MULTIMETER USE

VOLTAGE

Voltage is an electrical pressure or force that pushes the current through a circuit. The pressure is measured in Volts and the symbol V (as in 12V) is used in the circuit diagrams. The letter "E" is also used for voltage and stands for Electromotive Force. Voltage can be compared to the pressure necessary to push water through a metering valve.

Low voltage to a lamp will cause the lamp to glow dimly. This can be caused by low source voltage (battery discharged or low alternator output), or by high circuit resistance in the circuit due to a poor connection. The resistance of the poor connection or poor ground acts as an additional load in the circuit, causing less voltage to be available to push current through the load device. Before making any meter measurements, it is important to briefly review the relationship between voltage, current, and resistance (Ohms Law).

OHMS LAW REVIEW

Ohms Law describes the relationship of voltage, current and resistance, and provides us with a formula to make calculations as is shown in **(Figure 5.3–1).**

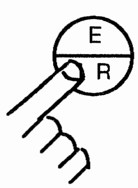
OHMS LAW

WHERE: I = CURRENT (AMPERES)
E = VOLTAGE (VOLTS)
R = RESISTANCE (OHMS)

1. I = E/R — THIS FORMULA STATES THAT CURRENT FLOW (I) = VOLTAGE (E) APPLIED TO A CIRCUIT DIVIDED BY TOTAL RESISTANCE (R) IN THE CIRCUIT. THIS SHOWS THAT AN INCREASE IN VOLTAGE OR A DECREASE IN RESISTANCE INCREASES THE CURRENT FLOW.

2. R = E/I — THIS FORMULA STATES THAT RESISTANCE (R) = VOLTAGE (E) APPLIED TO A CIRCUIT DIVIDED BY CURRENT FLOW (I) IN THE CIRCUIT. THIS ALLOWS US TO CALCULATE RESISTANCE NEEDED FOR A SPECIFIC CURRENT FLOW WITH A SPECIFIC VOLTAGE APPLIED (LIKE 12V).

3. E = IR (I MULTIPLIED BY R) — THIS GIVES THE VOLTAGE DROP ACROSS A PARTICULAR LOAD DEVICE (RESISTANCE) THAT IS PART OF A SERIES OF LOAD DEVICES.



MEMORIZE THE FORMULA IN THE CIRCLE, THEN YOU ONLY HAVE TO COVER THE "LETTER" THAT YOU WISH TO CALCULATE, WITH YOUR FINGER, AND YOU HAVE THE FORMULA. FOR EXAMPLE: IF YOU COVER THE LETTER "I", THE FORMULA IS I = E/R.

Figure 5.3–1 – Ohms Law

If any two of the values are known for a given circuit, the missing one can be found by substituting the values in amperes, volts, or ohms and solving for the missing value.

In a typical circuit, battery voltage is applied to a bulb through a 10-amp fuse and a switch **(Figure 5.3–2)**. Closing the switch turns on the bulb.

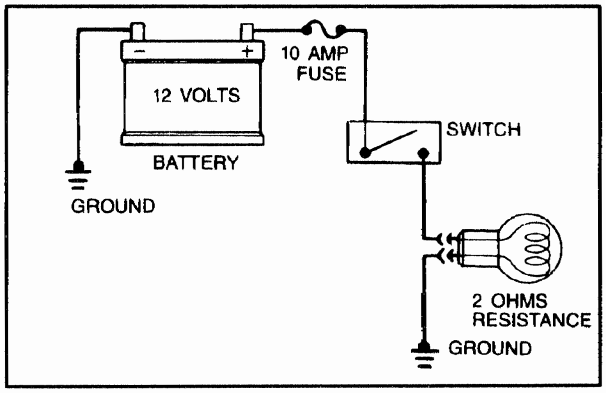


Figure 5.3–2 – Simple Electrical Circuit

To find the current flow use the formula:

I = E / R

Filling in the numbers for the circuit in **Figure 5.3–2**, we have:

I = 12V/2 ohms or I= 12 divided by 2 = 6 amperes of current flow.

