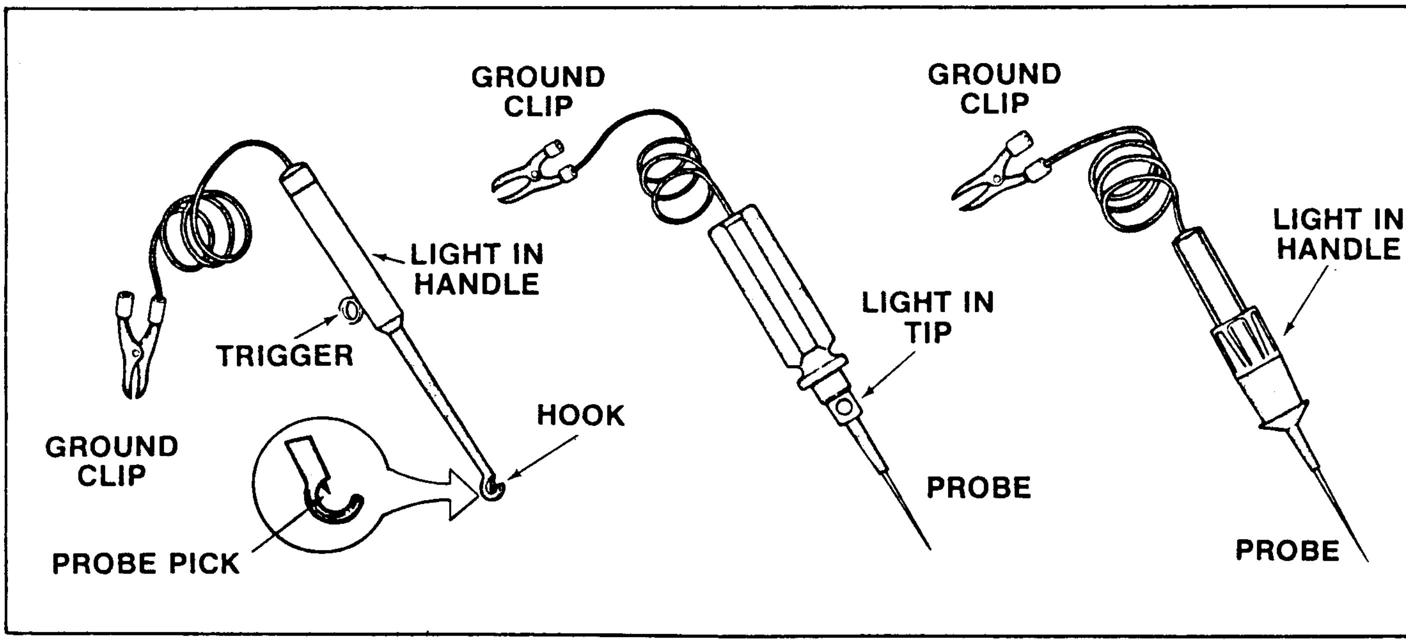



FIGURE 78. TYPICAL 12-VOLT TEST LIGHTS

Never use a jumper for anything other than *temporary* bypassing of components in a circuit.

## 12-VOLT TEST LIGHT

A twelve-volt test light is another easy-to-use piece of test equipment. Twelve volt test lights come in different styles but all have three main parts — a ground clip, a probe, and a light (Figure 78). The most commonly used 12-volt test lights have pick-type probes; two of these types are shown in Figure 78. At the left in Figure 78 is a type of 12-volt test light known as a "wrap-around" light.

To use a 12-volt test light, connect the ground clip to a good ground and probe wherever necessary with the pick. The pick should be sharp so that it can penetrate wire insulation to make contact with the wire, without making a large hole in the insulation. The wrap-around light is handy in hard to reach areas or where it is difficult to support a wire to push a probe pick into it. To use the wrap around light, hook the wire to be probed with the hook and pull the trigger. A small pick will be forced through the wire insulation into the wire core.

## USES OF THE 12-VOLT TEST LIGHT

Like the jumper wire, the 12-volt test light is used to isolate opens in circuits. But, whereas the jumper wire is used to bypass the open to operate the load, the 12-volt test light is used to locate the presence of voltage in a circuit. In the example shown in Figure 79, if the test light probe is at point A and the light in the handle glows, you know that there is power up to the lamp; therefore, if the lamp doesn't operate normally, either it is burnt out or its ground is not good.

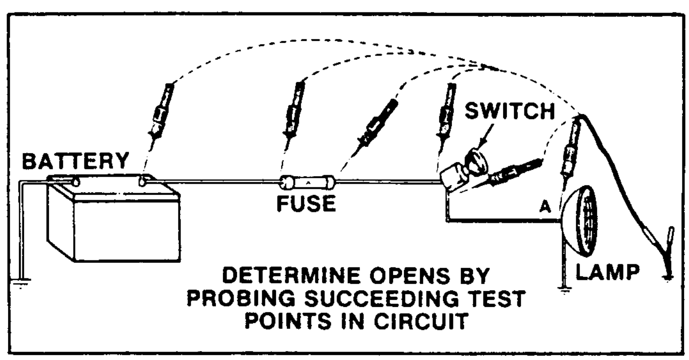



FIGURE 79. CHECKING FOR OPENS WITH A 12-VOLT TEST LIGHT

If the 12-volt test light does *not* glow when its probe is at point A, you know that there is an open circuit between the battery and point A. Then, just as you did with the jumper wire, you can move the test light in successive steps back toward the battery until the light in the handle does glow. When it does glow, the open is between the probe and the point previously probed.

**NOTE:**
Do not be confused by the term "12-volt" test light. The test light does not detect that 12 volts, or any particular *amount* of voltage, is present. It only detects that *some* voltage is present. It is advisable before using the test light to touch its terminals across the battery posts to determine that the test light, itself, is operating properly.

## "LOUD" TEST LIGHT

A "loud" test light is a handy tool for diagnosing for grounds. This piece of test equipment is handy because the technician can connect it into the circuit and leave it. He is then free to work in other areas of the car. Because the test light is bright and audible, he can see and hear the test results from any location.

The loud test light, however, is not a standard piece of equipment. It will have to be homemade.

## FABRICATION

To build a loud test light, Refer to Figure 80.

1. Connect a test lead to the ground terminal of a sealed-beam head light. (A head light connector is not necessary, but makes replacement of the light easier, should it burn out.)

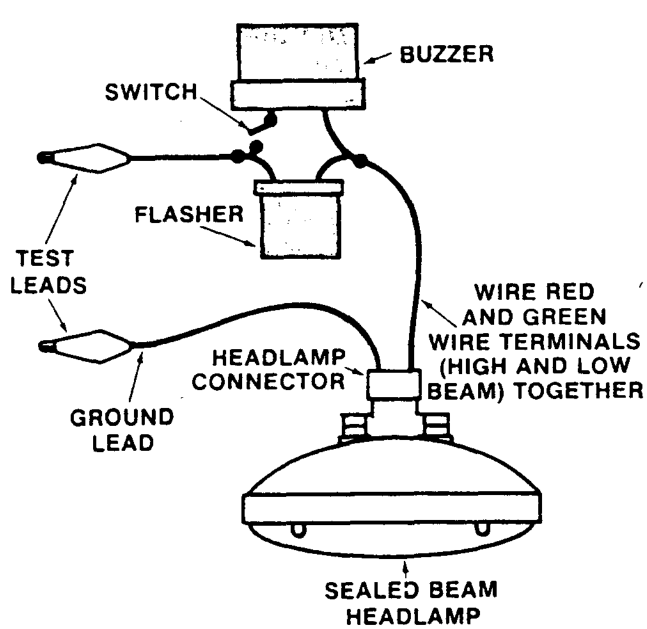



FIGURE 80. "LOUD" TEST LIGHT

2. Wire the high-beam and low-beam terminals (red and green wires) together.
3. Connect a second test lead to the high/low-beam terminals.
4. Connect a flasher in series in one of the test leads.
5. If desired, connect a buzzer in parallel with the flasher.
6. To turn off the buzzer when the audible signal is not wanted, connect a switch into one of the buzzer leads.
7. For the most-versatile use, fabricate several adapters from old wiring harnesses to connect the light into various circuits.
8. To provide ease of use and protection, mount the whole assembly in a box.

## USES OF THE "LOUD" TEST LIGHT

The "loud" test light is essentially a bright, audible, 12-volt test light, and can be used like a 12-volt test light to check for open circuits.

### OPEN CIRCUIT TESTING

To use the loud test light to test for open circuits, use it exactly as a 12-volt test light. A standard 12-volt test light, however, is usually easier to use for these types of tests. The loud test light is of greater value in testing for shorts.

### SHORT CIRCUIT TESTING

The loud test light is particulary valuable in testing for shorts. Unlike the self-powered test light and ohmmeter (the use of which is explained later), the loud test light can be used with power applied to the circuit. To use the loud test light to check for shorts, it must be connected in series in the circuit. As shown in Figure 81 the fuse panel is a convenient place to connect the loud test light into the circuit. To use the loud test light:

1. Connect the loud test light into the circuit.
2. Using the wiring diagram of the particular circuit, work systematically through the circuit to isolate the short.

The light will glow dimly and the buzzer will sound softly when the lamp is in series with a properly operating load. If the light grounds through a short, however, it will flash brightly and the buzzer will sound loudly. It's easy to tell the difference.

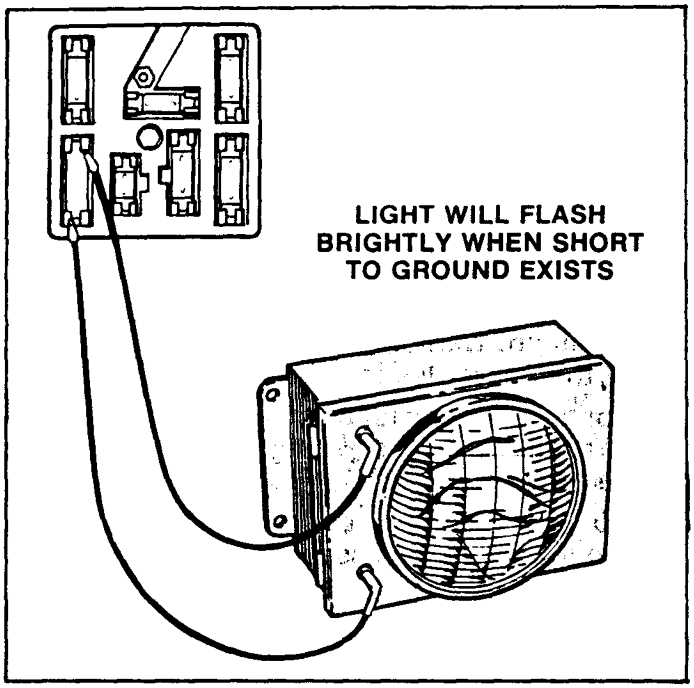



FIGURE 81. LOUD TEST LIGHT CONNECTED IN SERIES AT THE FUSE PANEL

## SELF-POWERED TEST LIGHT

The self-powered test light is, as its name implies, self-powered by a 1½-volt pen-light battery. Two types of self-powered test lights are shown in Figure 82. One type is similar in design to the 12-volt test light. This type has both the battery and the light in the handle and a pick-type probe tip. The second type has the light toward the open tip, so that the light illuminates the contact point.

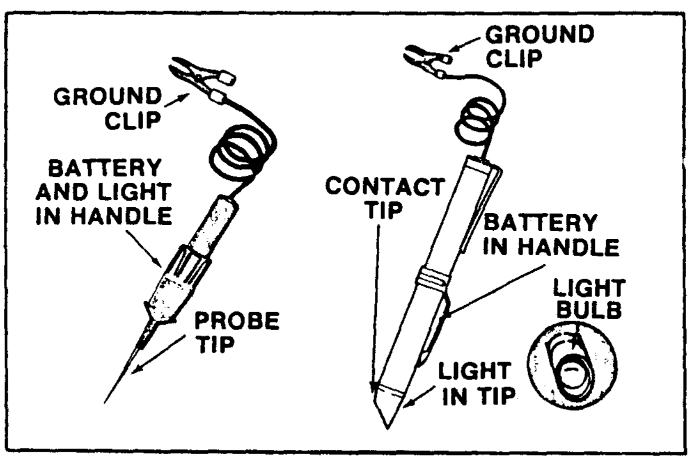



FIGURE 82. TYPICAL SELF-POWERED TEST LIGHTS

## USES OF THE SELF-POWERED TEST LIGHT

The self-powered test light is a dual-purpose piece of test equipment. It can be used to test for either open or short circuits when power is isolated from the circuit.

### Open Circuit Testing

Use the self-powered test light, as shown in Figure 83, to check for open circuits.

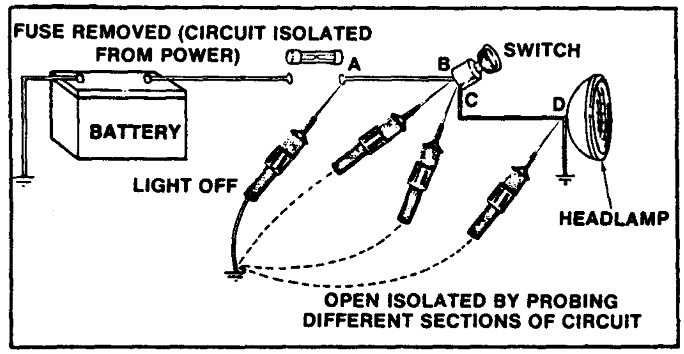



FIGURE 83. CHECKING FOR OPEN CIRCUITS WITH A SELF-POWERED TEST LIGHT

1. Isolate the circuit from power.
2. Connect the test light ground clip to a good ground.
3. Probe sections of the circuit sequentially with the test light. (Start from either end of the circuit.)

If the light is out, the open is between the probe and the circuit ground. If the light is on, the open is between the probe and the end of the circuit toward the power source.

### Short Circuit Testing

By isolating the circuit both from power and from ground, and using the self-powered test light as shown in Figure 84, you can check for shorts to ground in the circuit. To check that there is, indeed, a short:

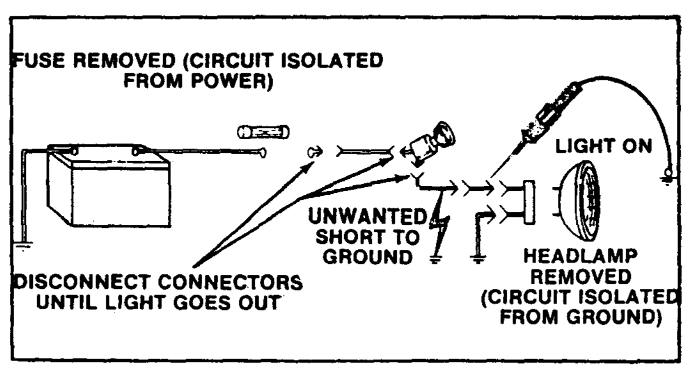



FIGURE 84. CHECKING FOR SHORT CIRCUITS WITH A SELF-POWERED TEST LIGHT

1. Isolate the circuit from power and ground.
2. Connect the test light ground clip to a good ground.
3. Probe any easy to reach test point in the circuit.

If the light comes on, there is a short somewhere in the circuit. To isolate the short:

1. Probe a test point at either end of the isolated circuit. (The light will be on.)
2. Leave the test light probe connected.
3. Open connectors, switches, remove parts, etc., sequentially, until the light goes out.

When the light goes out the short is between the last circuit component opened and the previous circuit component opened.

**NOTE:**
The 1½-volt battery in the test light does not provide much current. A weak battery may not provide enough power to illuminate the test light even when a complete circuit is made (especially if there are high resistances in the circuit). Always make sure, therefore, that the test battery is strong. To check the battery, briefly touch the ground clip to the probe; if the light glows brightly the battery is strong enough for testing.

**CAUTION:**
Never use a self-powered test light to perform checks for opens or shorts when power is applied to the electrical system under test. The 12-volt vehicle power will quickly burn out the 1½-volt light bulb in the test light.

## OHMMETER

The ohmmeter is a piece of test equipment designed to read resistance (ohms) in a circuit. Figure 85 shows a typical ohmmeter. Although there are several different styles of ohmmeters, all will usually have the following features in addition to the meter movement: a selector switch, which permits the selection of different ranges of resistance (usually, the selector switch allows the multiplication of the meter reading by 10, 100, 1000, and 10,000); a set adjust, which also allows the meter to be set at zero, initially, for accurate measurement. The Rotunda ohmmeter has a built-in feature that allows the ohmmeter to be used as a self-powered test light.

## USES OF THE OHMMETER

The ohmmeter can be used to perform continuity tests for opens or shorts (either by observation of the meter needle or as a self-powered test light) and to read actual resistance in a circuit.

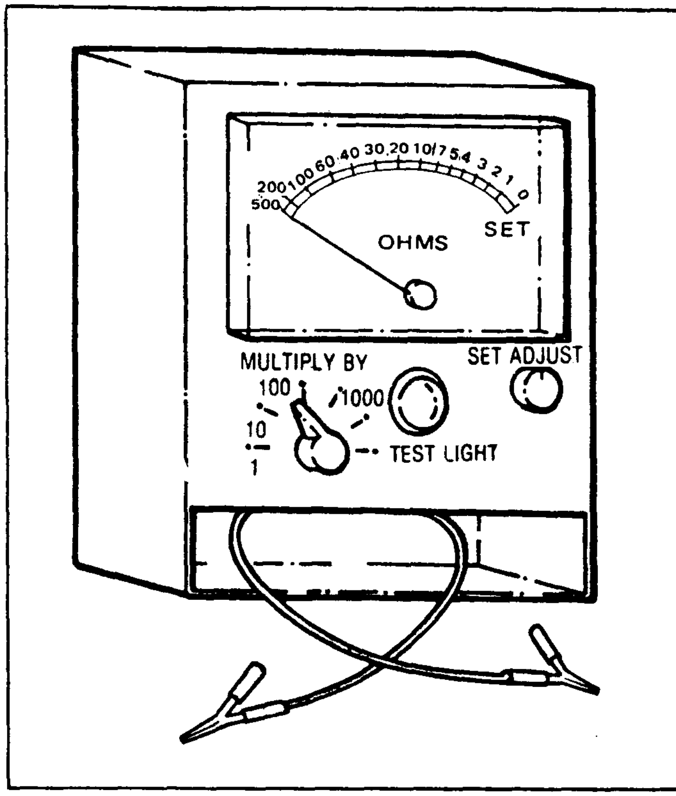



FIGURE 85. TYPICAL OHMMETER

### TEST LIGHT CHECKS

To use the ohmmeter as a self-powered test light:

1. Isolate the circuit from power (and ground, if necessary).
2. Set the selector switch to TEST LIGHT.
3. Check the circuit as described for the self-powered test light.

### OPEN CIRCUIT TESTING

When checking a circuit for opens as in Figure 86:

1. Isolate the circuit from power.
2. Set the selector switch to the highest range.

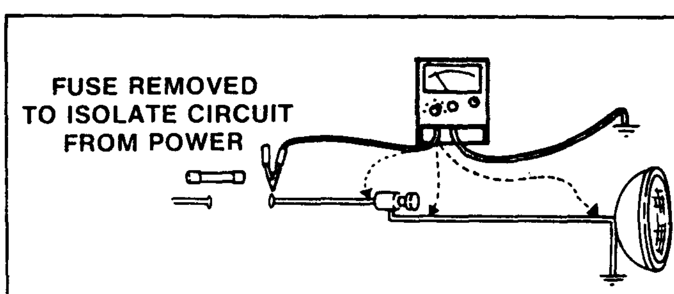



FIGURE 86. CHECKING FOR OPEN CIRCUITS WITH AN OHMMETER

3. Ground one of the ohmmeter leads.
4. Probe segments of the circuit sequentially.

In using the meter for making continuity checks, do not be concerned with the actual resistance readings. Zero resistance, or any resistance readings, indicate continuity in the circuit. Infinite resistance indicates an open in the circuit. A high resistance reading, where there should be none, indicates an unwanted high resistance in the circuit.

## Short Circuit Testing

Checks for short circuits are made in the same manner as checks for open circuits except that the circuit must be isolated from both power and normal ground. As shown in Figure 87:

1. Isolate the circuit from both power and ground.
2. Connect one meter lead to a good ground.
3. Starting at either end of the isolated circuit, sequentially probe segments of the circuit.

Infinite resistance indicates no continuity to ground. Zero resistance indicates a dead short to ground.