The bulb in this circuit operates at 6 amps and is rated to operate at this level. With 12 volts applied, the bulb will glow at the rated output level (candlepower rating). However:

- If the voltage applied is low (low battery), then (the value of E is lower) and current flow will be less and the bulb will glow less brightly.
- Or if the connections are loose, or the switch corroded, the circuit resistance will be greater (value of R will be larger) and the current flow will be reduced and the bulb will glow less brightly.

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OHMS LAW REVIEW (Continued)

Being able to determine voltage drops is important because it provides the following information:

- Too high a voltage drop indicates excessive resistance. If, for instance, a blower motor runs too slowly or a light glows too dimly, one can be sure that there is excessive resistance in the circuit. By taking voltage drop readings in various parts of the circuit, the problem can be isolated (corroded or loose terminals for example).
- Too low of a voltage drop, likewise, indicates low resistance. If for instance, a blower motor ran too fast, the problem could be isolated to a low resistance in a resistor pack by taking voltage drop readings.
- Maximum allowable voltage drop under load is critical, especially if there is more than one high resistance problem in a circuit. It is important because all voltage drops in a circuit are cumulative. Corroded terminals, loose connections, damaged wires or other similar conditions create undesirable voltage drops that decrease the voltage available across the key circuit components. Remember our earlier discussion, the increased resistance from the undesirable conditions will also decrease the current flow in the circuit and all the affected components will operate at less than peak efficiency. A small drop across wires (conductors), connectors, switches, etc. is normal. This is because all conductors have some resistance, but the total should be less than 10 percent of the total voltage drop in the circuit.

USING THE VOLTMETER

In electrical diagnosis, the voltmeter is used to answer:

- Is voltage present?
- What is the voltage reading?
- What is the voltage drop across a load device?

When using a voltmeter to determine if voltage is present to power a device, connect the positive meter lead to input connection of the device (positive side) and connect the negative meter lead to good vehicle ground **(Figure 5.3–3)**. This shows how much of the source voltage is available to the device. Note that the meter is connected in parallel to the device.

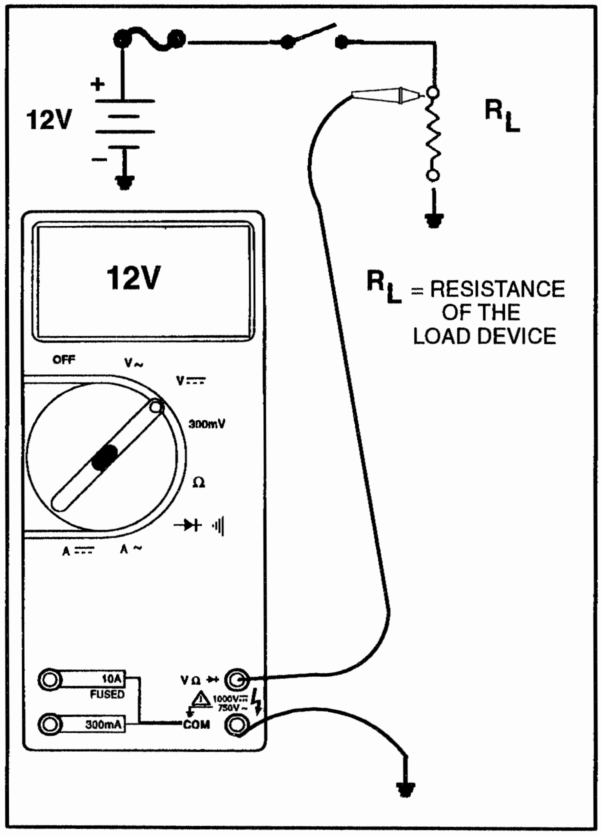

Figure 5.3–3 - Checking Power To A Load Device

Should we need to determine if voltage is available at a connector where we can't readily connect to the device, we can connect the meter in parallel as shown in **(Figure 5.3–4)**. The meter internal resistance is very high so little current will flow in the circuit, and the voltage can be read accurately.

To check the voltage drop across a load device **(Figure 5.3–5)**, connect the positive lead of the voltmeter to the positive side of the device and the negative meter lead to the negative side of the device.