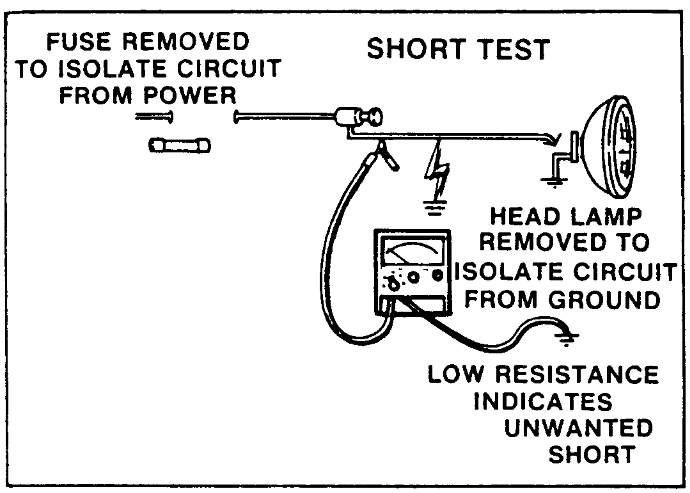



FIGURE 87. CHECKING FOR SHORT CIRCUITS WITH AN OHMMETER

## Resistance Measurement

To assure accurate resistance readings, always "zero" the ohmmeter before taking measurements. To zero the meter:

1. Place the selector switch in its lowest range.
2. Touch the two meter leads together.
3. Turn the "SET ADJUST" until the meter needle is exactly on zero.

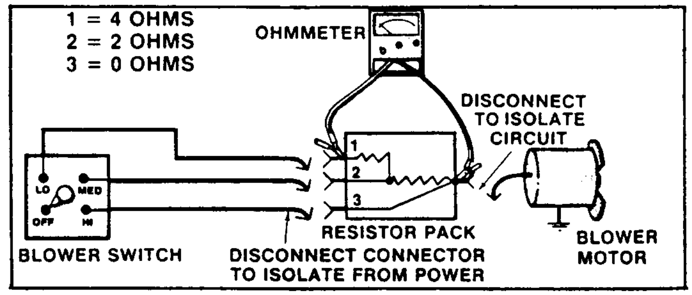



FIGURE 88. TAKING RESISTANCE MEASUREMENTS WITH AN OHMMETER

To take resistance measurements, refer to Figure 88 and proceed as follows:

1. Isolate the circuit from power.
2. Where necessary to avoid reading parallel resistances, also isolate at least one side of the resistance to be checked.
3. Connect the meter leads across (to both sides of) the resistance.
4. Read actual ohms on the meter scale.

In the example shown in Figure 88, the 3-terminal connector is disconnected to isolate the circuit from power. The single-terminal connector is also disconnected to isolate the resistor pack from possible parallel resistances (although none are shown in this simplified circuit). The meter is connected across the resistor pack. Assuming all resistors in the resistor pack are 2-ohms, readings taken at terminals 1, 2, and 3 should be 4, 2, and zero respectively. If any of the readings are incorrect, the resistor pack should be replaced.

**CAUTION:**
Never use an ohmmeter with power applied to the circuit. Like the self-powered test light, the ohmmeter is designed to operate on its own power supply. The 12-volt electrical system power could damage the meter.

## VOLTMETER

A voltmeter is, of course, a piece of test equipment used to measure voltage in a circuit. Voltmeters usually have two scales on the meter dial and a selector switch to allow the selection of different voltages. The meter shown in Figure 89 is typical of voltmeters used in testing automotive electrical systems. It has a three-position selector switch (4V, 20V, 40V), and two scales (4V, 20V).

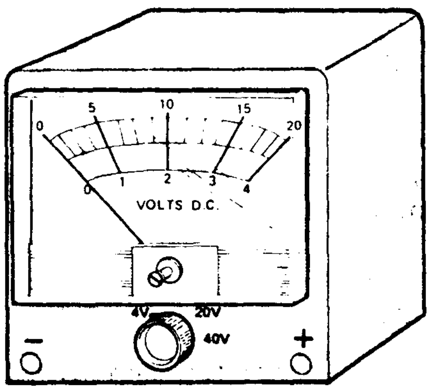



FIGURE 89. TYPICAL VOLTMETER

## READING THE VOLTMETER

For the voltmeter shown in Figure 89:

1. To read up to 4 volts, set the selector to 4V and read the 4V scale.
2. To read up to 20 volts, set the selector to 20V and read the 20V scale.
3. To read up to 40 volts, set the selector to 40V and read the 4V scale. (Multiply the reading by 10.)

## CONNECTING THE VOLTMETER

The voltmeter has a *positive* and a *negative* lead. To avoid damage to the meter, always observe polarity as follows:

1. Always connect the negative lead to negative side of the circuit (to ground or nearest the ground side of the circuit).
2. Always connect the positive lead to the positive side of the circuit (to the power source or nearest the power source).

Note that the negative voltmeter lead will always be black and that the positive voltmeter lead will always be some color other than black (usually red).

## USES OF THE VOLTMETER

Depending on how the voltmeter is connected into the circuit, it has several uses.

### QUICK BATTERY CONDITION CHECK

To measure the condition of a battery, connect the battery as shown in Figure 90:

1. Set the voltmeter selector switch to the 20V position.
2. Connect the meter negative lead to the negative post of the battery.
3. Connect the positive meter lead to the positive post of the battery.
4. Turn on some of the car's electrical system (headlights and blower, for instance) to provide a load.
5. Read voltage on the 20V scale.

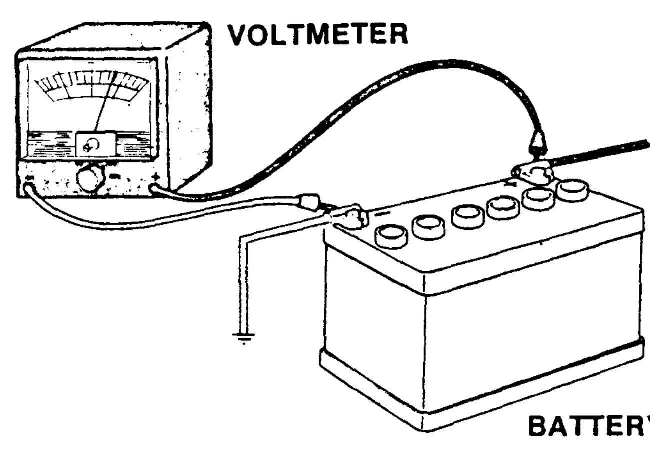



FIGURE 90. CHECKING BATTERY SOURCE VOLTAGE WITH A VOLTMETER

A well-charged battery should register over 12 volts. If the meter reads below 11.5 volts, the battery power may be insufficient to operate the electrical system properly. In effect, this test determines voltage available from the battery.

### AVAILABLE VOLTAGE MEASUREMENT

Nominal battery voltage is 12 volts when "fully charged". When the battery is supplying current to one or more circuits it is said to be "under load". When everything is off the electrical system is under a "no-load" condition. A fully charged battery may show about 12.5 volts at no load; will drop to 12 volts at medium load; will drop lower at heavy load. If the battery is partially discharged, the voltage decrease under heavy load may be pronounced, even though the battery shows 12 volts or more at no load. When allowed to discharge further the battery's available voltage under load will decrease more severely.

If the battery is down to 25 percent of its full charge, the voltage has dropped to a point where lights will burn dim, motors will run slowly, etc. Figure 91 tabulates various voltages available at various loads and battery state of charge.

| BATTERY STATE OF CHARGE (SPECIFIC GRAVITY) | | | | | |
|---|---|---|---|---|---|
| LOAD ON BATTERY | 1.265 FULL CHARGE | 1.250 95% CHARGE | 1.230 ¾ CHARGE | 1.200 ½ CHARGE | 1.175 ¼ CHARGE |
| NO LOAD | 12.7 VOLTS | 12.6 VOLTS | 12.5 VOLTS | 12.4 VOLTS | 12.2 VOLTS |
| 5 AMPERES | 12.5 VOLTS | 12.4 VOLTS | 12.3 VOLTS | 12.1 VOLTS | 11.8 VOLTS |
| 15 AMPERES | 12.3 VOLTS | 12.2 VOLTS | 12.0 VOLTS | 11.7 VOLTS | 11.3 VOLTS |
| 25 AMPERES | 12.1 VOLTS | 11.9 VOLTS | 11.6 VOLTS | 11.2 VOLTS | 10.7 VOLTS |

THIS IS THE RANGE IN WHICH MOST VEHICLE BATTERIES NORMALLY OPERATE IN CUSTOMER SERVICE.

AT 1.180 AND BELOW, STARTING WILL BE UNRELIABLE AND FUNCTION OF OTHER CIRCUITS MAY BE ERRATIC.

FIGURE 91. AVAILABLE VOLTAGE UNDER DIFFERENT LOADS AND STATES OF CHARGE

To measure available voltage, connect the voltmeter as shown in Figure 92:

1. Set the meter selector switch to the 20V position.
2. Provide power to the load. (Turn the blower motor switch to LO.)
3. Connect the negative meter lead to a good ground.
4. Probe various points of the circuit with the positive lead of the meter.
5. Observe the voltage readings on the 20V scale.

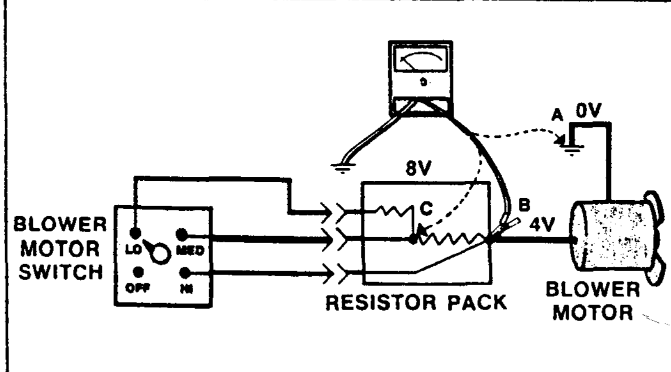



FIGURE 92. CHECKING AVAILABLE VOLTAGE WITH A VOLTMETER

Assuming that each of the resistors in the resistor pack and the motor are all of the same resistance the meter readings would be as follows with the blower switch in LO:

Point A = 0V
Point B = 4V
Point C = 8V

The reason for the differences in available voltage at each point is due to *voltage drop* by the resistors.

## Voltage Drop

To review and summarize what is meant by "voltage drop," refer to Figures 93 and 94. Resistances "drop" (reduce) voltage. When current flows through a resistance, the voltage beyond the resistance is reduced (the larger the current the greater the reduction in voltage). When no current is flowing, such as shown in the open circuit in Figure 93, there is no voltage drop because there is no current flow. All points in the circuit which are connected to the power source are at the same voltage as the power source. In the closed circuit (current flowing) shown in Figure 94, there is a drop in voltage beyond the 2-ohm resistor and again beyond the 2-ohm bulb. Because both of the loads are in series and both are at 2 ohms, they each drop half of the voltage (6 volts each). The total voltage drop always equals the total source available voltage. In a long circuit with many connectors, a series of small unwanted voltage drops due to corrosion, etc., at the connectors can add up to a total loss of voltage which impairs the operation of the normal loads in the circuit. Figures 95 and 96 illustrate this point. The starter relay operates in two stages. The coil of the relay is energized first, drawing the relay contacts closed; then, the starter motor is energized. In Figure 95, at the moment of ignition switch contact, the full available battery power is available to energize the relay coil. The relay coil is energized even though there is a high resistance at the battery terminal because the coil requires little voltage to energize it. As soon as the coil is energized, the starter motor is energized drawing most of the power. Due to the high resistance at the post, the coil then only has about 1 volt to hold it closed, but 1 volt is insufficient, so the relay contacts open as in Figure 96. When open, the motor is de-energized and the coil again is energized. The cycle repeats itself and a clicking is all that is heard at the starter motor — all due to a high-resistance voltage drop at the battery post.

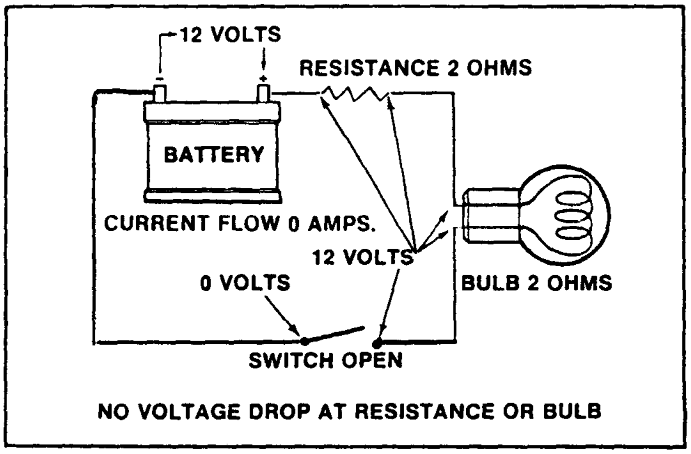



FIGURE 93. ZERO CURRENT FLOW EQUALS ZERO VOLTAGE DROP

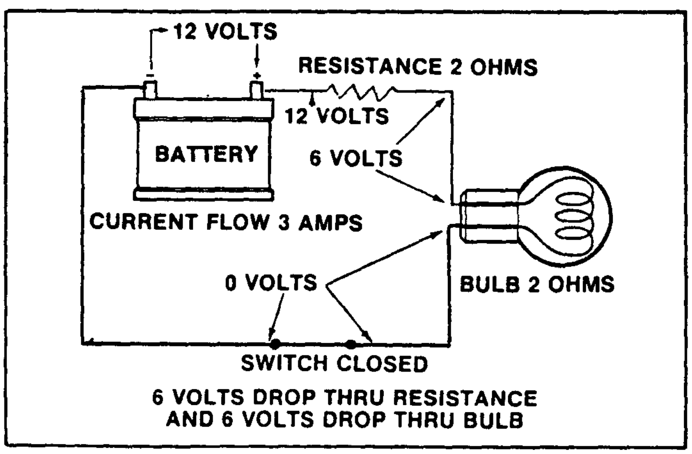



FIGURE 94. RESISTANCES DROP VOLTAGE IN A CIRCUIT

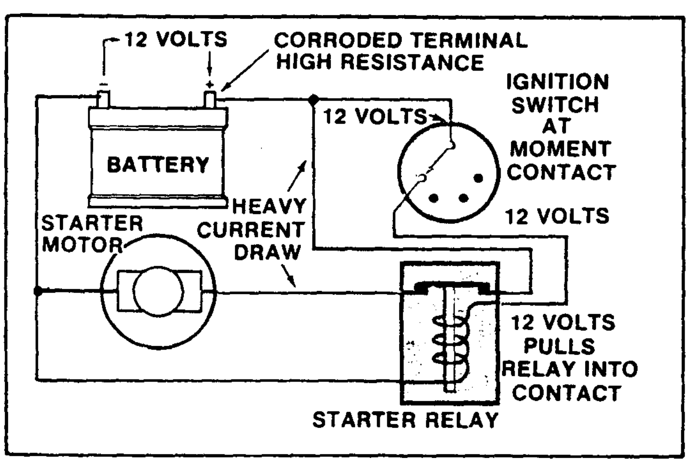



FIGURE 95. VOLTAGE SUFFICIENT TO DRAW POWER TO COIL THROUGH HIGH-RESISTANCE CORRODED TERMINAL

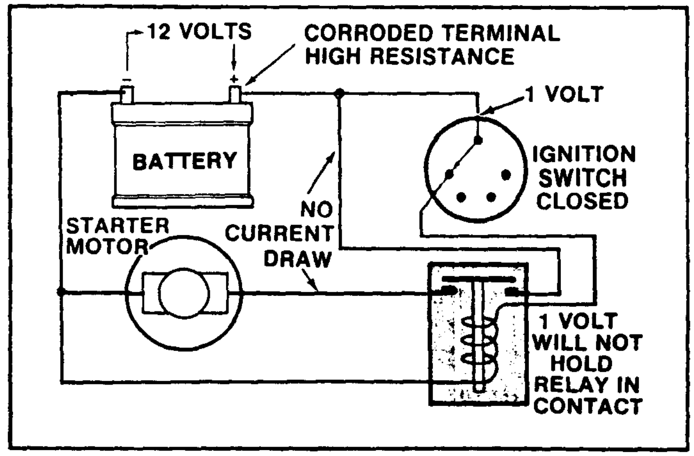



FIGURE 96. VOLTAGE INSUFFICIENT TO HOLD CONTACTS WHEN STARTER MOTOR DRAWS CURRENT

## INDIRECT COMPUTATION OF VOLTAGE DROPS

To compute the voltage drops in various parts of a circuit (Figure 97):

1. Set the voltmeter selector switch to the 20V position.
2. Connect the meter negative lead to a good ground.
3. Probe all resistances in the circuit with the positive meter lead.
4. Operate the circuit in all modes.
5. Observe the voltage readings on the 20V scale.

In the example shown in Figure 97, the meter reading would be as follows:

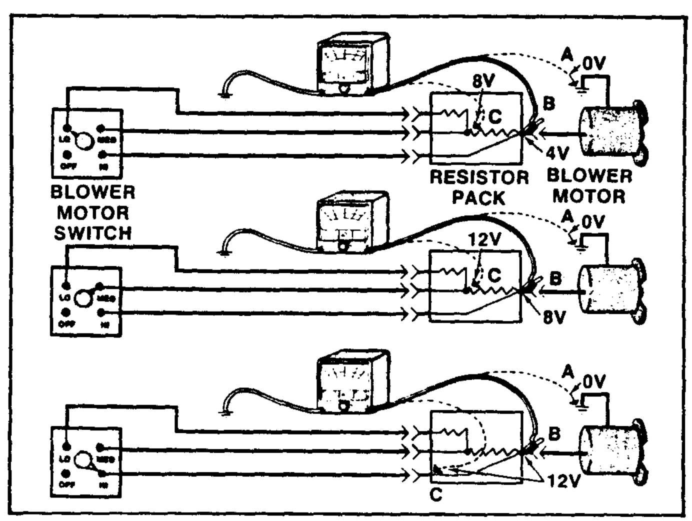



FIGURE 97. COMPUTING VOLTAGE DROPS INDIRECTLY

| | | PROBE POINT | | |
|---|---|---|---|---|
| | | A | B | C |
| BLOWER | OFF | 0V | 0V | 0V |
| MOTOR | LO | 0V | 4V | 8V |
| SWITCH | MED | 0V | 8V | 12V |
| POSITION | HI | 0V | 12V | 12V |

Assuming a 12-volt original available voltage, the voltage drops by the two resistors and the load are as follows:

VOLTAGE DROP

| | | First Resistor | Second Resistor | MOTOR |
|---|---|---|---|---|
| BLOWER | OFF | Not in Circuit | Not in Circuit | Not in Circuit |
| MOTOR | LO | 4V | 4V | 4V |
| SWITCH | MED | Not in Circuit | 4V | 8V |
| POSITION | HI | Not in Circuit | Not in Circuit | 12V |

In LO, the two resistors drop a total of 8 volts, leaving 4 volts to operate the motor. The motor, therefore, runs at low speed.

In MED, only the second resistor, which drops only 4 volts, is in the circuit. With 8 volts available to the motor then, it runs at medium speed.

In HI, both resistors are bypassed and the full 12 volts is available to the motor. The motor, thus, runs at high speed.

The above is a quick and accurate, but indirect, method of computing voltage drops. Voltage drops can also be taken directly.

## Direct Measurement of Voltage Drops

If the voltmeter is connected as shown in Figure 98, voltage drops can be measured directly:

1. Set the voltmeter selector switch to the 20V position.
2. Connect the voltmeter negative lead to the ground side of the resistance of load to be measured.

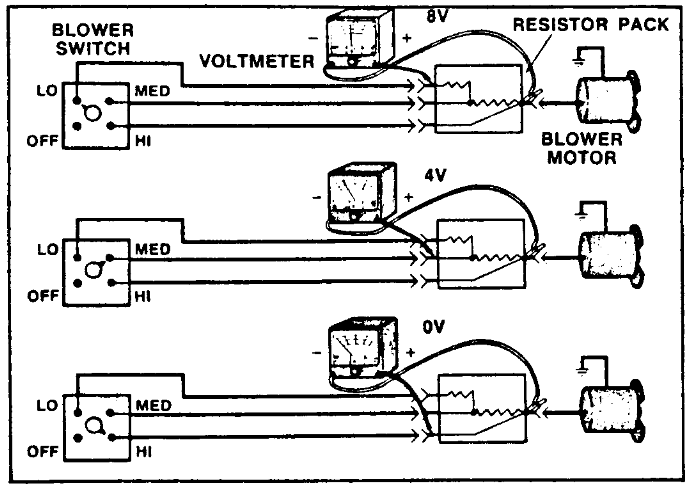



FIGURE 98. DIRECT MEASUREMENT OF VOLTAGE DROPS

3. Connect the positive lead to the positive side of the resistance or load to be measured.
4. Read the voltage drop directly on the 20V scale.

In the example shown in Figure 98 the voltages dropped in the various switch positions are:
LO = 8V
MED = 4V
HI = 0V

These are the same results as computed by the indirect method.

You may wonder why it is important to know what voltage drops are. Being able to determine voltage drops gives us the following information:

Too high a voltage drop indicates too high a resistance. If, for instance, the blower motor runs too slowly, you can determine if there is too high a resistance in the resistor pack. Perhaps the problem could be caused by corroded terminals on the resistor pack. By taking voltage drop readings in all parts of the circuit, you can isolate this problem.

Too low a voltage drop, likewise, indicates too low a resistance. If, for instance, the blower motor ran too fast in MED and/or LO, the problem can be isolated to the resistor pack by taking voltage drop readings in all parts of the circuit. (This problem could be caused by a shorted resistor.)

*Maximum allowable voltage drop* under load is critical, especially if there is more than one high resistance problem in a circuit, because, like all resistances, all voltage drops are cumulative. A small drop is normal. (This is due to the resistance of the conductors.)

## HIGH RESISTANCE TESTING

To check for undesired high resistances proceed as follows:

1. Set the voltmeter selector switch to the 4V position.
2. Connect the voltmeter positive lead to the positive post of the battery.
3. Turn on the headlights and heater/AC blower to provide a load.
4. Probe various points in the circuit with the negative voltmeter lead.
5. Read the voltage drop on the 4V scale.

Maximum allowable volt drops are as follows:

| POINT PROBED | VOLTAGE DROP |
|---|---|
| Fuse Panel | .7V |
| Ignition Switch | .5V |
| Headlight Switch | .7V |
| Ignition Coil B Terminal (Switch in "Start") | .5V |
| Any Other Load | 1.3V |

## NO-LOAD VOLTAGE DROP MEASUREMENT

You will have noticed that in the voltage drop tests made above the voltage drops were all taken while a load is operative. Voltage drops can only be taken while a load is operating. Without current flow, there will be no voltage drop. To illustrate this point connect a voltmeter as shown in Figure 99:

1. Disconnect the load (the motor) from power.
2. Set the meter selector switch to the 4V position.
3. Connect the meter negative lead to a good ground.
4. Probe all parts of the circuit with the meter positive lead.
5. Move the blower motor switch through all positions.

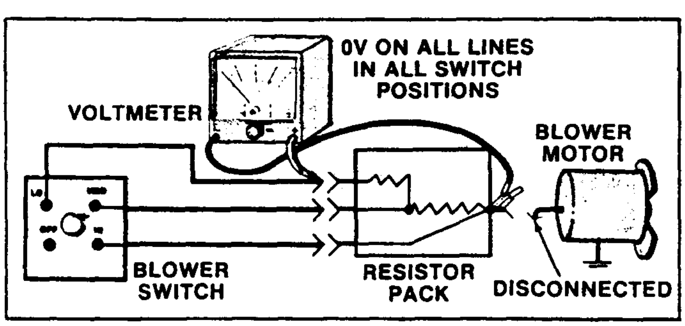



FIGURE 99. NO-LOAD VOLTAGE DROP MEASUREMENT

6. Read the voltage drop on the meter.

You will read zero volts at all points and in all switch modes, again, because there is no voltage drop in a no-load circuit.

## NO-LOAD AVAILABLE VOLTAGE MEASUREMENT

If there is no voltage drop anywhere in a no-load circuit, obviously, available voltage should be the same in all parts of the circuit, regardless of resistances in any part of the circuit. To prove this point connect the meter as shown in Figure 100:

1. Set the meter selector switch to the 20V position.
2. Disconnect the load (motor) from power.
3. Probe all points in the circuit in all switch modes.
4. Read the available voltage on the 20V scale.

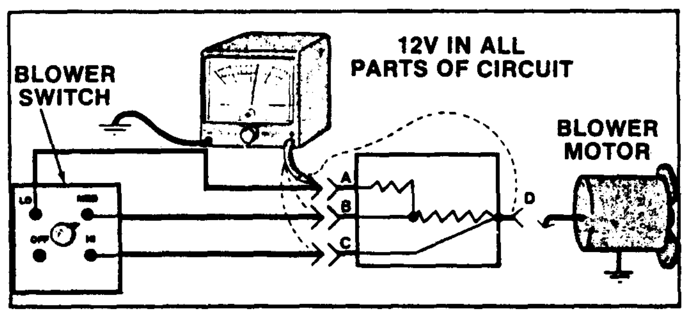



FIGURE 100. NO-LOAD AVAILABLE VOLTAGE MEASUREMENT

You will read 12 volts on all lines in all blower motor switch positions (except OFF). Because all wires (A, B, and C) are connected commonly at point D and because without a load the resistors will not drop the voltage, points A, B, C, and D will always be at the same available voltage regardless of switch position.

## BATTERY-TO-CASE TESTING

Contaminants such as battery acid, dirt, salt, etc., thrown up from the road can settle on the battery case. If not cleaned off periodically these contaminants can accumulate until a circuit is formed between the battery posts or from the positive battery post to ground. When this happens, the battery can be drained of power. To check for this unwanted condition, connect the voltmeter as shown if Figure 101:

1. Set the voltmeter selector switch to the 4V position.
2. Connect the voltmeter positive lead to the positive post of the battery.

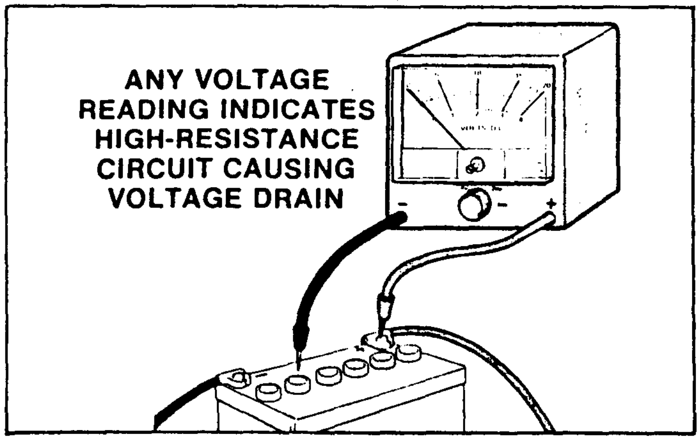



FIGURE 101. BATTERY-TO-CASE TESTING

3. Probe several places on the battery case with the negative meter lead.
4. Observe the meter.

Any reading on the meter indicates a high-resistance circuit that may be draining the battery. The case should be cleaned.

## Battery Cable-To-Post Testing

Corrosion can sometimes develop between the battery post and the battery cable connector. When this happens, a high-resistance can develop which can prevent power flow out of the battery. To check for this condition, refer to Figure 102 and proceed as follows:

1. Set the voltmeter selector switch to the 4V position.
2. Turn on the headlights and heater/AC blower to provide a load.
3. Place the positive meter lead on the positive battery *post.*

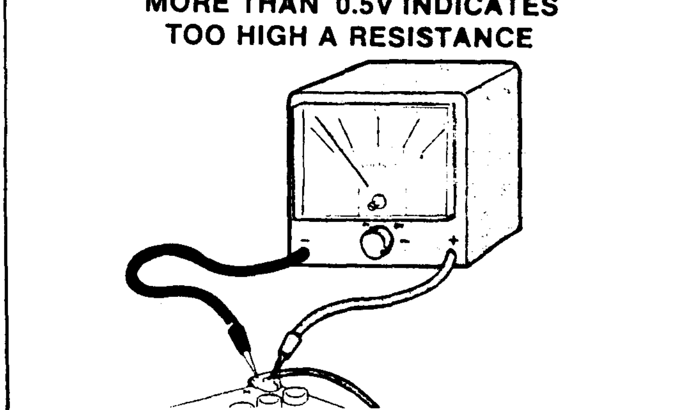



FIGURE 102. BATTERY CABLE-TO-POST TESTING

4. Place the negative meter lead on the positive battery cable *connector.*
5. Read the voltage drop on the 4V scale.
6. Remove the meter leads.
7. Place the negative meter lead on the negative battery post.
8. Place the positive meter lead on the negative battery post cable connector.
9. Read the voltage drop on the 4V scale.

Any voltage drop greater than 0.05 volt, at either post, indicates too high resistance. The battery cables should be removed and both the cable connectors and posts cleaned.

## Battery-To-Sheet Metal Testing

The car body and frame act as the ground circuit for the electrical system. These should be zero resistance throughout the ground circuit. Corrosion, however, at ground straps from sheet metal to the engine block to the battery negative cable, can cause a high resistance in the ground circuit. To check for this condition, refer to Figure 103 and proceed as follows:

1. Set the voltmeter selector switch to the 4V position.
2. Turn on the headlights and heater/AC blower to create a load.
3. Connect the voltmeter negative lead to the battery negative terminal.
4. Probe the sheet metal in several places with the voltmeter positive lead. (Make sure the lead makes contact with bare metal.)
5. Observe the voltage drop on the 4V scale.

Any voltage drop greater than 0.05V indicates a high resistance in the ground circuit. Isolate, clean, and tighten all ground connections.

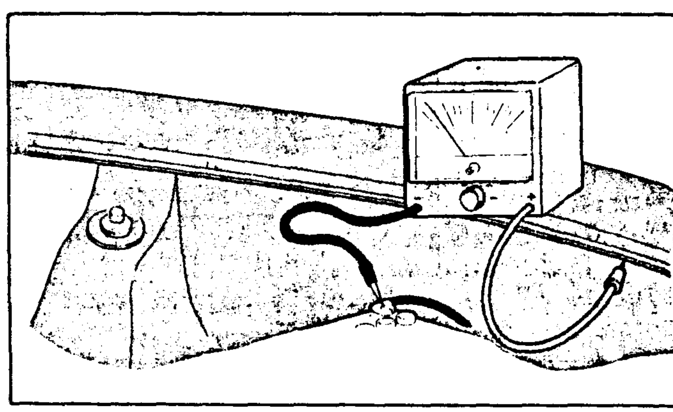


FIGURE 103. BATTERY-TO-SHEET METAL TESTING

## AMMETER

The ammeter is a meter used to measure current (in amperes). Current flow in a circuit varies directly as voltage varies; current flow varies inversely as resistance varies. With that in mind, consider the following:

- More current flows when the charging system is operating. (Voltage is increased.)
- More current flows through a heavily loaded motor.
- Less current flows when control resistors are switched into a circuit. (Resistance is increased, as when the blower motor switch is turned to LO.)
- Less current flows from a partially discharged battery. (Voltage is decreased, as when the charging system is not operating.)

As is true for voltage, when current flow is less lights are dimmer and motors run more slowly.

## USES OF THE AMMETER

At normal operating voltage, most circuits have a characteristic amount of current flow, referred to as current draw. By referring to specified current draw rating, measuring current draw, and comparing the two, much useful diagnostic information can be gained.

### Battery Current Drain Testing

Sometimes a high-resistance short to ground can drain the battery without blowing a fuse. This type of short can be difficult to locate. To verify that there is a high-resistance short to ground, refer to Figure 104 and proceed as follows:

1. Turn off all electrical systems.
2. Disconnect the battery positive cable.

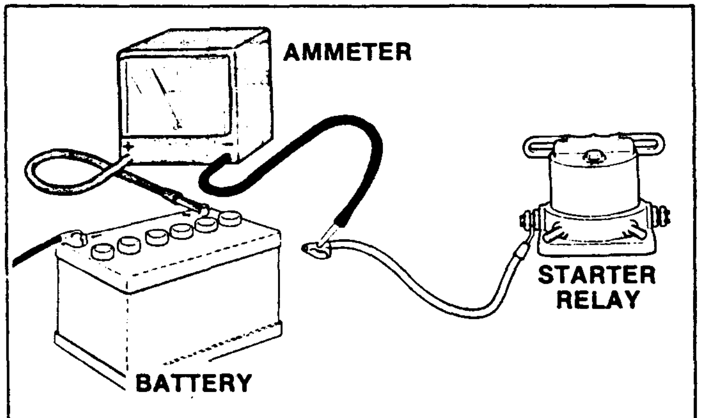



FIGURE 104. BATTERY CURRENT DRAIN TESTS

3. Connect the ammeter between the battery positive post and the removed cable or the cable stud on the starter relay. (Be sure to observe polarity as with the voltmeter.)

   **NOTE:**
   Ammeters come in several different sizes with different amperage scales. Generally, an ammeter with a scale range up to 20 to 30 amps is most useful for automotive systems (except for checking the starting and charging systems). Battery current drain should be checked on a 3- or 4-amp scale when possible.

4. Read the current draw on the ammeter.

There should be no current draw when all electrical systems are shut off. Any current draw indicates a short somewhere in the system.

**NOTE:**
Systems with electric clocks may draw some current for a short period of time. Allow a few seconds for the clock to wind before taking a current draw reading. Digital clocks draw current constantly and should be disconnected while making this test. Anti-theft alarm systems, illuminated entry systems, and the 1974 seat-belt warning systems all draw current constantly. The current draw, however, is in milliamperes, and is usually too small to read on this type of ammeter.

### Circuit Isolation

To find the fused circuit with the undesired short, proceed as follows:

1. Leave the ammeter connected as shown in Figure 104.
2. Pull fuses from the fuse block.
3. Observe the ammeter.

When the ammeter needle drops to zero, the circuit where the short exists has been isolated.

To find a short in an unfused circuit, proceed as follows:

1. Leave the ammeter positive cable connected to the battery positive post as shown in Figure 104.
2. Disconnect the feed wires from the starter relay terminals.
3. Move the negative ammeter lead from one feed wire terminal to another.
4. Observe the meter scale.

The ammeter will show current on the terminal of the circuit having the short.

**NOTE:**
The power distribution system in the wiring diagrams, indicates where to proceed for further diagnosis.

## Motor Current Draw Testing

Motor current draw tests can be used to determine the operating condition of motor driven mechanisms.

Assume you have a problem reported that a left-rear power window runs slowly and stops. Through previous systematic problem isolation you've determined that only the left-rear window has a problem, so you know that the power supply is all right. Through logic then you can assume that the problem lies in:

- A high resistance in the motor circuit
- A worn or damaged motor
- A mechanical bind in the window mechanism

The logical next step is to make voltage drop tests to check for high resistances and current draw tests to check out the motor. Refer to Figure 105.

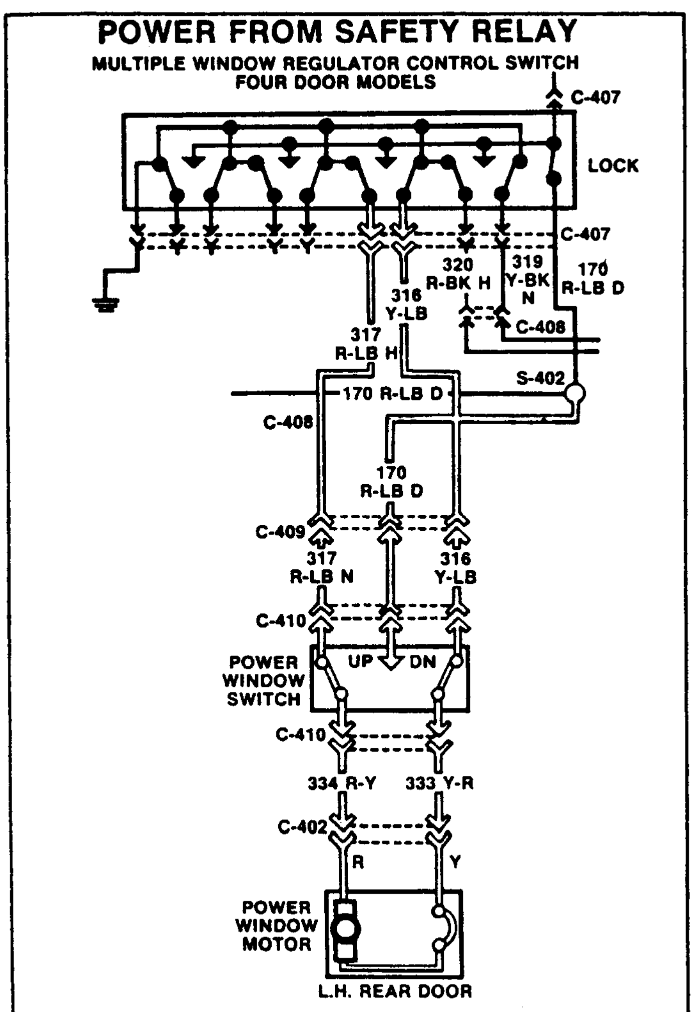



FIGURE 105. POWER WINDOW CIRCUIT (LEFT REAR)

To make voltage drop tests remove the switch from the left rear door panel. To check for a high resistance in the hot circuit to the switch refer to Figures 106 and 107, and proceed as follows:

1. Connect a jumper wire between switch terminals 170 and 333.
2. Connect a jumper wire between switch terminals 334 and 317.
3. Connect the voltmeter negative lead to terminal 170.
4. Connect the voltmeter positive lead to battery power.
5. Read the voltmeter on the 4V scale.

A high reading would indicate a high resistance in the hot circuit to the switch. For the purposes of this discussion, however, assume that the reading is very low. The hot circuit, therefore, is OK.

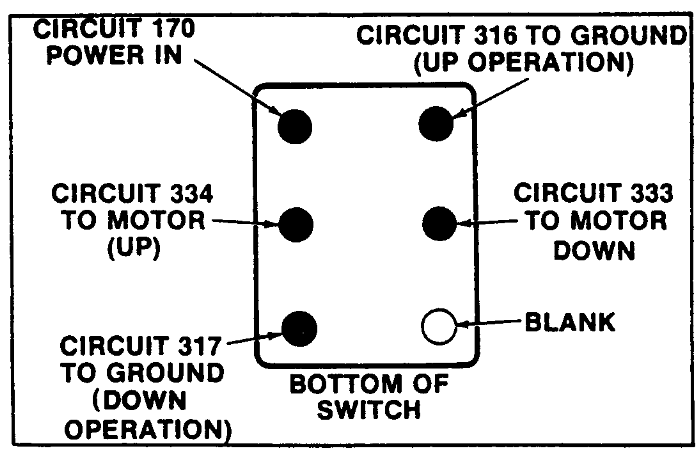



FIGURE 106. CIRCUIT CONNECTIONS AT LEFT REAR POWER WINDOW SWITCH

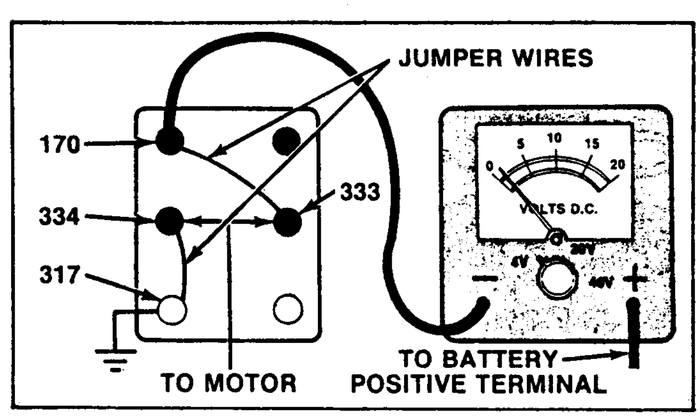



FIGURE 107. VOLTAGE DROP TEST BETWEEN HOT CIRCUIT AND SWITCH

The logical next step is to check voltage drop in the ground circuits. Refer to Figure 108 and proceed as follows:

Connect a jumper wire between switch terminals 170 and 334.

Connect a jumper wire between switch terminals 333 and 316.

Connect the voltmeter negative lead to ground.

Connect the voltmeter positive lead to switch terminal 333.

Read the meter on the 4V scale.

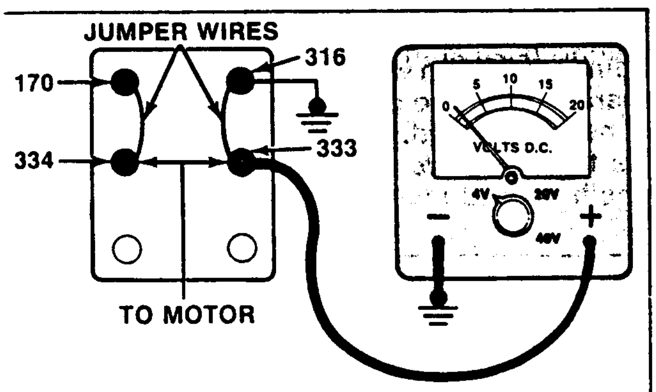



Fig. 108. VOLTAGE DROP TEST BETWEEN MOTOR AND GROUND (UP OPERATION)

Again, a high reading indicates a high resistance. Assume again, however, that the reading is extremely low, which indicates that the circuit from the door switch through the master switch to ground, for UP operation, is OK.

Refer to Figure 109 and proceed as follows to check the ground circuit for DN operation:

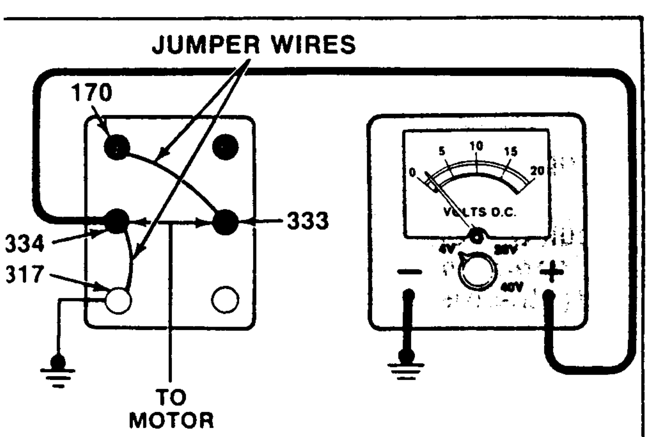



Fig. 109. VOLTAGE DROP TEST BETWEEN MOTOR AND GROUND (DN OPERATION)

1. Connect a jumper wire between switch terminals 170 and 333.
2. Connect a jumper wire between switch terminals 334 and 317.
3. Connect the voltmeter negative lead to ground.
4. Connect the voltmeter positive lead to switch terminal 334.
5. Read the meter on the 4V scale.