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USING THE VOLTMETER (Continued)

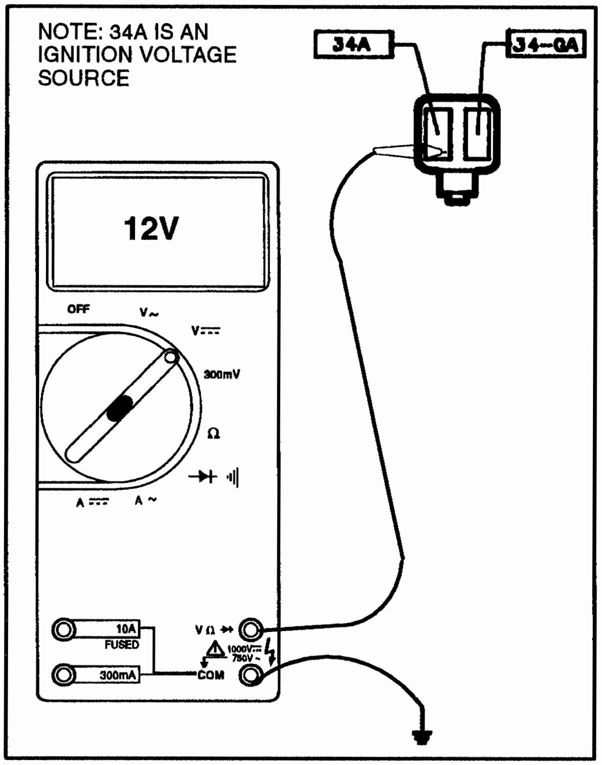

Figure 5.3–4 - Checking Power To A Connector

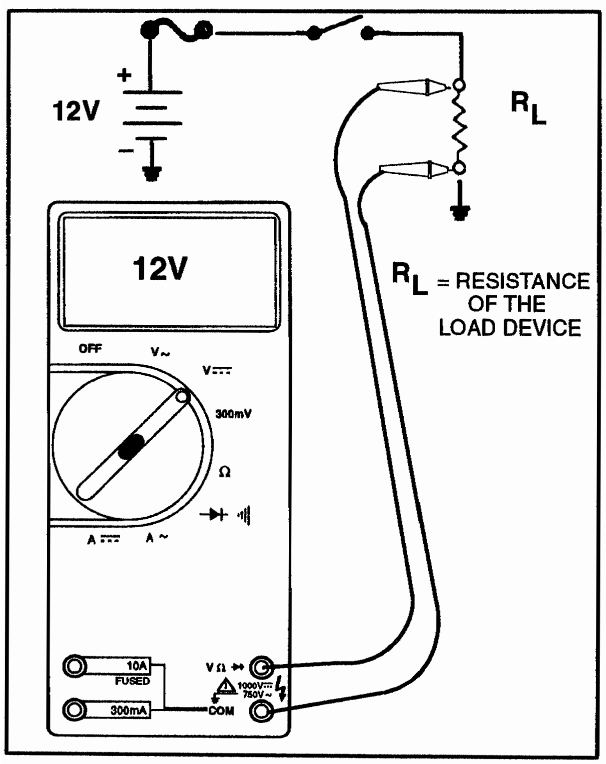

Figure 5.3–5 - Checking Voltage Loss

With the device operating, this will measure the voltage drop across the device. Notice in **(Figure 5.3–5)** that since we only have one device, all of the voltage should be dropped at the device. In any circuit, the voltage applied will equal the voltage dropped in the circuit. If in this circuit we only dropped 9V across the load, that would indicate that our wires, connections, etc. were dropping the other 3V, which would indicate excessive circuit resistance.

AMMETER

An ammeter is used to measure current flow (amperage) in a circuit. Amperes are units of electron flow, which indicate how many electrons are passing through the circuit. Ohms Law indicates that current flow in a circuit is equal to the circuit voltage divided by total circuit resistance. Since amps (I) is the current in the circuit, increasing voltage also increases the current level (amps). Also, any decrease in resistance (ohms) will increase current flow (amps).