Again, assume a low reading, indicating the circuit from the door switch through the master switch to ground is OK for DN operation.

This indicates that, if a high resistance exists, it will have to be between the switch and motor. You could check this by removing the door panel and performing further voltage drop tests. To save time, however, it is more logical to perform motor current draw tests while you are at the switch.

To perform the motor current draw test for UP operation, refer to Figure 110 and proceed as follows:

1. Connect a jumper wire between switch terminals 333 and 316.
2. Connect the ammeter negative lead to switch terminal 334.
3. Connect the ammeter positive lead to switch terminal 170.
4. Read the meter.

Specifications call for a 4-amp normal current draw. Assume that 4 amps are read, indicating that the motor is OK.

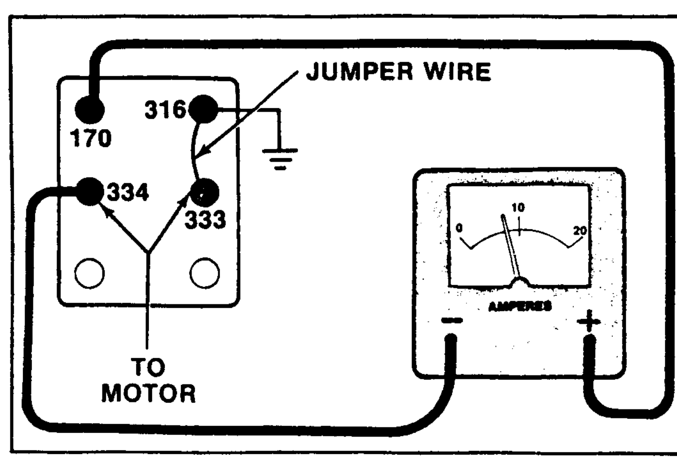



FIGURE 110. MOTOR CURRENT DRAW TEST (UP OPERATION)

To check motor current draw for DN operation refer to Figure 111 and proceed as follows:

1. Connect a jumper wire between switch terminals 334 and 317.
2. Connect the ammeter negative lead to switch terminal 333.
3. Connect the ammeter positive lead to switch terminal 170.
4. Read the meter.

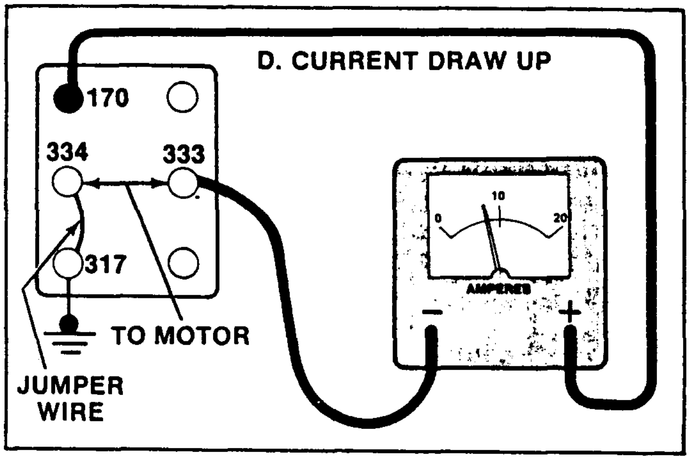



FIGURE 111. MOTOR CURRENT DRAW TEST (DN OPERATION)

Assume an 8-amp reading. This indicates that the circuit is overloaded. A high resistance in the motor circuit is eliminated as a problem because that would *reduce* current draw. The motor, itself, was proved OK in the UP current draw test. The problem, then, is probably a binding window mechanism.

**NOTE:**
Notice that all the ammeter tests are conducted with the ammeter in series with the circuit — between the power source and ground. Notice also that all of the voltmeter readings are taken with the meter connected in parallel with the circuit — across the circuit being checked. Current readings are *always* taken in *series.*

## Summary of Problem Isolation

To reinforce some of the points made in the above discussion, when performing diagnosis:

1. When only *one component* in a system does not operate, begin diagnosis at the *component.*
2. If a component does not operate properly, always check the ground.
3. When *several components* in a circuit do not operate, begin diagnosis at the *common source of power, or common ground* (if there is one).
4. Where possible, always check at *accessible points* before difficult-to-reach points.

Sometimes a technician who is not used to performing electrical diagnosis is reluctant to tackle an electrical repair job. He has some misgivings because he feels he doesn't understand electricity. But what he really doesn't understand is that electric diagnosis is easy; that is, it's easy provided such diagnosis is undertaken in a systematic manner.

## THE SYSTEMATIC APPROACH TO DIAGNOSIS AND REPAIR

Unless the cause of an electrical problem is immediately apparent, it is always advisable to start at the start, and to follow tried and proven techniques. The sure-fire approach to electrical diagnosis and repair, is to adhere closely to the following six basic steps:

1. Verify the complaint.
2. Define the type of problem.
3. Isolate the problem.
    - Trace the circuit
    - Use logic
    - Test systematically
4. Validate the cause of the problem.
5. Repair the cause of the problem.
6. Test the repair.

## VERIFYING THE COMPLAINT

Verifying the complaint is a valuable and necessary step in conducting an electrical diagnosis. Verifying the complaint tells you two important things: first, it shows you that there is, indeed, a problem; second, it permits you to find out much about the problem at first glance.

Most owners do not give accurate and detailed descriptions of their car's problems. If a driver has a problem in his car's lighting system, for instance, he'll usually report something such as, "The lights don't work." This sort of description really doesn't tell you much about the real nature of the problem. So you must verify the problem — check it out — to find out just which light or lights "don't work," which lights do work, and other possibly related symptoms. By thus verifying the problem, you'll actually be well on your way to isolating the problem area. You'll know, for instance, whether the problem is in one, or more, or all of the headlights, taillights, parking lights, sidemarker lights, etc. This gives you a good indication of where to start your diagnosis. If one headlight is out, for instance, it's an entirely different problem than if both headlights are out, or if all the lights are out.

## DEFINING THE TYPE OF PROBLEM

The second step in a systematic approach to diagnosis and repair is to define the type of problem. As shown in Figure 112, a typical circuit is composed of a battery, conductors, a fuse, a switch, and a load (in this case a light bulb), and a ground. In this circuit, or any circuit, only three possible things can go wrong and cause a problem (Figure 113):

1. An open circuit
2. A short circuit
3. A high resistance

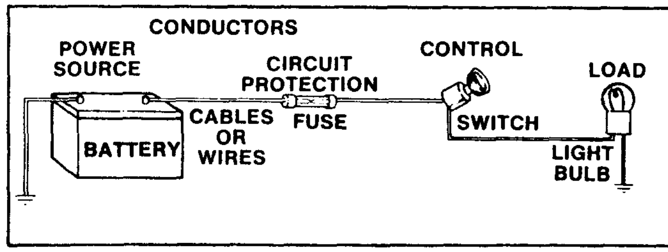



FIGURE 112. TYPICAL CIRCUIT

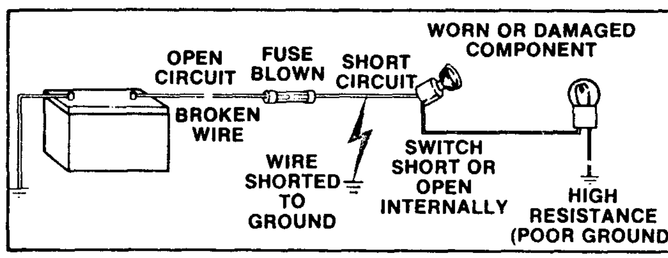



FIGURE 113. POSSIBLE PROBLEMS IN A TYPICAL CIRCUIT

A worn or damaged load usually shows up as an open, short, or high resistance. Often you can tell at a glance just what the source of the problem is.

### Open Circuit

As covered earlier in this manual, power will not flow in an open circuit because there is no complete path for the current from and to the power source. The following are examples of open circuits (Figure 114):

1. Broken or loose conductors or connectors.
2. Blown fuses or popped circuit breakers.
3. Internally open components such as switches, bulbs, etc.
4. *Extremely* high resistances, which often cause the same symptoms as the other types of open circuits.

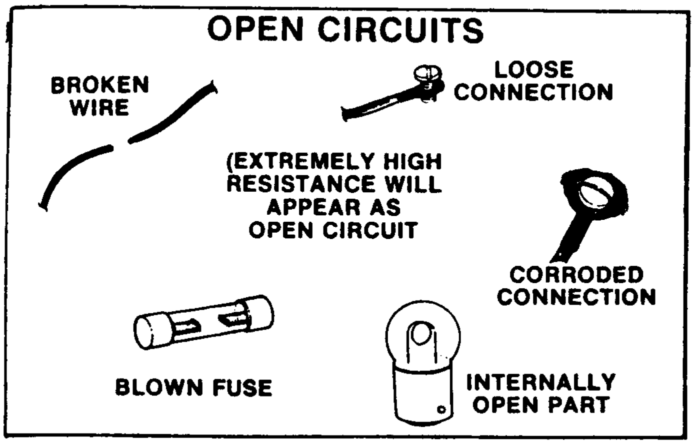



FIGURE 114. TYPICAL EXAMPLES OF OPEN CIRCUITS

Opens due to broken wires are usually caused by accidental damage or vibration. If damaged, the problem is usually visually apparent. Often, however, if the wire is broken by vibration, it is broken within its insulated covering and can only be discovered by testing.

Normal wear will cause certain parts, such as light bulbs, to open internally (burn out). The same normal wear will also cause other parts, such as switches and motors, to become open internally after extended use. If such parts wear out after limited service, however, you might suspect some other cause, such as overloads in the circuit.

In diagnosing open circuits, inspect for obvious causes such as cut or kinked wires, frayed insulation, and corroded terminals and connectors. Corrosion causes a high resistance, and a resistance that is extremely high will often act exactly like an open.

One of the most bothersome types of opens is the intermittent type of open. Intermittence may be caused, for instance, by a wire that has broken within its insulation but still is making contact while the car is stopped. Then, when the car is moving and vibrating, the intermittence occurs. In searching for this type of open, you should wiggle the circuit wiring around with your hand to see if you can cause the open symptom to come and go.

Blown fuses and popped circuit breakers show up as open circuits. These circuit protection devices open because of overloads. You can spot a blown fuse easily by looking at it. A blown fuse or popped circuit breaker is, however, a *symptom* of a short or overload somewhere in the circuit.

## Effects of Opens on Voltage and Current

In a normally operating circuit, such as the simple parallel circuit shown in Figure 115, the left branch is receiving power; current flows through lamps 1 and 2; and, if tested with a voltmeter, the circuit would read 12 volts on the hot side and zero voltage on the ground side. Because the right branch of the parallel circuit is open at the switch, it is not powered.

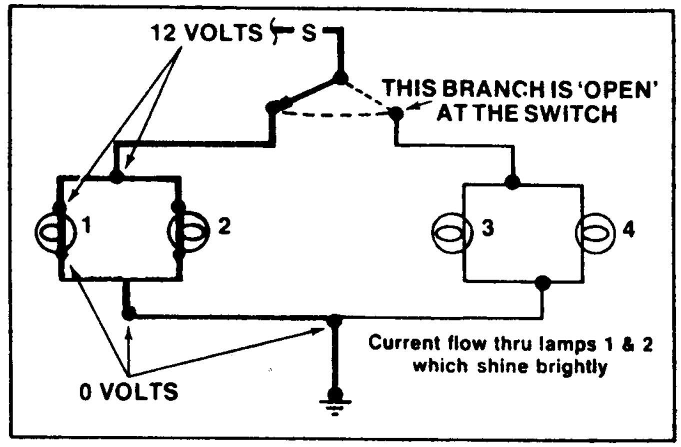



FIGURE 115. NORMALLY OPERATING SIMPLE PARALLEL CIRCUIT

If an open occurs in the ground side of the powered branch, as shown in Figure 116, the continuous path for electricity is broken, so no current flows. Voltage will be at 12 volts at all parts of the circuit between the power source and the open. The lesson to be learned from this example is that in a *simple* series or *simple* parallel circuit, when open, *no current will flow and all points that are connected to the power source will be at source voltage.* This is demonstrated in the section on the use of the voltmeter in the section on "Test Equipment."

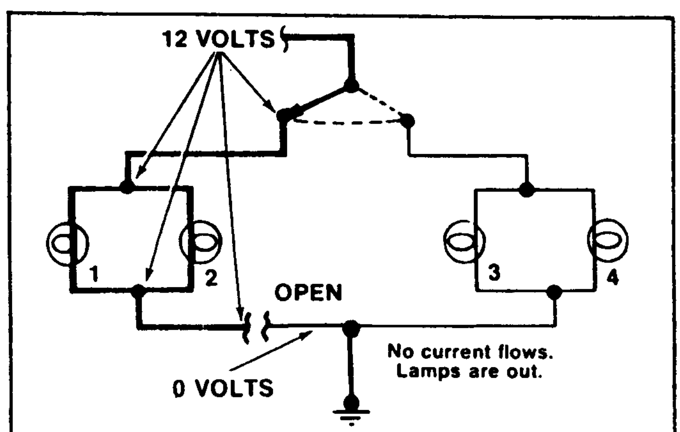



FIGURE 116. SIMPLE PARALLEL CIRCUIT WITH OPEN IN GROUND SIDE OF POWERED BRANCH

In more complex circuits, however, opens often have different effects on voltage and current. Figure 117 illustrates a variation of the circuit shown in Figures 115 and 116. When this circuit is operating normally, as in Figure 117, lamps 1 and 3 are powered when the switch is as shown. In this circuit, when an open occurs in the ground side of the powered branch, such as shown in Figure 118, an *alternate* path to ground exists through lamps 2 and 4. Lamps 1, 2, and 4 then are in series, and all are in parallel with lamp 3. The higher resistance in the series branch of the circuit will cause lamps 1, 2, and 4 to glow dimly, while lamp 3, having less resistance will glow brightly. Voltage reading will be 12 volts at both lamp 1 and lamp 3. In diagnosing for opens, therefore, it is helpful to study the wiring diagrams for common points in the circuit and to look for alternate current paths.

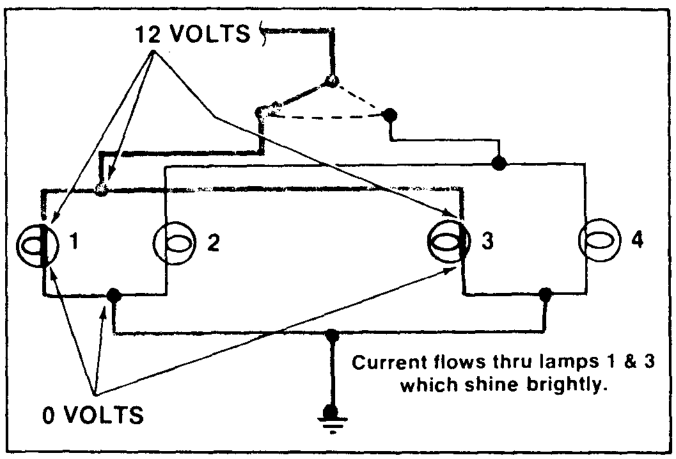



FIGURE 117. NORMALLY OPERATING COMPLEX PARALLEL CIRCUIT

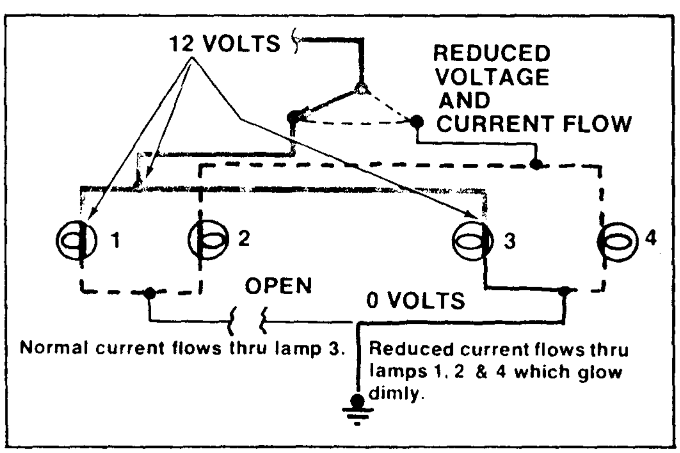



FIGURE 118. COMPLEX PARALLEL CIRCUIT BECOMES SERIES-PARALLEL CIRCUIT WITH OPEN IN GROUND SIDE OF POWERED BRANCH

## SHORT CIRCUIT

To repeat what was covered earlier, a short circuit occurs whenever a circuit is completed in a way that was not designed. Short circuits are most noticeable when they create an accidental current path which bypasses the current away from the load or the control device.

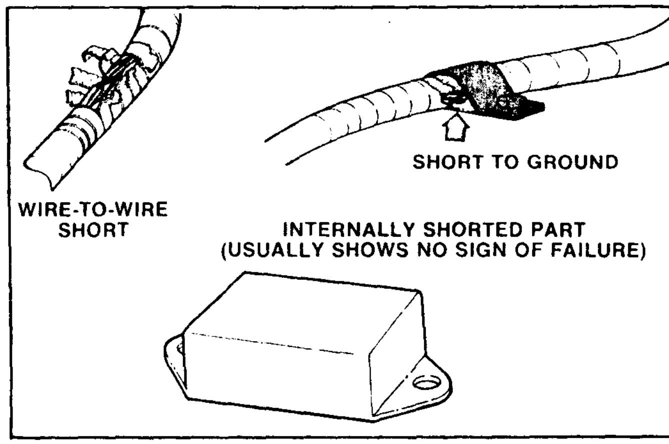



FIGURE 119. TYPICAL SHORT CIRCUITS

Short circuits (Figure 119) happen whenever a "hot" conductor accidentally makes contact with another conductor or with ground. Parts can also be shorted internally. Depending on the type of short (wire to wire, or hot wire to ground), you'll actually get two different types of symptoms. The wire-to-wire short often may cause some funny things to happen. The wiring for the turn signals and the horn, for instance, is in the steering column harness. If a certain couple of wires within this harness become shorted together, the horn could sound whenever the turn signal lever was moved. Figure 120 illustrates how this could happen. A short in the steering column harness (or

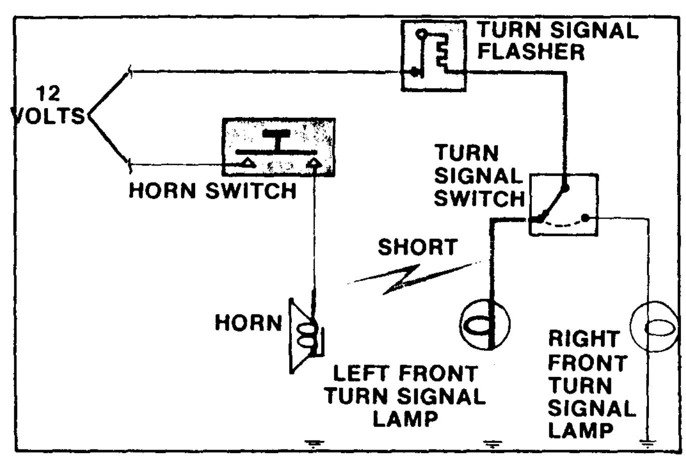



FIGURE 120. TYPICAL WIRE-TO-WIRE SHORT CIRCUIT

any harness) is usually caused by pinching or crushing the harness, damaging the insulation or adjacent wires. If the two wires shown in Figure 120 make contact the horn will blow intermittently whenever the left turn signal is turned on and the left turn signal will flash whenever the horn button is pressed.

A short to ground, depending on where it occurs, will have different effects. Refer to Figure 121. If a short to ground occurs at point A in Figure 121, the load and both switches will be bypassed. The circuit will be overloaded (zero resistance will cause an extremely high current flow), and the fuse will blow. Obviously, even if the fuse did not blow, the light would not operate even if both switches were closed. Current takes the path of least resistance; very little current, therefore, would flow through the resistance of the load.

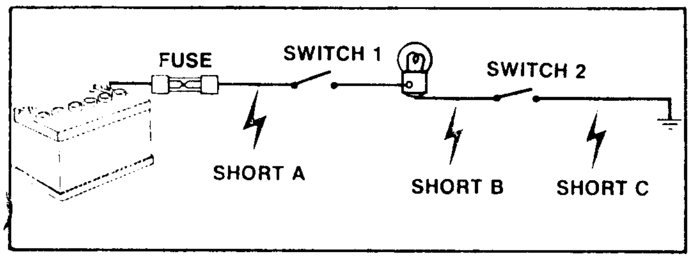



**FIGURE 121. EFFECT OF SHORTS IN DIFFERENT SEGMENTS OF A CIRCUIT**

If the short occurred at point B in Figure 121, only switch No. 2 would be bypassed. If switch No. 1 is closed, the light bulb will operate, regardless whether switch No. 2 is opened or closed. Current does flow through the load, and the circuit, therefore, is not overloaded. So, the fuse will not blow. The only thing that happens is that switch No. 2 becomes ineffective and the light bulb operation can only be controlled by switch No. 1.

If a short should occur at point C in Figure 121, nothing out of the ordinary would happen. Only the designed ground is bypassed, but an alternate path to ground is provided by the short. In effect, therefore, there is no apparent problem.

Like open circuits, short circuits are usually caused by accidental damage or wear due to conductors being pinched against sheet metal by clamps or components, fasteners driven through wires, wires routed over sharp metal edges which cut or chafe through insulation, misplaced metal parts which contact uninsulated portions of wires, etc.

Loads may become shorted internally due to extended overloads.

When inspecting for suspected short circuits, look for obvious fraying or bare wires. Like intermittent open circuits, intermittent short circuits are the most difficult type to isolate. Use the same technique — wiggling the wires — to see if you can cause the symptoms to come and go.

Also, be sure to relate the symptoms of the short circuit to its probable location. As illustrated in Figure 122:

- A short between the power source and the load will blow a fuse. (If the circuit is unfused the conductor will overheat, the insulation will melt, and the wire will probably burn in two.)
- If there is a switch between the load and ground (as with engine warning lights), and the short is between the load and the switch, the load will be on constantly.
- If the short is between all components and ground, it will have no effect. (In all probability, no problem will be reported.)

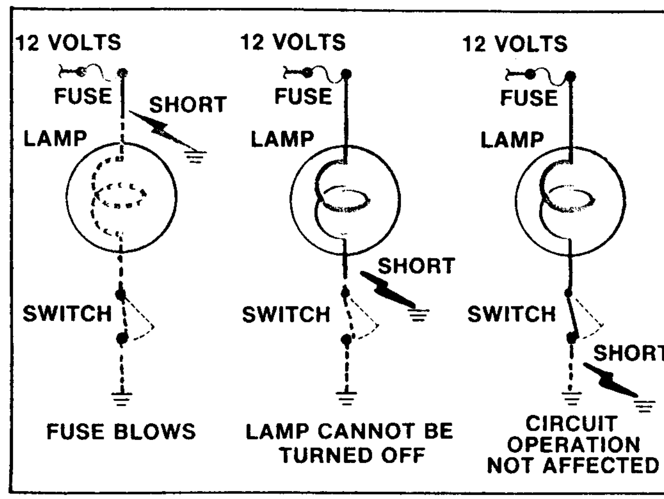



**FIGURE 122. EFFECT/LOCATION RELATIONSHIP OF SHORT CIRCUITS**

## High Resistance

A high resistance, in terms of a problem, is any resistance in the circuit that is higher than it is designed to be. High resistances (Figure 123) often occur due to corrosion, looseness, or inadequate contact area at terminals, connectors, and grounds. High resistances can also occur internally in components.

A high resistance, in effect, creates a load. The extra load in the circuit, in turn, causes the other loads in that circuit to operate at reduced power.

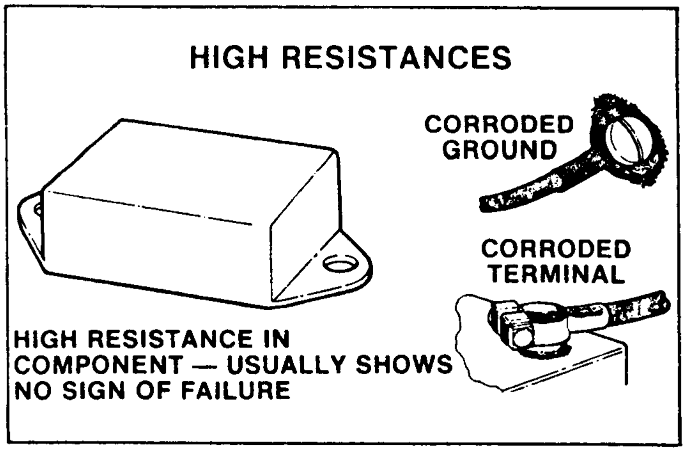



FIGURE 123. TYPICAL EXAMPLES OF HIGH RESISTANCES

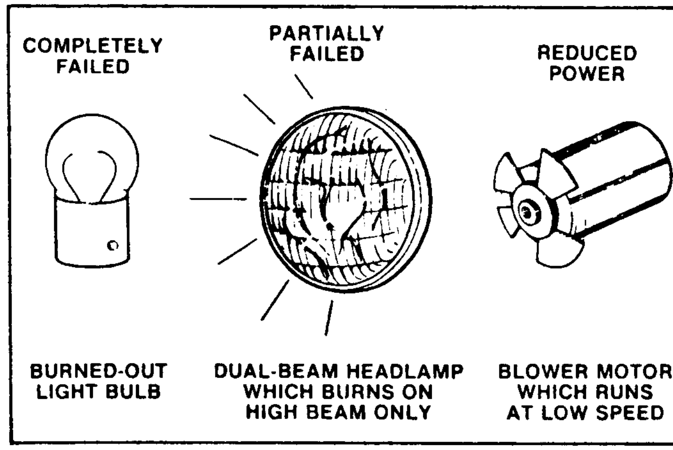



FIGURE 124. TYPICAL WORN OR DAMAGED LOADS

Thus, where a high resistance exists, lights will glow dimmer, motors will run slower, etc. In extreme cases, high resistances may act exactly like open circuits. If a ground terminal becomes excessively corroded, for instance, its resistance (which is designed to be zero) may become so high that none of the loads in the circuit will operate at all.

High resistance at connectors, terminals, and grounds is usually caused by water, road salt, etc., or by the insulating properties of oil, grease, or dirt that gets into tl e connection. Loads that develop high resistances may do so because of damage, wear, overloads, or vibration. This internal resistance, like all internal damage, is difficult to spot. Corrosion, oil, etc., in connectors, terminals, and grounds are sometimes visible, but often hard to see with the naked eye. This type of high resistance must be checked with test equipment.

## Worn or Damaged Load

If the load is worn out or damaged (Figure 124), sometimes you can tell so just by looking at it. In a light bulb, you can sometimes see a burnt-out filament or some discoloration. In a motor, you can sometimes see evidence of burning. Often, however, the load shows no evidence of failure. When this occurs, you have to rely on your observation of the entire system, logic, and, particularly, testing to determine that the load has failed. If through observation, you suspect that a part has failed, proceed as follows to make sure:

1. Check that there is power to the component. (See use of jumper wires to provide power, as explained later.)
2. Check that the component is properly grounded.
3. Test systematically to isolate the problem.

## ISOLATING THE PROBLEM

After you've verified and defined the type of problem you're faced with, you must next isolate the problem. Isolating the problem involves, essentially, separating the circuit into simpler circuits. You can separate complex circuits into simpler circuits by two methods — physically by pulling apart connectors, etc., or mentally (and this is where your use of logic is important) by reference to wiring diagrams. Reference to the wiring diagrams allows two significant time savings:

1. The wiring diagrams allow you to separate complex circuits into simpler circuits without physically touching the vehicle.
2. The wiring diagrams allow you to perform some diagnosis mentally, without using test equipment. Testing may be time consuming, particularly if done in inaccessible areas.

Remember the example cited earlier: if one headlight is out, it's an entirely different problem than if both headlights are out, or if all the lights are out. The wiring diagrams and logic, of course, will tell you that if only one headlight is out, the problem is most likely a burnt-out headlamp, or at least that it can be found no further away than the wiring splice or connection that provides power to both headlights, or the headlight ground. Often by merely looking at the wiring diagram for a particular system, you can eliminate much of the complex circuit as being non-involved in the problem, and concentrate further diagnosis only on the branches that could possibly be the source of the problem. Consider Figure 125. This is a relatively complex circuit, in which three simpler circuits (backup lamp, turn signal, and air conditioning) are fed power through the ignition

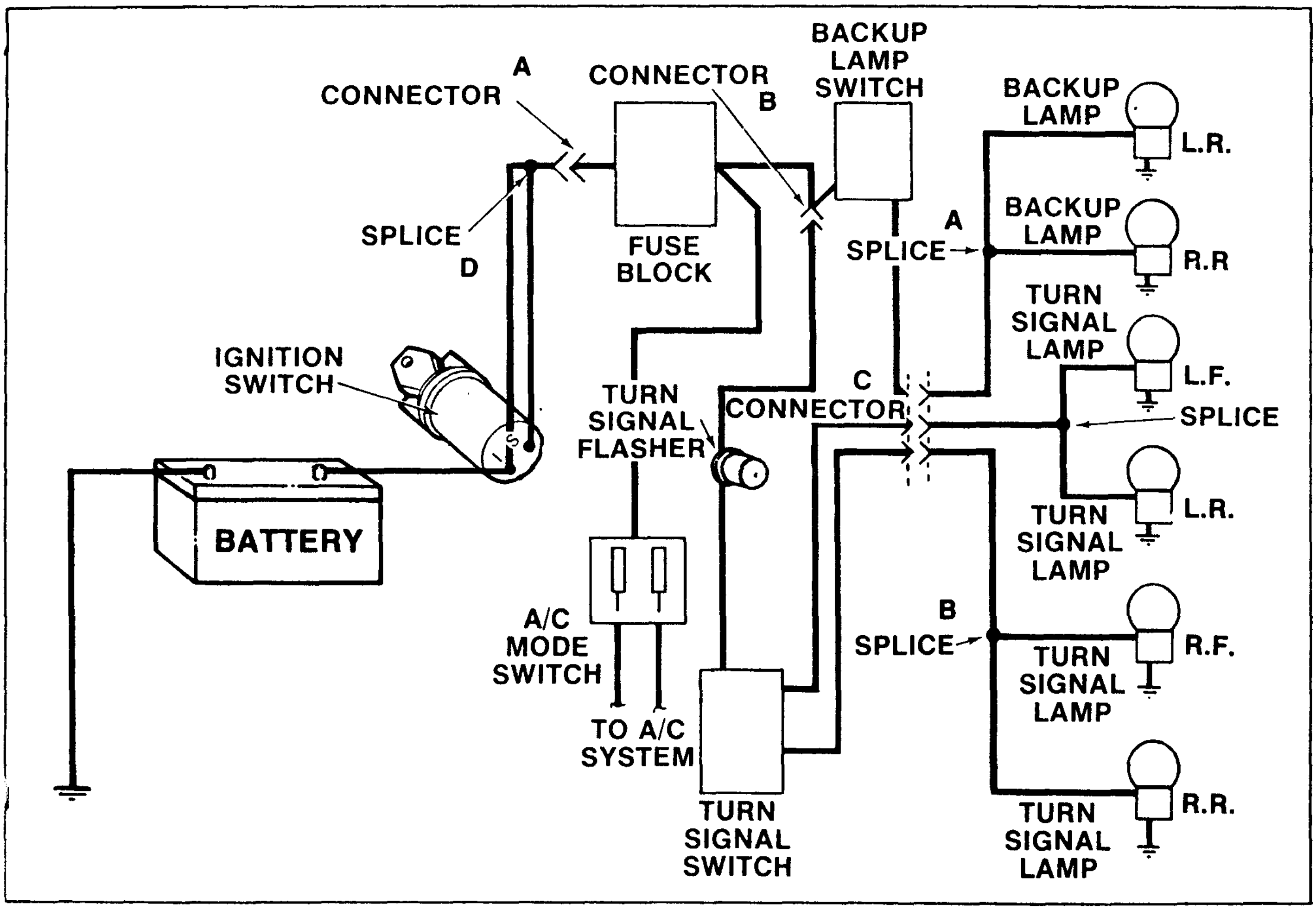



FIGURE 125. BACKUP LAMP, TURN SIGNAL LAMP, A/C SYSTEMS ON SAME CIRCUIT

switch, connector A, and the fuse block. We have previously seen that there are only four things that can go wrong with a circuit (open circuit, short circuit, high resistance, inoperative load). And we've also seen how to identify the type of problem. Now we have a look at where these types of problems can occur. They can occur in four places in the circuit:

1. At the load
2. Somewhere between the load and the power source
3. Somewhere between the load and the ground
4. At the power source

If you can correlate your identification of the problem type with your isolation of the problem area you'll be well on your way to fixing the problem.

## Problems at the Load

An inoperative load is generally the easiest type of problem to isolate. Referring again to Figure 125, if the RR backup lamp failed to operate, while the LR lamp did operate, the RR lamp is probably burnt out. But you could also have a problem between the load and splice A or between the load and ground.

## Problems Between the Load and Ground

If the RR backup lamp did not operate while the LR did, there could be an open circuit between the lamp and ground. This can be checked by testing as described in the section on test equipment. Poor grounds cause most of the problems in automotive electrical systems, so your next check should always be to determine if the ground is good. If it is good, the problem may be somewhere between the load and the power source.

## Problems Between the Load and Power Source

If power is not getting to the RR lamp, there must be an open somewhere between the battery and the lamp. You could start checking the power flow to the lamp from the battery, to the ignition switch, to connector A, to the fuse block, to connector B, to the backup lamp switch, to connector C, to splice A, to the RR lamp. By doing so you would be separating the circuit into simpler circuits and doing an effective job of diagnosis; you would also be wasting a lot of time.

Logic tells you that, if the LR backup lamp is working, the circuit has power to splice A. Obviously, then if there is no power to the RR lamp, the open must be between splice A and the RR lamp.

Generally, therefore, if only one component in a system is inoperative, start diagnosis at the component. Again, however, this advice must be tempered by logic. For example, if a power window motor does not operate, do not begin diagnosis of the problem by taking apart the door to get at the motor. To save time, start by checking the power window switch and other more accessible points between the switch and power source. Don't perform the time-consuming tasks until previous testing has isolated the problem to the motor itself.

Applying logic to diagnosis of the entire circuit shown in Figure 125, you see that if *none* of the lamps work, certainly the lamps themselves and their individual grounds are not the problem. If the A/C system operates properly, while none of the lamps light, the problem is isolated to somewhere between the fuse block and connector C. And, most likely, because the backup circuit and turn signal circuit are *both* inoperative, the individual components (backup lamp switch and turn signal flasher and switch) are also all right. The problem, then, is isolated to either connector C or the wire between the fuse block and connector B.

When several components in a circuit are inoperative, therefore, begin your diagnosis at the common source of power (the wire between the fuse block and connector B, or connector C).

### Problems at the Power Source

Problems at the power source, like problems at the load, are usually easy to diagnose because everything supplied by the power source will be inoperative. If nothing electrical operates, therefore, you know you have a dead battery, damaged battery cables, perhaps a bad ground cable connection, or perhaps a bad connection at the starter terminal.

Although the battery is the ultimate power source, you can consider such things as the ignition switch, fuses, other switches, and splices as secondary power sources. If, referring to Figure 125 again, none of the lights worked and the A/C system also didn't work, while other systems fed off the ignition switch *did* operate, you should consider the fuse feeding backup/turn signal/A/C circuits as the power source and start diagnosis there.

The beautiful advantage in using the wiring diagrams to separate the circuits into simpler circuits, mentally, is that you can do it quickly, without touching the car or test equipment, and thereby save a lot of motion as well as a lot of time.

## TEST SYSTEMATICALLY

Sometimes problems cannot be isolated or, rather, can be isolated only so far by using logic and the wiring diagrams. In these cases, the various types of test equipment at your disposal become invaluable. In order to use the test equipment effectively, however, you often will have to separate the circuits, physically, into simpler circuits.

### Separation into Simple Circuits

For testing, circuits can be separated into simpler circuits by either of two methods: separation at connectors and switches, or by cutting and resplicing when finished.

### Separation at Connectors and Switch

To simplify a circuit by separating at connectors, you merely pull apart the connector to gain access to the connector terminals for testing purposes (Figure 126). Simpler circuits can also be

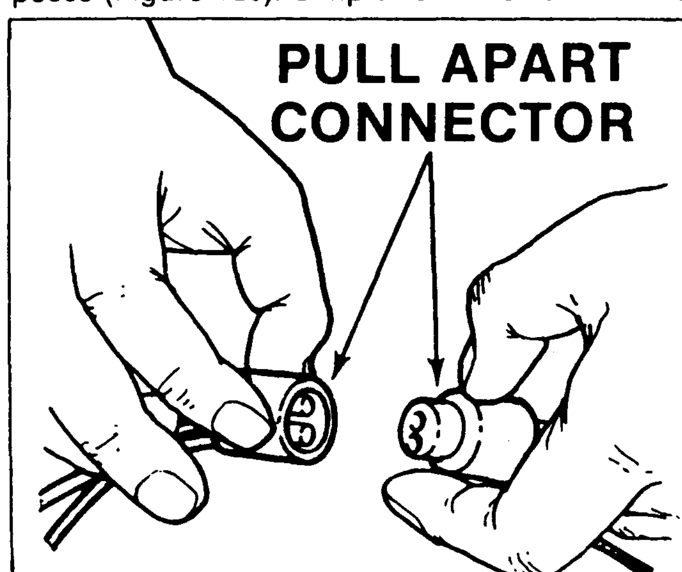



FIGURE 126. SEPARATING A CIRCUIT AT A CONNECTOR

achieved by opening switches in the circuits. The circuit shown in Figure 127 can be separated into three simpler segments (segments A, B, C) just by opening switch 1 and switch 2. By opening both switches and removing the fuse and bulb as well, the circuit is separated into five segments.

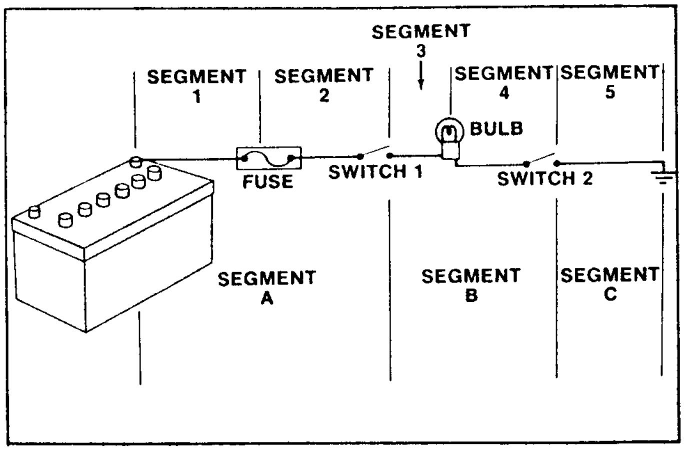



FIGURE 127. SEPARATING A CIRCUIT INTO SIMPLER CIRCUITS

## CUTTING AND SPLICING

In some areas the circuit can be made more simple only by cutting wires. This method is used as a last resort when the circuit must be made simpler than can be done by opening switches, connectors, etc., or in areas where there are no convenient means of opening the circuit. Once you cut the wire, strip the insulation from the wire ends to attach the test equipment. After testing the circuit, slip a butt connector onto the exposed wire ends and securely crimp on a butt connector (Figure 128). Whichever method you use, the whole purpose is to simplify the circuit to make the most effective use of your test equipment.

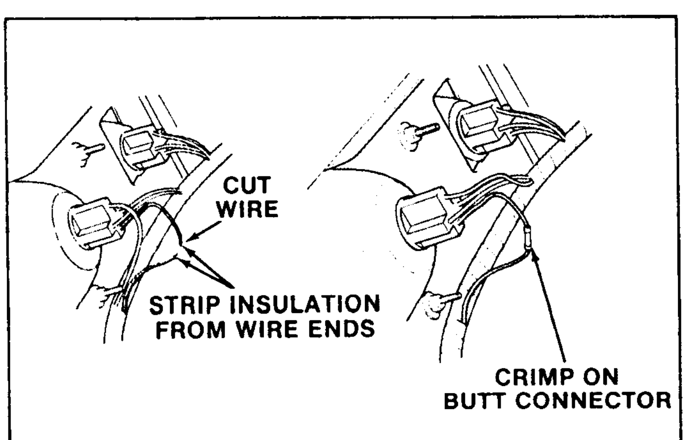



FIGURE 128. CUT AND SPLICE METHOD OF CIRCUIT SEPARATION

## VALIDATING THE CAUSE OF THE PROBLEM

The fourth step in the systematic approach to diagnosis is to validate the cause of the problem. This means that, after you have isolated a problem by using the wiring diagrams and/or test equipment, you test to confirm that, by correcting the condition you have found, you do, in fact, eliminate the original complaint in *all modes of operation*. Actually, this is merely the first step in repairing the problem.

## REPAIRING THE CAUSE OF THE PROBLEM

Step number five in the systematic approach is to make the repair. It is assumed that the user of this manual, having validated the cause of the problem can perform such repairs as replacing electrical parts. Repairing wiring calls for some special techniques which are explained in the section on repair.

## TESTING THE REPAIR

The sixth and final step in the systematic approach to diagnosis and repair is to check that the repair does,indeed, correct the problem. The final checkout should be thorough to avoid the possibility of a comeback. When making the final checkout of the repaired system, be sure to check, not only the area of repair, but also all other possibly related systems. Often, particularly in the case of intermittent problems, a road test may be necessary to assure that the problem does not recur under dynamic conditions.