At normal operating voltage, most circuits have a characteristic amount of current flow, referred to as current draw. Current draw can be measured with a ammeter. Referring to a specified current draw rating for a component (electrical device), measuring the current flow in the circuit, and comparing the two (the rating versus the actual measured) can provide valuable diagnostic information.

An ammeter is connected in series with the load, switches, resistors, etc. (**Figure 5.3–6)** so that all of the current flows through the meter. The meter will measure current flow only when the circuit is powered and operating. Before measuring current flow, we need to know approximately how much current will be present to properly connect the meter. The DMM is fused to measure up 10 amps using the 10A connection point.

The estimate of current flow can easily be calculated. In **(Figure 5.3–6)**, the resistance of the light bulb is 2 ohms. Applying ohms law, we can calculate that current flow will be 6 amps (6A = 12V/2 ohms). If we remove the fuse, and install the ammeter as shown, with the switch closed we will measure 6 amperes of current flowing in the circuit. Notice that the ammeter is installed so that all the current in the circuit flows through it. The ammeter is installed in series.

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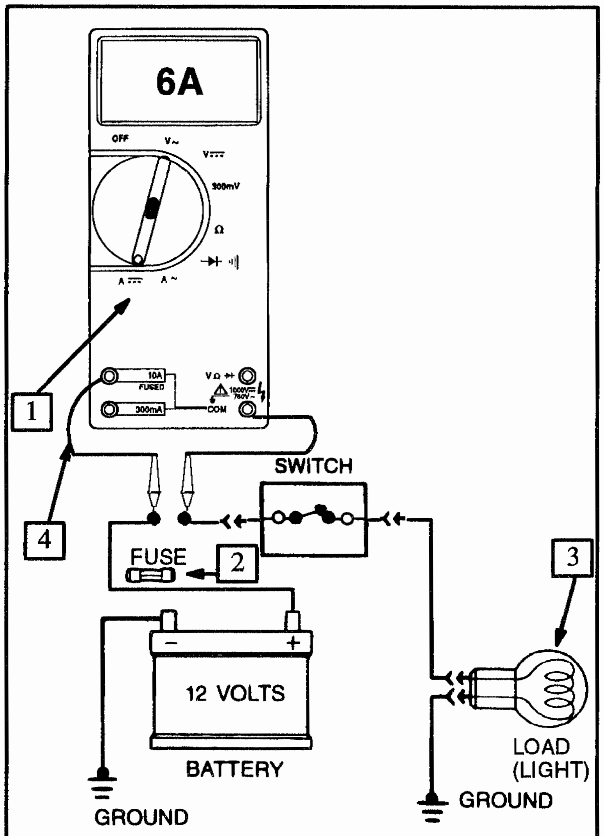
USING THE AMMETER (Continued)



1 - DMM SET TO MEASURE DC CURRENT
2 - FUSE SHOWN REMOVED
3 - LIGHT BULB (2 OHMS RESISTANCE)
4 - METER LEAD CONNECTED TO 10A METER JACK

Figure 5.3–6 - Installing The Ammeter

WARNING– Always make sure the power is off before cutting, soldering or removing circuit component before inserting the DMM for current measurements. Even small amounts of current can be dangerous.

Excessive current draw means that more current is flowing in a circuit than the fuse and circuit were designed for. Excessive current will open fuses and circuit breakers. Excessive current draw can also quickly dis-charge batteries. An ammeter is useful to help diagnose these conditions. On the other hand, there are times reduced current draw will cause a device (electric window motor for example) to operate poorly. Remember increased circuit resistance causes lower current to be available to the device. Loose or corroded connections can frequently cause this problem.

OHMMETER

The ohmmeter is used to measure resistance (ohms) in a circuit. Like the ammeter and voltmeter, there are both analog and digital meters available. It is recommended that the digital meter (Fluke 88 DVOM) be used. See ELECTRONIC CIRCUIT TESTING in this section.

CAUTION –The ohmmeter can only be used on circuits where power has been removed. The meter contains its own low voltage power supply and the power from 12-volt systems may damage the meter.