## SUMMARY OF THE SYSTEMATIC APPROACH

The importance of using a logical and systematic approach cannot be over-emphasized. Compared to the diagnosis-by-the-seat-of-your-pants methods used by some technicians, the approach just described will save you much time and effort.

Here is a good example of a haphazard approach that's been taken an untold number of times, often by technicians who consider themselves pretty sharp. When one turn signal lamp goes out, for instance, almost everyone's first instinct is to change the bulb. That's not an approved method of diagnosis and repair, but it's not a bad idea; it's a fast method for light bulbs. But when replacing the bulb doesn't fix the problem, often the next instinct is to replace the flasher, and then to think about the switch. Actually, most of the time, when the lamp isn't burnt out, the fault is a poor ground at the lamp. So you can see how the parts-replacement method can lead to wasted time and expense.

# REPAIR

Repairs to wiring and connectors require some special techniques that you may not be familiar with.

## WIRING REPAIRS

In making wiring repairs it is important that you always replace wires with wires that are at least as heavy. Wire gauge numbers are inverse to their weight. (A 14-gauge wire is heavier than an 18-gauge wire.)

Wires are color-coded to aid in identification. When possible, use wires with the same color code as the wires being replaced.

## STRIPPING AND CRIMPING

A standard wire-stripping and crimping tool is shown in Figure 129. This tool has three working areas for cutting, stripping, and crimping. Note that the tool has different sizes for stripping and crimping. The terminal and butt connectors, shown in Figure 130, are color-coded according to the wire gauges they accept:

- Red = 18 to 22 gauge
- Blue = 14 to 16 gauge
- Yellow = 10 to 12 gauge

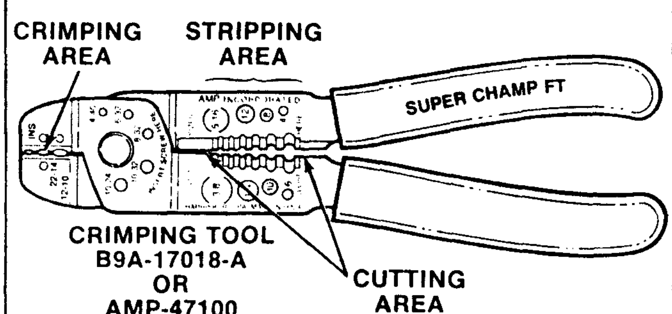



FIGURE 129. STANDARD STRIPPING/CRIMPING TOOL

To strip a wire and crimp on a connector:

1. Using the proper-size stripping hole to avoid cutting or nicking the wire strands, strip enough insulation off the wire to get full penetration of the wire into the connector.
2. After selecting the proper-gauge connector, crimp it on securely in the area of the stripped wire using the proper hole on the tool.

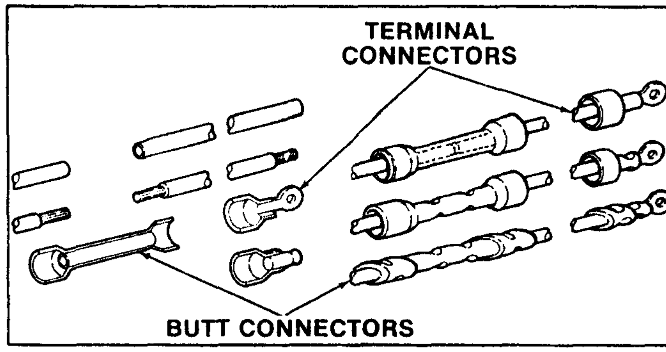



FIGURE 130. TERMINAL AND BUTT CONNECTORS

3. Also crimp the connector in the area of the wire insulation. (Two crimps on terminal connectors, four crimps on butt connectors.)
4. In areas where the connector will be exposed to weather, securely tape the joint to keep out moisture.

To test the crimp pull on the wires. It should not be possible to pull the wire out of a good crimp. Use an ohmmeter to check resistances across the joined wires or across the terminal and wire. There should be no measurable resistance from one side of the crimp to the other.

## SPLICING WIRES

Wires which are open, exposed, or otherwise damaged are repaired by simple splicing. Where possible, if the wiring harness is accessible and the damaged place in the wire can be located, it is best to open the harness to check for all possible damage.

In inaccessible harnesses, however, such as shown in Figure 131, the harness must be bypassed as follows:

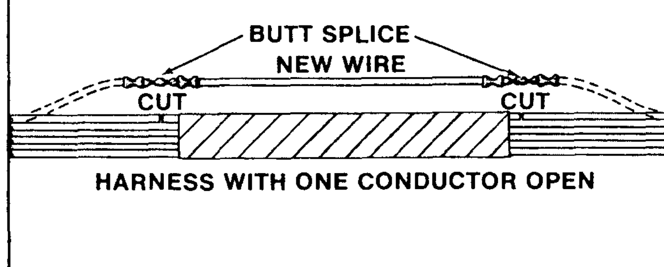



FIGURE 131. WIRE SPLICE BYPASSING INACCESSIBLE HARNESS

1. Locate both ends of the damaged wire.
2. Cut the wire near both ends of the harness wrapping.
3. Crimp a sufficient length of new wire at both cuts, bypassing the harness.
4. Tape the exposed ends and connections.

When replacing fuse links (Figure 132) be sure to use released (14526) fuse-link wire — *never* ordinary wire. Use a fuse link wire that is four gauge sizes smaller than the wire in the circuit. (If the circuit wire is 14 gauge, use 18 gauge fuse link.). When crimping 16-, 18-, or 20-gauge fuse link to a heavy-gauge wire, always double the stripped end of the fuse link to improve contact and retention after it is crimped.

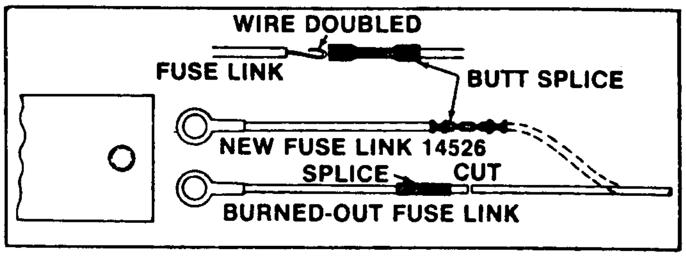



FIGURE 132. SPLICING NEW FUSE LINK

To bypass damaged contacts in molded connectors (which have non-replaceable contacts), use bullet connectors, as shown in Figure 133. Tape the connection if it is exposed.

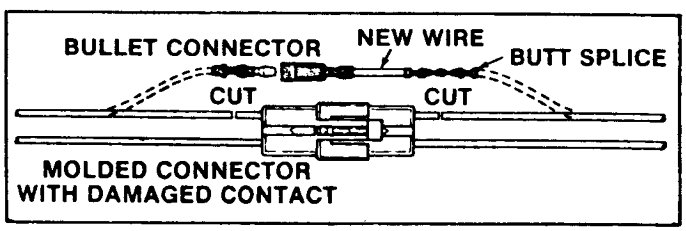



FIGURE 133. BYPASSING MOLDED CONNECTOR WITH BULLET CONNECTOR

## REPAIRING HARD-SHELL CONNECTORS

Unlike molded connectors, the terminal contacts in most hard-shell connectors can be replaced. Hard-shell connectors that are weatherproof (like solid-state ignition module connectors) and certain other hard-shell connectors in which the leads are molded into the shell, have non-replaceable terminals. Figure 134 shows six major types of hard-shell connectors in which the terminals can be replaced. Whenever the connector shell shows evidence of burning, melting, or breaks or cracks, replace the connector shell. Replace individual terminals that are burnt, corroded, distorted, or loose.

To replace a connector terminal (Figure 135):

1. Remove the terminal from the connector shell.
2. Cut the wire as close as possible to the terminal.
3. Strip the wire, using the correct tool. (Insulation should project beyond the insulation crimp tabs, but should not touch the wire crimp tabs. The wire should project into the terminal approximately 1/16 -inch beyond the wire crimp tabs.)

**NOTE:**
The insulation crimp must be tight to prevent the insulation from sliding back on the wire when the wire is pulled. The insulation must be visibly compressed under the crimp tabs. The ends of the crimp tabs must be turned in for a firm grip on the insulation.

The wire crimp must be made with all wire strands inside the crimp. The terminal must be fully compressed on the wire strands. The ends of the crimp tabs must be turned in to make a firm grip on the wire. To assure proper crimps the crimping tool must have anvil-shaped crimping jaws to turn in the ends of the crimp tabs, as well as different size jaws to accommodate different size wires.

To test the crimp, attempt to pull the wires out of the terminal. Use an ohmmeter across the wire and terminal to check for a good crimp. There should be no measurable resistance between the wire and terminal.

## REPAIRING AMP-TYPE CONNECTORS

Amp-type connectors can be identified by a "bridge" or the pin half and "latching legs" on the socket half (Figure 136). The pins and sockets are held in the shell by locking tabs. To replace a pin or socket:

1. Squeeze the tabs, as shown in Figure 136, to separate the connector.
2. Insert special tool CAAZ-17018-B into the mating end of the shell, over the pin or socket to be replaced.

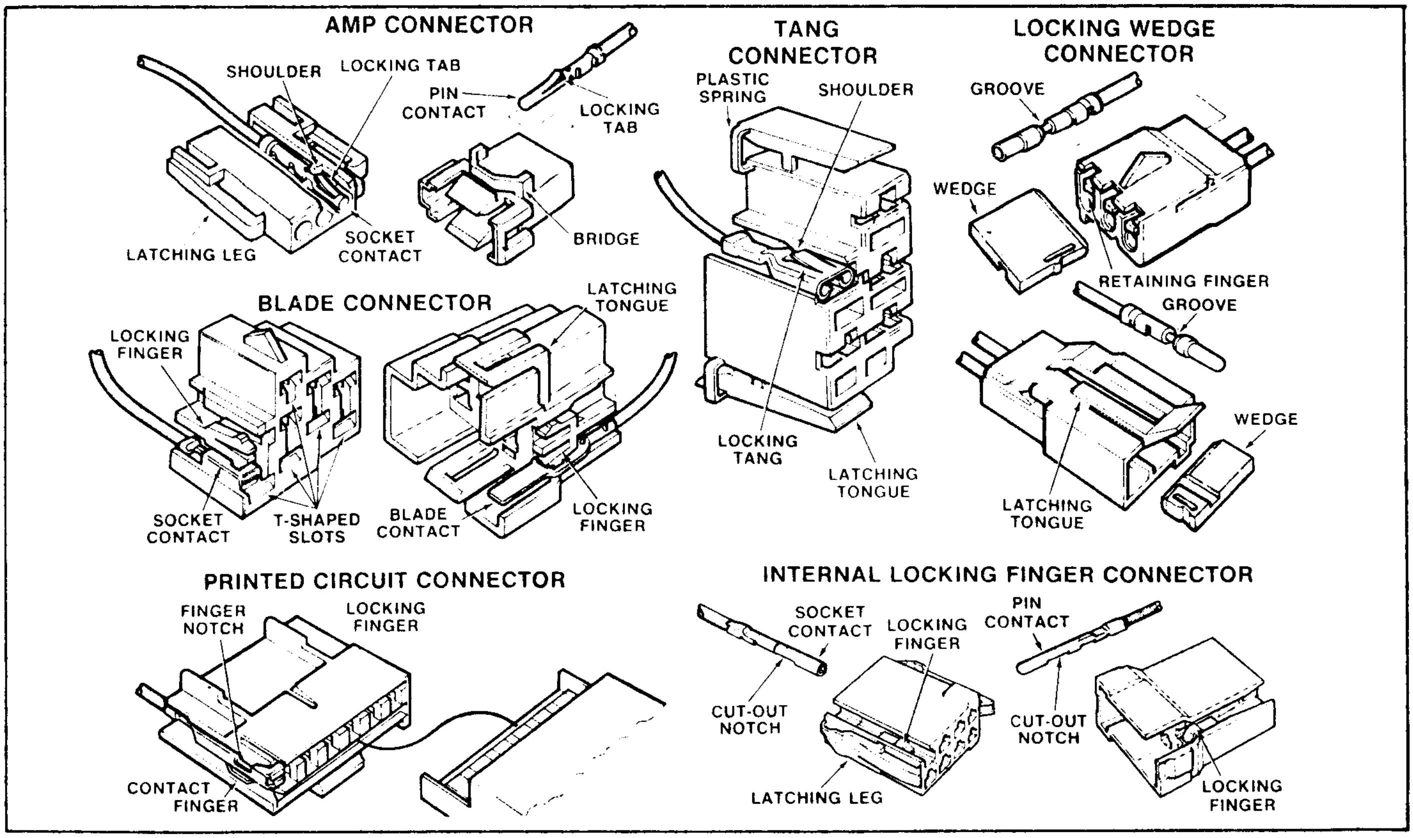



FIGURE 134. SIX TYPES OF HARD-SHELL CONNECTORS

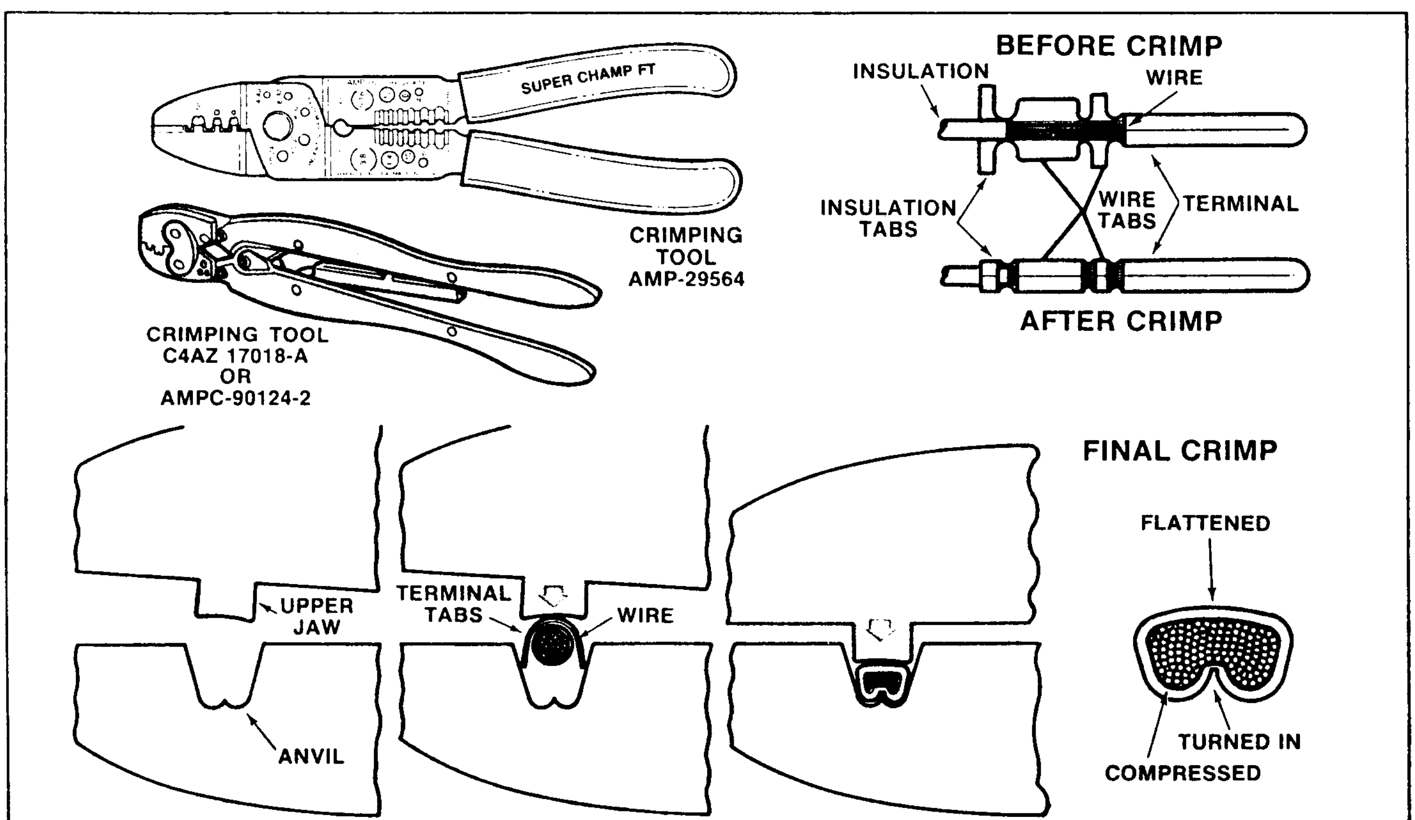



FIGURE 135. CONNECTOR TERMINAL CRIMPS

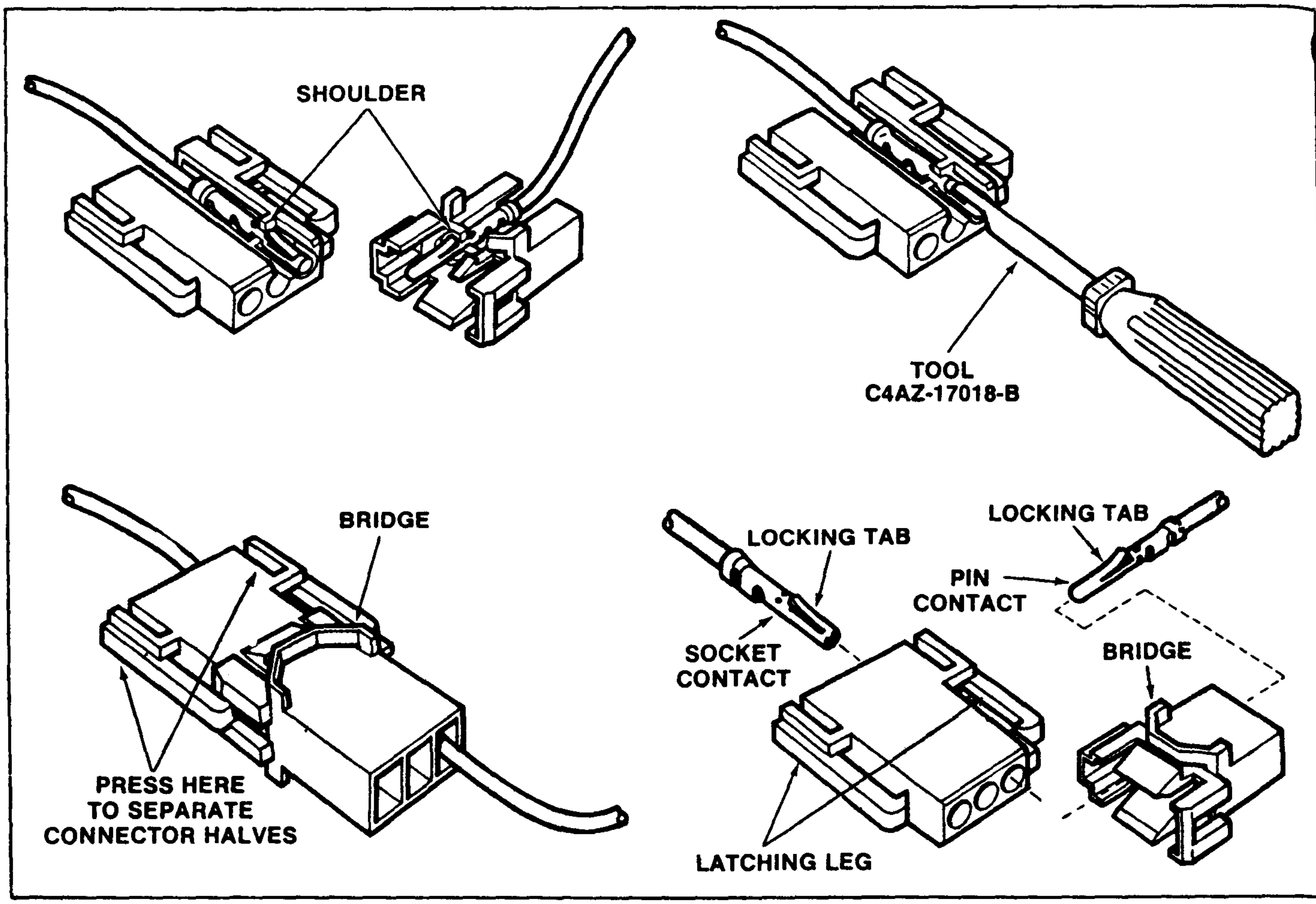



FIGURE 136. REPAIRING AMP-TYPE CONNECTORS

3. Push in on the wire to free the locking tab.
4. Push in and rotate the tool to force the locking tab to retract into the pin or socket.
5. Pull on the wire to pull the pin or socket from the shell.
6. Using standard techniques, crimp on the proper size and type new pin or socket.
7. Push the pin or socket into the shell until the retaining tab snaps out behind the shoulder in the shell.

## REPAIRING LOCKING WEDGE CONNECTORS

Locking-wedge connectors can be identified by red or brown colored wedge release tabs which are visible through windows in the connector shell (Figure 137). The pins and sockets are held in the shell by plastic retaining fingers which are part of the shell and which snap between two shoulders on the pins and sockets.

The wedges are held in the shell by a snap-lock tab on one end of each wedge which snaps into the window in the shell when the wedge is fully seated. To replace a terminal in a locking-wedge connector:

1. Lift the latch tongue and pull the connector halves apart.
2. Press the wedge locking tab in and up (toward the mating end of the shell) until the wedge is forced out of the cavity in the shell.
3. Use a 1/8-inch wide screwdriver blade to lift the retaining finger away from the pin or socket.
4. Pull on the wire to withdraw the terminal pin or socket.
5. Replace the pin or socket with the proper size and type new pin or socket, according to standard techniques.

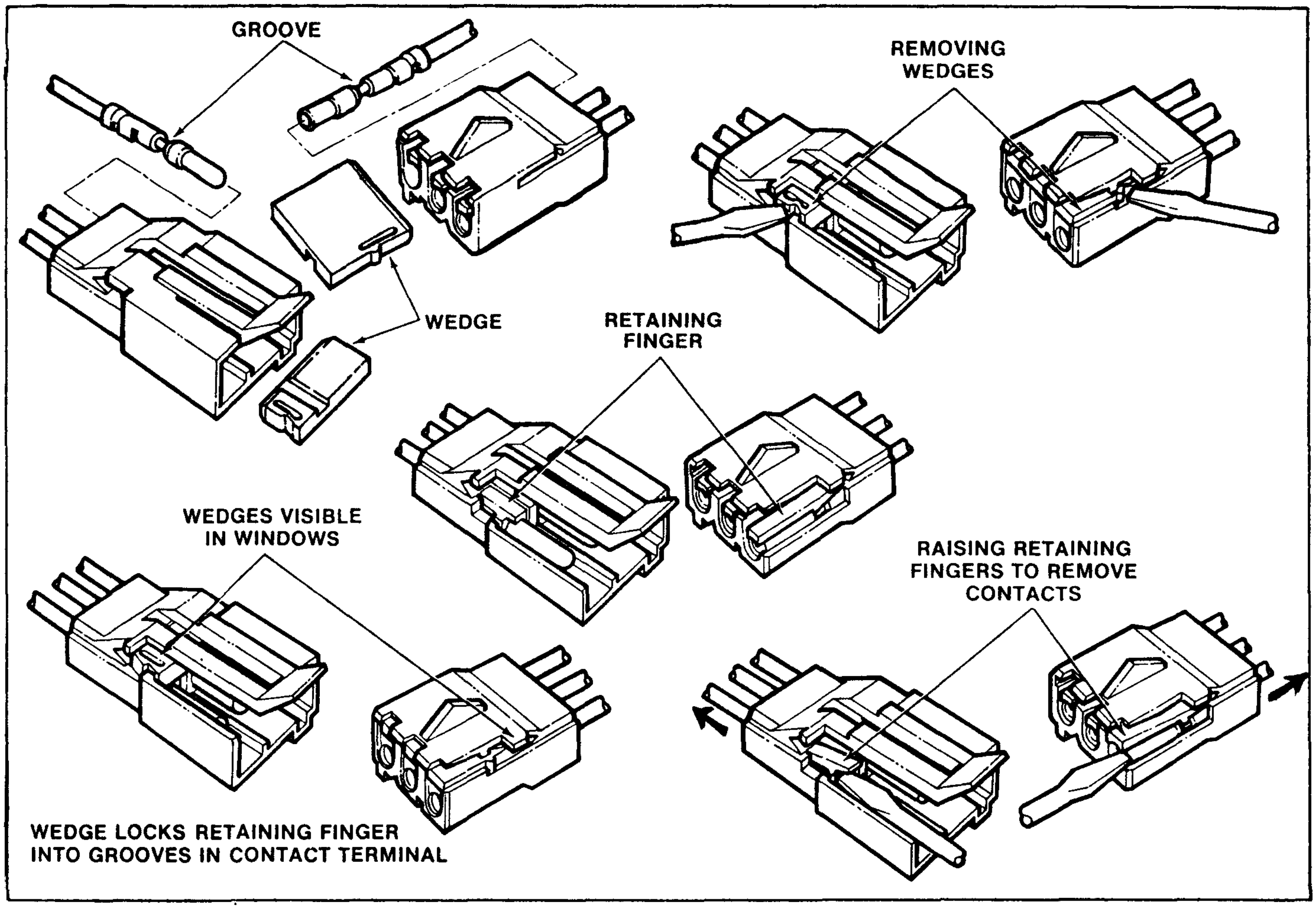



FIGURE 137. REPAIRING LOCKING-WEDGE CONNECTORS

6. Insert the pin or socket into the shell.
7. Push on the wire until the retaining finger snaps into place in the pin or socket.

**NOTE:**
Wedges are not included in replacement shells. When ordering new shells, also order the proper size wedge separately, under basic part number 14A468.

## REPAIRING FORD BLADE CONNECTORS

Ford blade connectors are identified by the T-shaped (or joined T-shaped, I-shaped) cavities in the mating end of the socket half of the shell, and by the visible blade terminals in the male half of the shell (Figure 138). The blades and sockets are held in the shell by plastic locking fingers, which are part of the shell, and which snap into rectangular cutouts in the blades and sockets.

The sockets are designed to make firm contact against both sides of the blades. To replace a blade or socket:

1. Lift the latch tongue and pull the connector halves apart. (The spring-loaded feature of the sockets against the blades make the connectors characteristically difficult to pull apart.)
2. Use a 1/8-inch wide screwdriver blade to lift the locking finger away from the blade or socket. (The locking nib on the locking finger is deeper than on wedge connectors. The finger must be forced well back to free the blade or socket.)
3. Pull on the wire to withdraw the blade or socket.)
4. Replace the blade or socket with the proper size and type new blade or socket, according to standard techniques.
5. Insert the blade or socket into the shell.
6. Push on the wire until the blade or socket snaps into place.

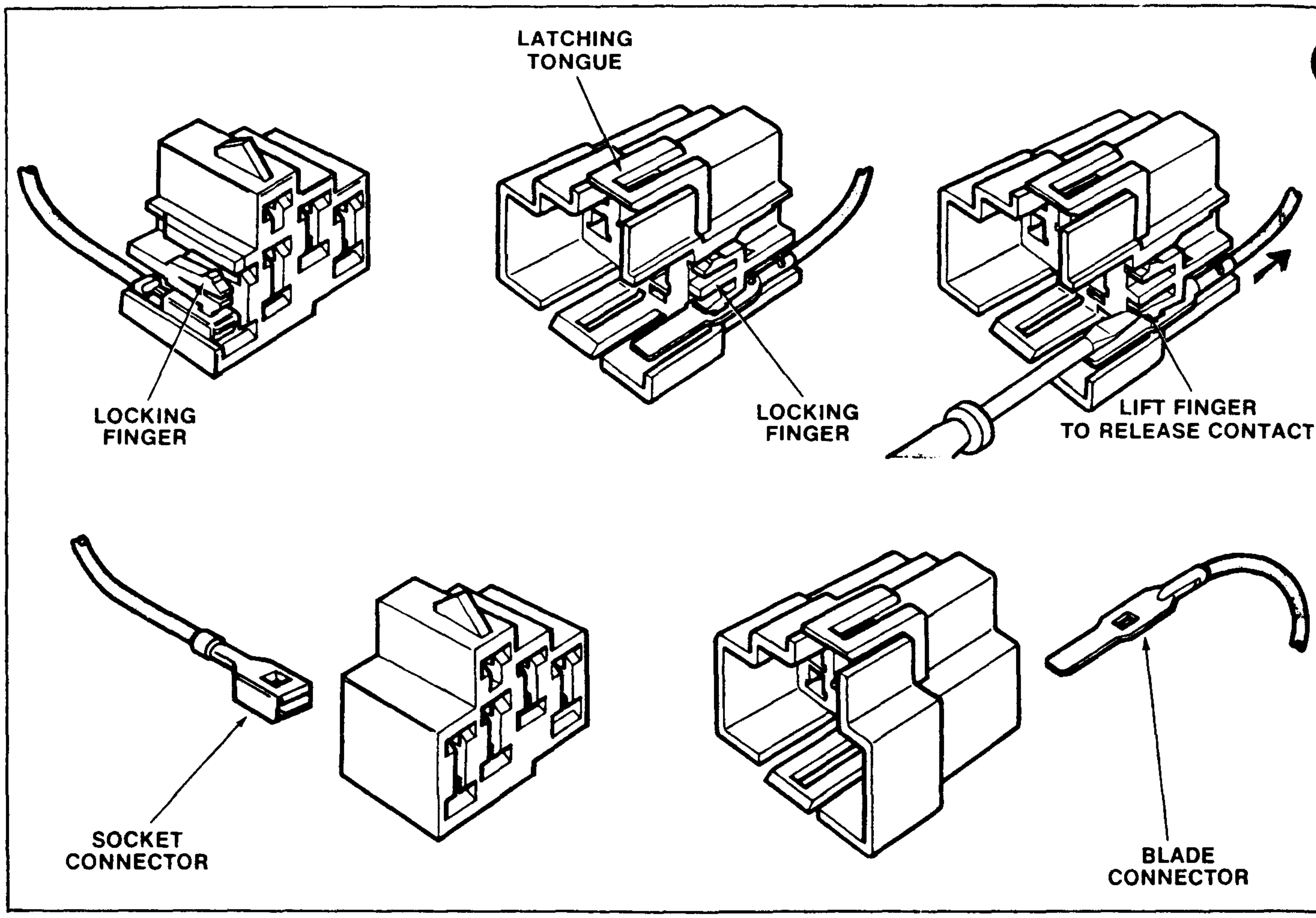



FIGURE 138. REPAIRING FORD BLADE CONNECTORS

**NOTE:**
It is important, when joining the connector halves, to make sure the two halves are pushed firmly together. The blades and sockets make very firm contact when engaged; strong pressure is required to join, as well as separate them. After joining the connector halves, always inspect the connector to make sure that the latching tongue is all the way over its mating nib.

Note also that the socket half of blade connectors is sometimes used to connect to components which have blade-type contacts.

Tang-type connectors (Figure 139) are primarily used to connect the harness to the ignition switch. They are identified by the unique shape of their latching tongues which have plastic springs.

Sockets are held in the shell by tangs on the socket which snap out behind lips in the shell. To repair a tang-type connector:

1. Squeeze the locking tongues at the spring end and pull the connector off.
2. Insert a 1/8-inch screwdriver blade (or a heavy paper clip) into the narrow slot beside the socket.
3. Push on the wire (toward the mating end of the connector) and press in on the screwdriver (or paper clip) to force the tang down even with the socket.
4. Pull on the wire to withdraw the socket.
5. Replace the socket with the proper size and type of new socket, according to standard techniques.
6. Align the tang on the socket with the narrow slot on the shell.
7. Push in on the socket until the tang snaps into place behind the lip in the shell.

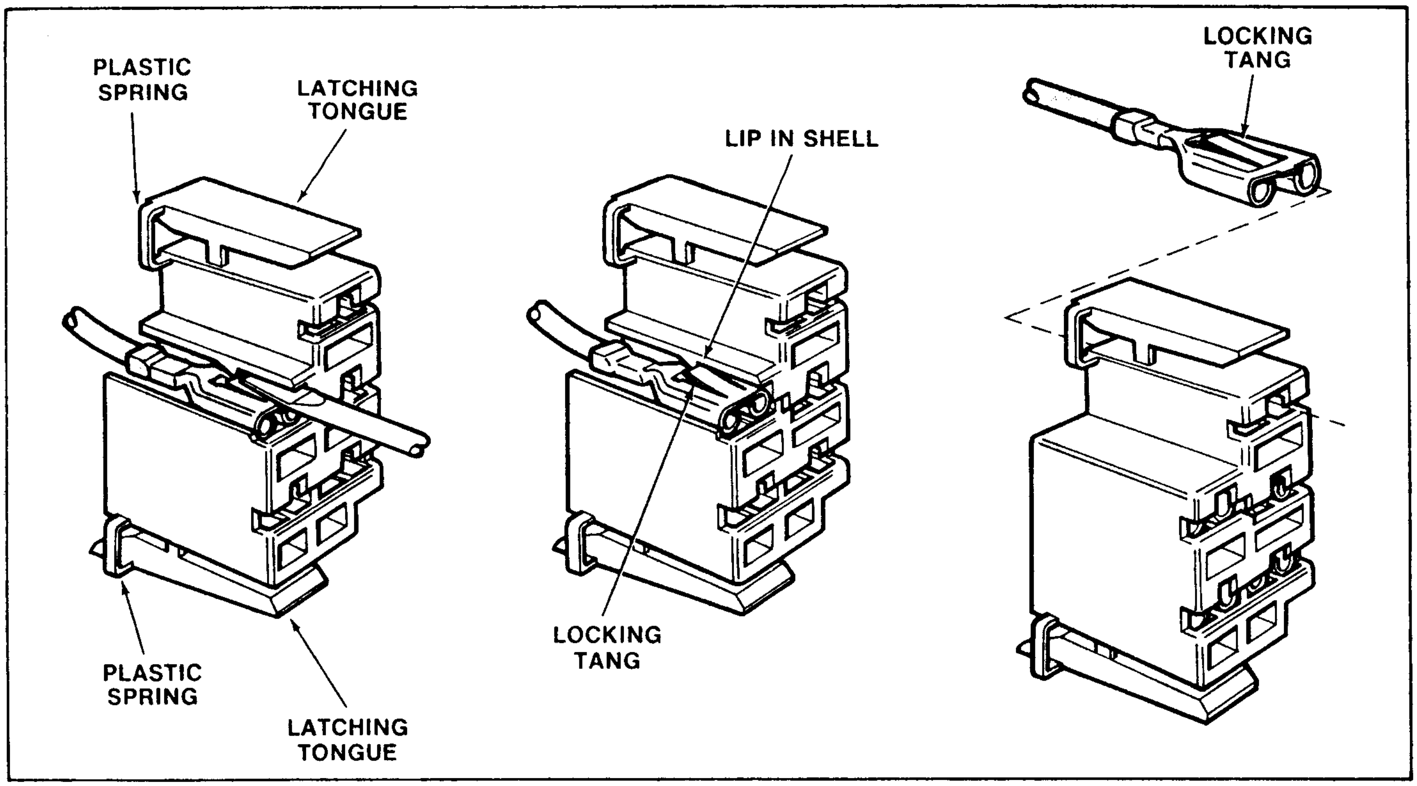



FIGURE 139. REPAIRING TANG-TYPE CONNECTORS

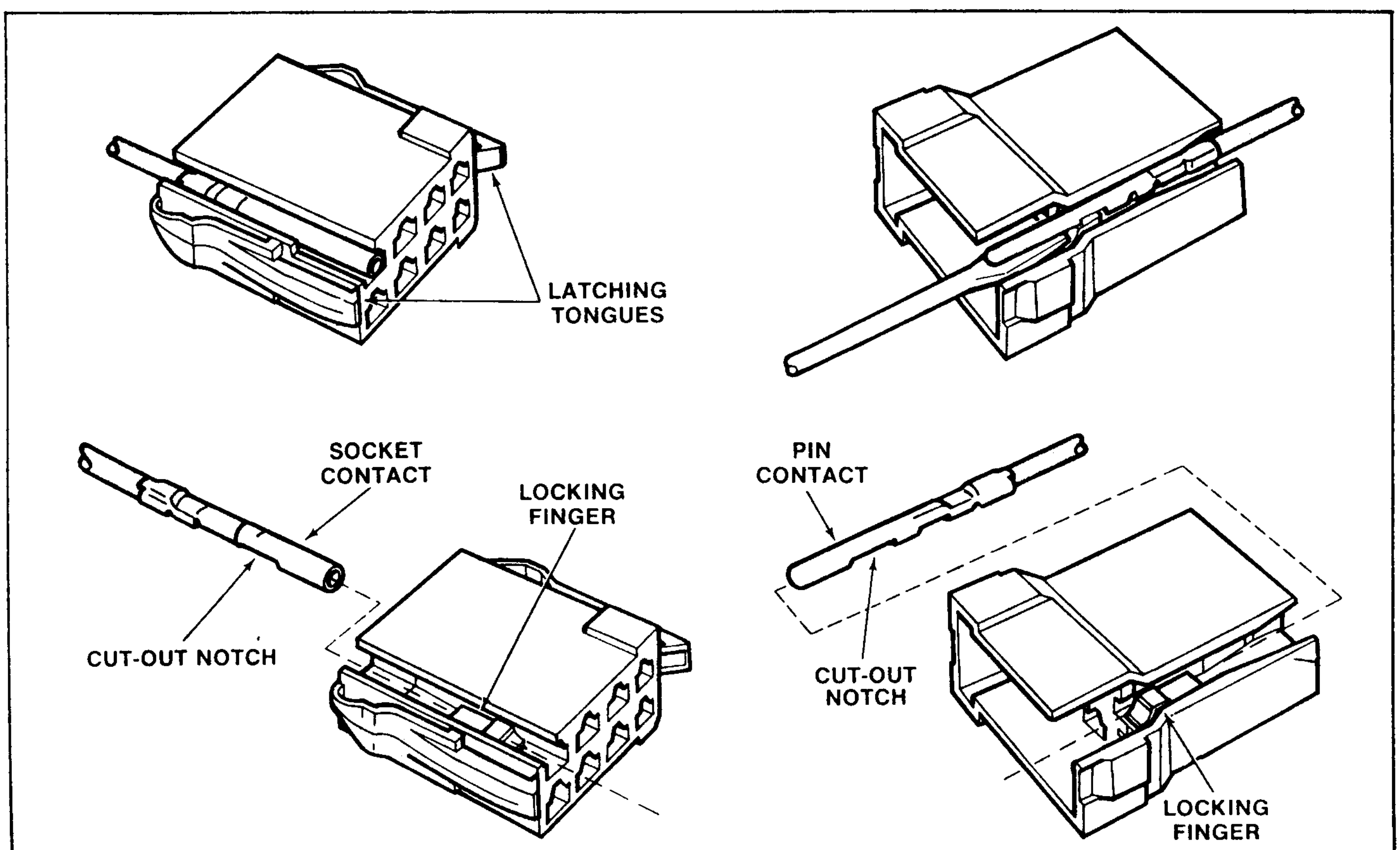



FIGURE 140. REPAIRING INTERNAL-LOCKING-FINGER CONNECTORS

## REPAIRING INTERNAL-LOCKING-FINGER CONNECTORS

Internal-locking-finger connectors (Figure 140) are identified by the fingers which are clearly visible in the contact cavities in the mating ends of the shell. The plastic fingers, molded into the shell, engage cutout notches in the pins and sockets to hold them in the shell. To repair an internal-locking-finger connector.

1. Lift the latching tongues and pull the connector halves apart.
2. Insert a 1/8-inch screwdriver blade into the mating end of the pin or socket cavity.
3. With the screwdriver blade, lift the plastic finger away from the pin or socket.
4. Pull on the wire to withdraw the pin or socket from the shell.
5. Replace the pin or socket with the proper size and type new pin or socket, according to standard techniques.
6. Align the notch in the pin or socket with the plastic finger in the cavity of the shell.
7. Push the pin or socket in until the finger engages in the notch.