Ohmmeters use a small battery to supply the voltage and current which flow through the circuit being tested. The voltage of the meter battery and the amount of current flow in the circuit are used with Ohms Law and the meter calculates the circuit resistance which is displayed by the meter. With the Fluke 88 DVOM, range selection and meter adjustment are not necessary.

MEASURING RESISTANCE

Resistance measurements determine:

- Resistance of a load
- Resistance of conductors
- Value of resistors
- Operation of variable resistors

To measure the resistance of a component or a circuit, power must first be removed from the circuit.

The component or circuit that is to be measured must be isolated from all other components or circuits so that meter current (from probe to probe) only flows through the desired circuit or component or the reading will not be accurate. Notice in **(Figure 5.3–7)** that if we wanted to measure the resistance of the load, most of the current flow from the meter would flow through the indicator lamp because it has less resistance. To measure the load, one connector to the load should be removed. It is not always apparent when a component must be isolated in such a manner, so it is usually a good practice to isolate the circuit or component by physically disconnecting one circuit.

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USING THE OHMMETER (Continued)

The ohmmeter leads are then placed across the component or circuit and the resistance will be displayed in ohms **(Figure 5.3–8)**. When checking a sensor or variable resistor such as fuel level gauge, heating the element or moving the arm should move the meter through a range of resistance that can be compared to a specification.