## REPAIRING PRINTED CIRCUIT CONNECTORS

Printed-circuit connectors (Figure 141) are identified by the rounded ends of the terminals that are visible at the mating end of the shell. Contact fingers on the terminals protrude through partitions in the shell into the cavity which receives the printed circuit board. The connector contacts have spring-loaded fingers which press against copper strips on the printed circuit board when the board is inserted into the cavity in the shell. The connector contact terminals are held in the shell by plastic locking fingers, which are part of the shell, and which snap into rectangular cutouts in the contact terminals. To repair a printed-circuit connector:

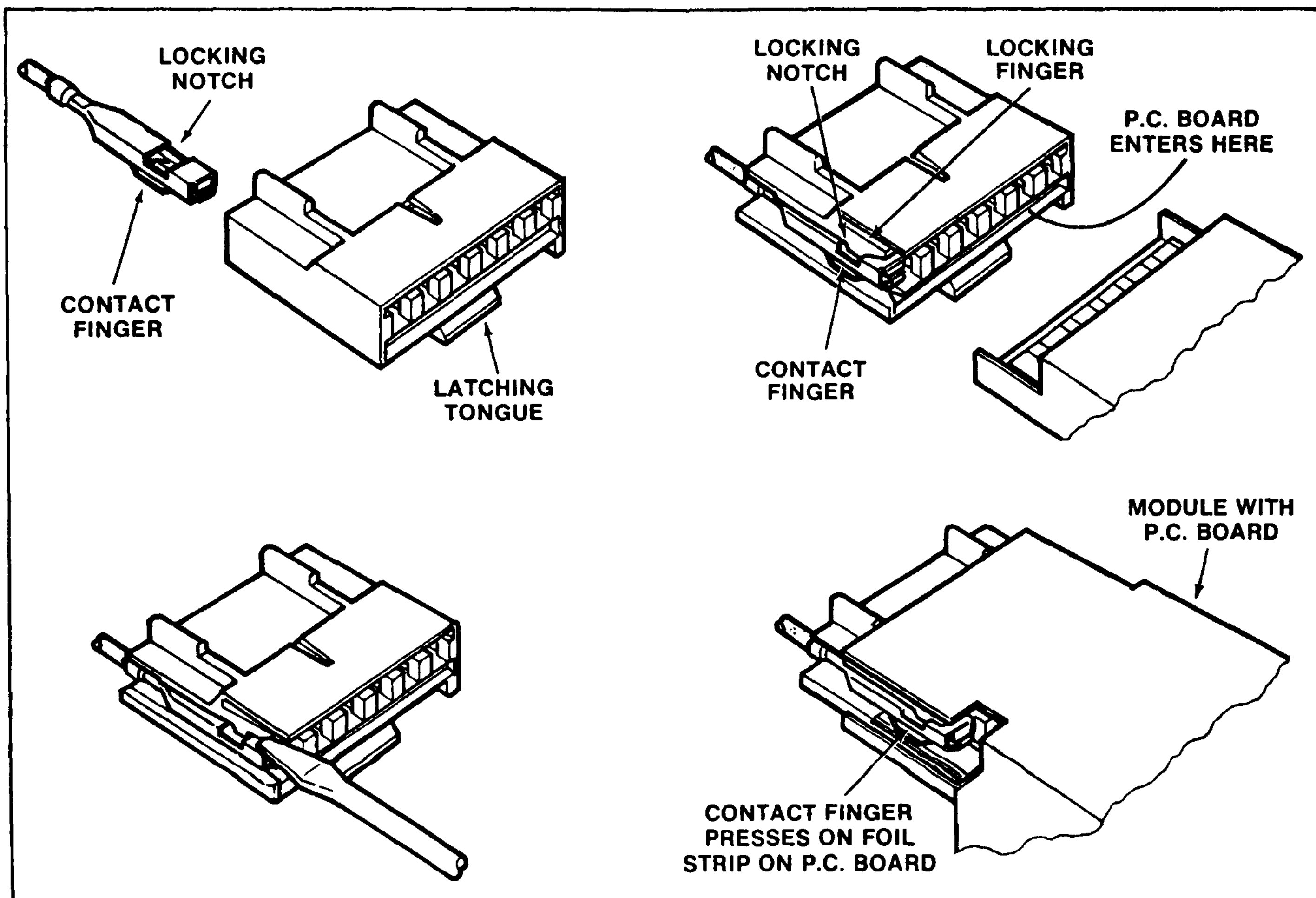



FIGURE 141. REPAIRING PRINTED-CIRCUIT CONNECTORS

1. Lift the latching tongue and pull on the wires to separate the connector from the component.
2. Using a 1/8-inch screwdriver blade, lift the locking finger away from the contact terminal. (The locking fingers are on the side of the contact opposite the printed circuit board.)
3. Pull on the wire to withdraw the contact terminal from the shell.
4. Replace the terminal with the proper size and type new terminal, according to standard techniques.
5. Align the new terminal so that the contact finger on the terminal faces the printed circuit board cavity in the shell.
6. Insert the terminal into the channel in the shell.
7. Push the terminal in until the retaining finger snaps into place in the cutout in the terminal.

## HARNESSES

Most of the wires and connectors you'll have to repair are in wiring harnesses. It is important for you to become familiar with the individual wiring harnesses and their routing for the vehicles on which you regularly perform maintenance. Figures 142 through 149 show wiring harnesses for a 1976 Granada/Monarch line. These harnesses will change from year to year, so each year you should make an effort to familiarize yourself with the changes. Such familiarization will be a great time saver for diagnosis and repair.

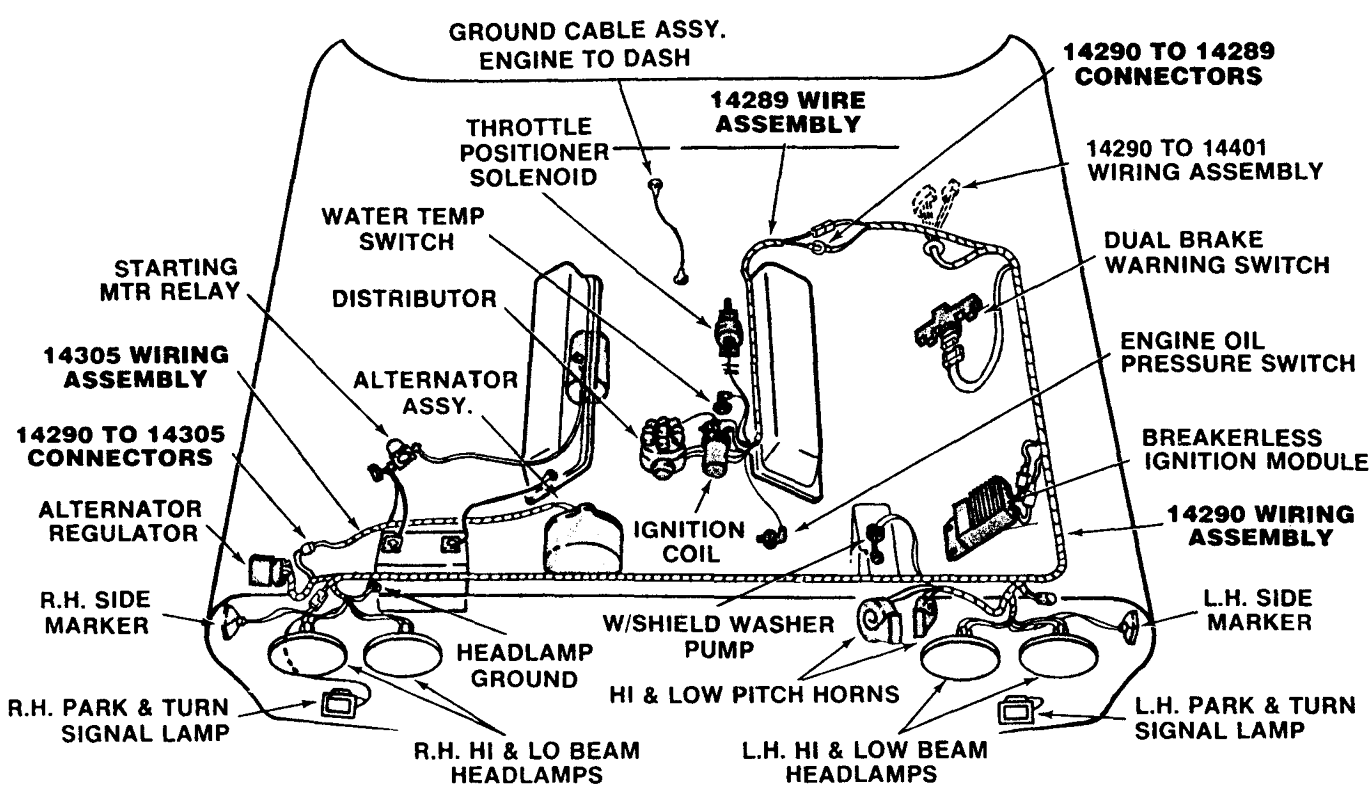



FIGURE 142. ENGINE COMPARTMENT HARNESSES

## BATTERY SERVICE INFORMATION

### Battery Safety

Although it rarely happens, batteries can explode. A common misconception is that for this to happen, the battery must be defective. On the contrary, the most common cause of the explosion is a spark or flame created by something outside of the battery.

Why is this true? Consider an inherent characteristic of all automotive batteries in use today - the production of hydrogen gas as a normal by-product of their operation. When charging current flows through a battery, a chemical reaction occurs that replaces the energy removed from the battery during periods of discharge. This chemical reaction results in the formation of hydrogen gas in the cell. Therefore, the caps for the filler holes are vented to relieve the pressure. It is easy to see how plugged vent caps could create a problem and why they should be checked periodically to make sure they are not plugged with dirt or other foreign matter.

As the gas escapes to the atmosphere, it results in a weak concentration of gas in the area of the battery. Hydrogen gas is explosive! Even in a very low concentration it is sufficient to be ignited by the spark, thus causing the battery to explode.

This does not mean that batteries will explode every time a spark occurs near them. In fact, they rarely do. Conditions have to be just right. Therefore, care should be used when working aournd a battery to make sure no sparks occur. Eye protection should be worn whenever working with batteries.

Before attempting to jump-start a vehicle, the battery terminals should be cleaned and tightened. Also, care should be used to make a good connection with the jumper cable clips.

### Jump starting in case of emergency with Auxiliary (Booster) Battery

Both booster and discharged battery should be treated carefully when using jumper cables. Follow exactly the procedure outlined below, being careful not to cause sparks:

1. Set parking brake and place automatic transmission in Park (neutral for manual transmission). Turn off lights, heater, and other electrical loads.

2. Remove vent caps from both the booster and the discharged batteries. Lay a cloth over the open vent wells of each battery. These two actions help reduce the explosion hazard always present in either battery when connecting "live" booster batteries to "dead" batteries.

3. Attach one end of one jumper cable to the positive terminal of the booster battery (identified by a red color, "P," or "+," on the battery case, post, or clamp) and the other end of same cable to positive terminal of the discharged battery. Do NOT permit cars to touch each other, as this could establish a ground connection and counteract the benefits of this procedure.

4. Attach one end of the remaining negative cable to the negative terminal (black color, "N" or "-") of the booster battery, and the other end to a ground (such as engine block, frame, etc.) at least 12 inches from the battery filler caps of the car being started. (Do not connect directly to the negative post of the dead battery.) Take care that the clamps from one cable do not touch the clamps on the other cable. Do not lean over the battery when making this connection. This ground connection must provide good electrical conductivity and current-carrying capacity. Avoid moving, hot, or electrical hazards such as fans, manifolds, and spark plug terminals.

5. Reverse this sequence exactly when removing the jumper cables.

6. Reinstall vent caps and throw cloths away as the cloths may have corrosive acid on them.

   (CAUTION: Any procedure other than the above could result in: (1) personal injury caused by electrolyte squirting out the battery vents, (2) personal injury or property damage due to battery explosion, (3) damage to the charging system of the booster vehicle or the immobilized vehicle.

   Do not attempt to jump-start a car having a frozen battery because the battery may rupture or explode. If a frozen battery is suspected, examine all fill vents on the battery. If ice can be seen, or if the electrolyte fluid cannot be seen, do not attempt to start with jumper cables as long as the battery remains frozen.)

When removing battery cables, always remove the ground cable first and replace it last. This will eliminate the danger of a spark from accidental grounding of the wrench when removing or replacing the positive cable.

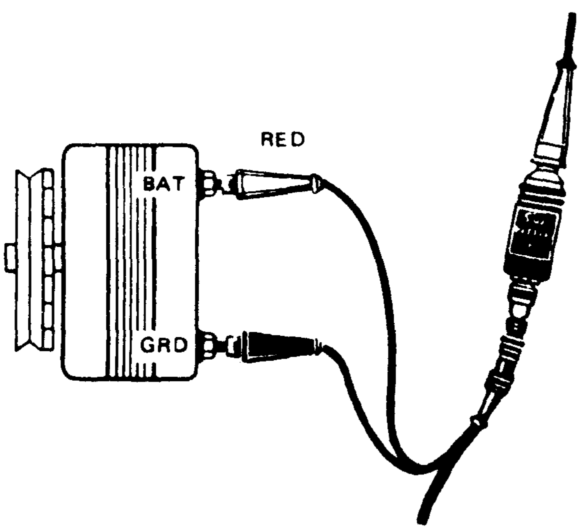
When a battery explodes while the vehicle is being driven down the road or while the engine is being cranked, a very likely cause is corroded or loose battery cable terminals. This can cause the connection to be broken by vibration while driving or by the high current demands while cranking, and a spark will occur.

Therefore, remember to keep any flames or sparks away when working near a battery and be sure all connections are clean and tight or it might explode.

## ALTERNATOR DIODE-STATOR TEST

An oscilloscope, when used properly, can be useful for purposes other than analyzing ignition systems. One such use is checking alternator rectifier diodes and the stator. The alternator need not be removed from the engine for this test, since the test is performed with the alternator operating under normal conditions. However, if defective stator or diodes are indicated the alternator must be removed, diodes tested and either diode or stator replaced.

This test does not replace the charging system output and voltage test. Final charging system tests should be accomplished using a Sun Volts Ampere Tester.




## TEST PROCEDURE

1. Turn Pattern Selector to Display position.
2. Turn Circuit Selector to Primary negative (-) or positive (+), depending on the vehicle battery ground polarity.
3. Set Primary Pattern Height control to the 40 V position.
4. Adjust trace to 0 line.
5. Tester to Alternator connections. (neg. grd. vehicle)
   Blue Cable;
   a. Connect red Primary pickup to the alternator output (BAT) terminal.
   b. connect black ground clamp to alternator ground terminal.
   Red Cable;
   a. connect Timing pickup to number one spark plug.
6. Start engine and run at 1500 RPM (approx.).
7. Apply electrical load to Alternator by turning on headlights to high beam.
8. Adjust Pattern Length control for full waveform coverage between the vertical lines of the scope screen.
9. Adjust brightness and focus as required.
10. Observe waveform and compare with those indicated below.

Results and Indications



NORMAL

OPEN DIODE

SHORTED DIODE

OPEN STATOR

SHORTED STATOR

# AC SYSTEM SERVICE PRECAUTIONS

1- Always be *absolutely sure* that the battery ground polarity and the charging system polarity are the same, when installing a battery.

2 - *Do not* polarize an alternator.

3 - *Never* short across or ground any of the terminals on either the alternator or the regulator.

4 - *Do not* operate an alternator on open circuit.

5 - Booster battery *must be* correctly connected.

6 - Battery charger *must be* correctly connected.

7 - *Always* disconnect the battery ground cable before replacing or servicing electrical units.

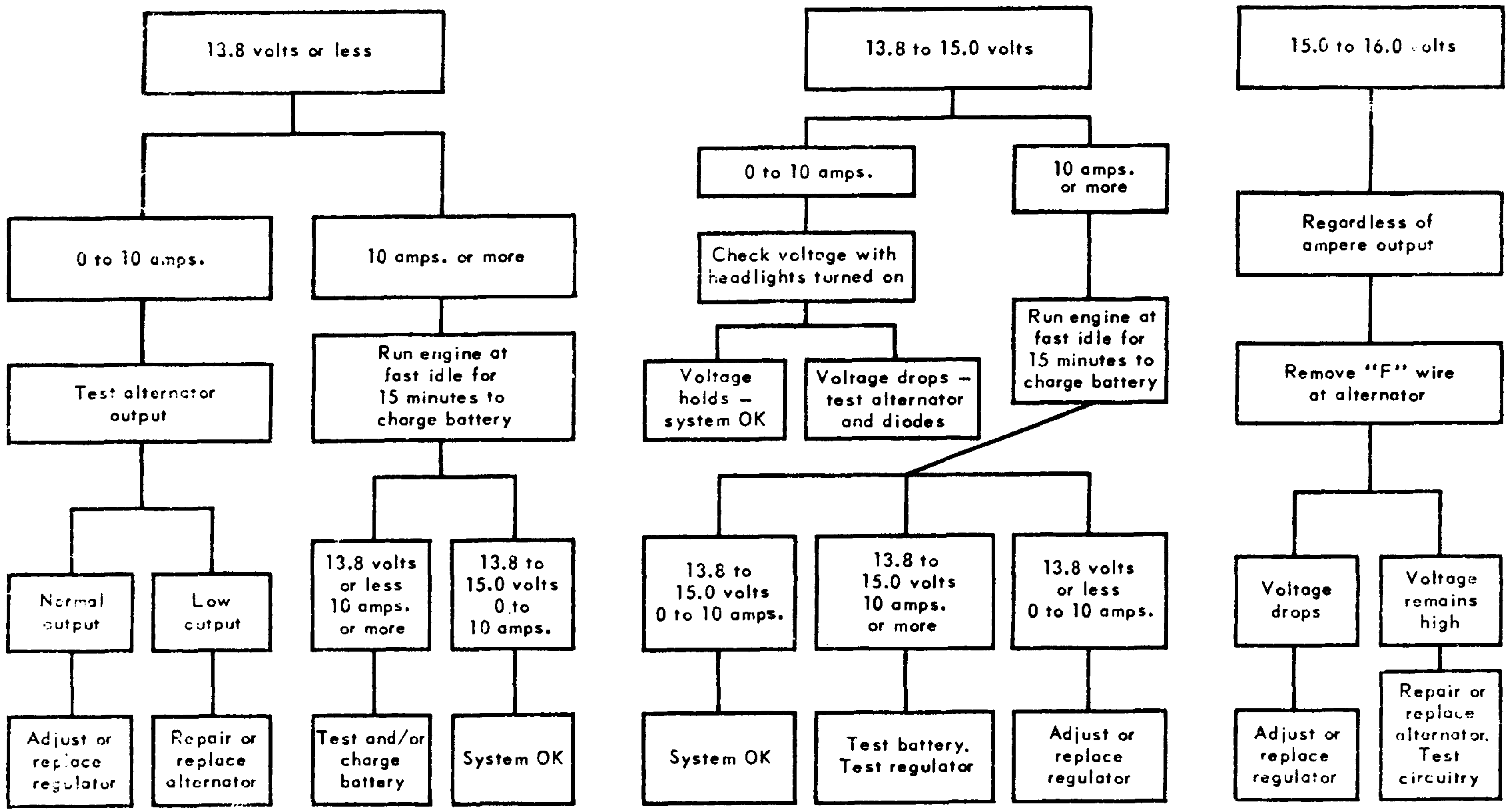
# ALTERNATOR AND REGULATOR QUICK CHECKS

Disconnect alternator output "BAT" lead and connect ammeter between disconnected lead and alternator "BAT" terminal. Connect voltmeter to alternator output "BAT" terminal and ground. Start engine and set engine speed at 1500 rpm.

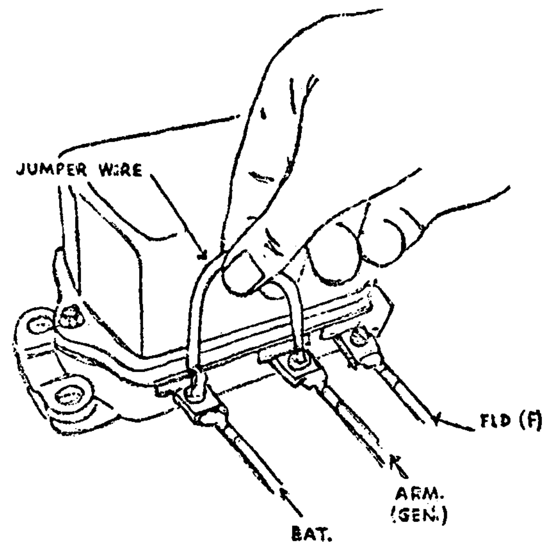
Caution: DO NOT allow voltage to exceed 16 volts. If voltage appears as though it would easily exceed 16 volts, check ammeter connections.

Alternator MUST NOT be operated without a load connected to the output terminal.

METER READING INDICATIONS



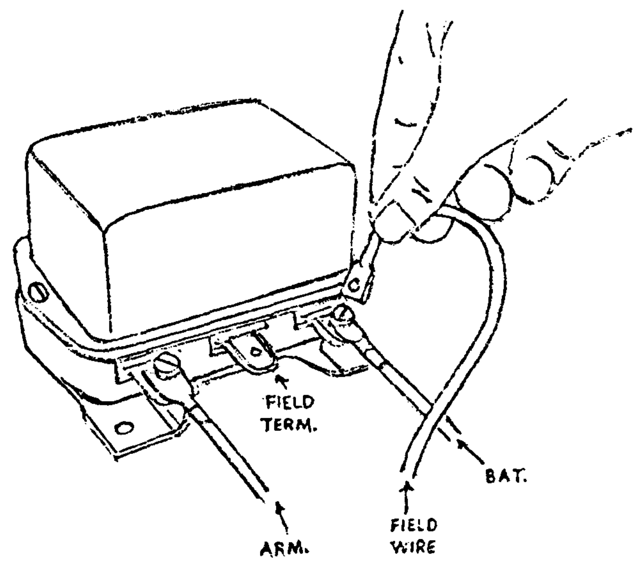
GENERATOR POLARIZING




DELCO-REMY — AUTOLITE — PRESTOLITE TYPES
("A" CIRCUIT)
GENERATOR REGULATOR

After making all connections but BEFORE starting engine:

1. Momentarily touch a jumper wire between "Arm" or "Gen" and "Bat" terminals of regulator. (The occurrence of a spark is normal.)




FORD TYPE
("B" CIRCUIT)
GENERATOR REGULATOR

After making all connections but BEFORE starting engine:

1. Disconnect "Fld" wire from regulator terminal.
2. Momentarily touch this "Fld" wire to the "Bat" terminal of regulator. (The occurrence of a spark is normal).
3. Reconnect "Fld" wire to "Fld" terminal on regulator.

CAUTION: Never touch battery lead to "Fld" terminal of the regulator as this will damage the regulator.

## NOTES