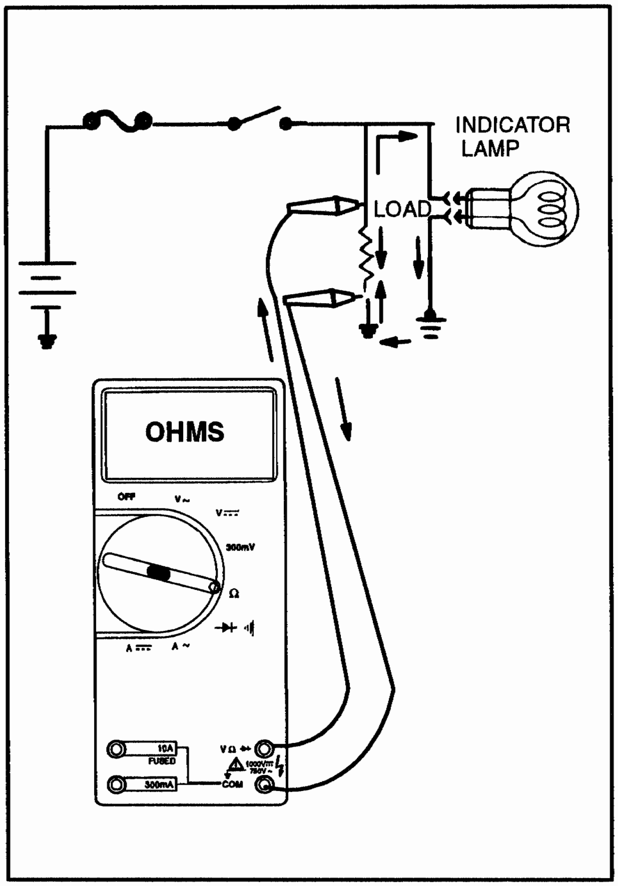

Figure 5.3–7– Improperly Isolating Component For Resistance Check

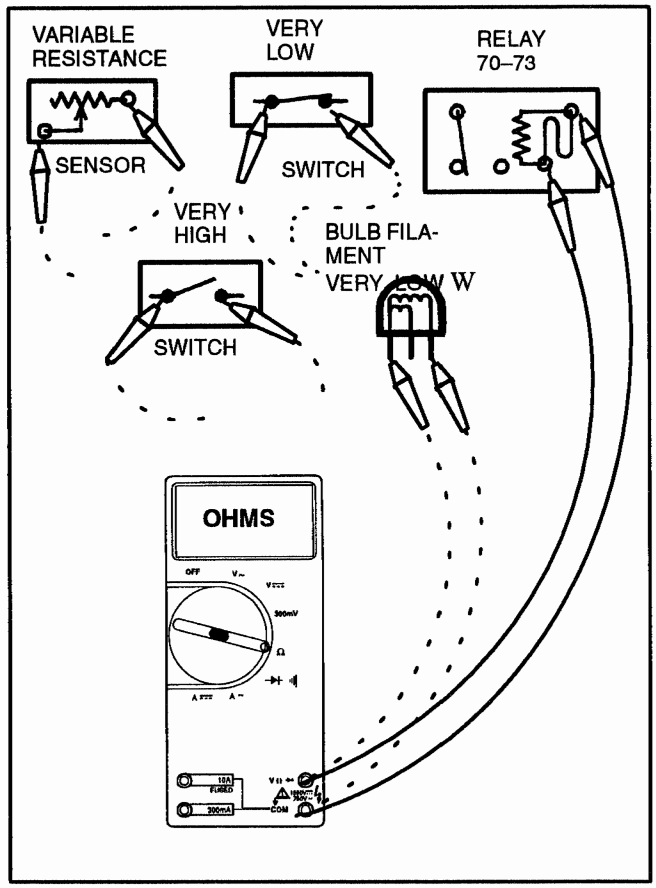

Figure 5.3– 8– Measuring Resistance

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USING THE OHMMETER (Continued)

CHECKING FOR OPEN CIRCUITS

Electrical circuits can be checked for opens using an ohmmeter. The circuit must first be disconnected from the power supply. The circuit to be checked must also be isolated from other circuits. Connect the meter to the open ends of the circuit as shown in **(Figure 5.3–9)**. A high reading (infinity) indicates there is an open in the circuit. A near zero reading is an indication of a continuous circuit. Notice also in **(Figure 5.3–9)** that we disconnected the circuit between the light and the ground. This precaution prevents reading a circuit as complete that may be shorted to ground ahead of the load device.

CHECKING FOR SHORT CIRCUITS

Checks for short circuits are made in a similar manner to that used to check for open circuits, except that the circuit to be checked must be isolated from both the power source and the ground point.

Connecting the ohmmeter as shown in **(Figure 5.3–10)** between an isolated circuit and a good ground point will allow checking the circuit for a short to ground. A short to ground will be indicated by a near zero reading, while a circuit not shorted to ground will cause the meter to read very high (near infinity). With the Fluke 88 DVOM, an open circuit will read “OL” on the meter display.

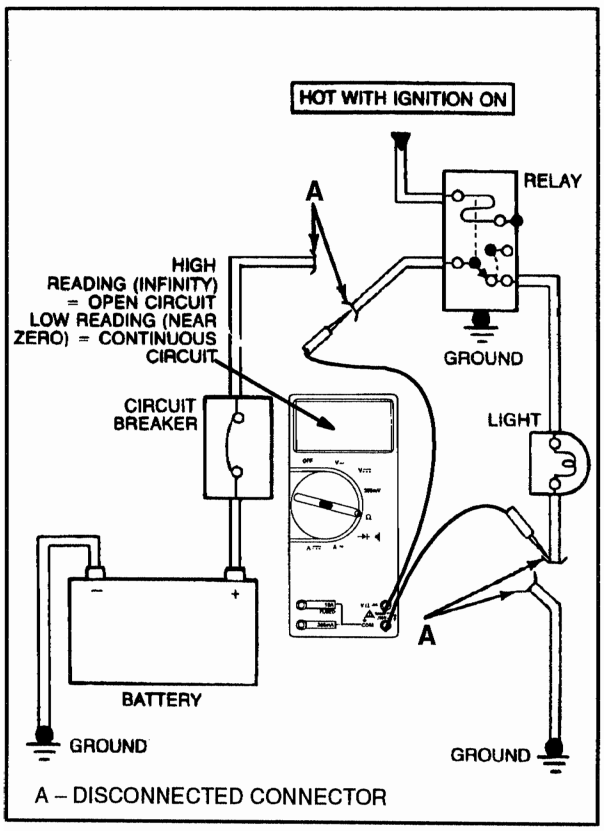

Figure 5.3–9 - Open Circuit Check Using An Ohmmeter

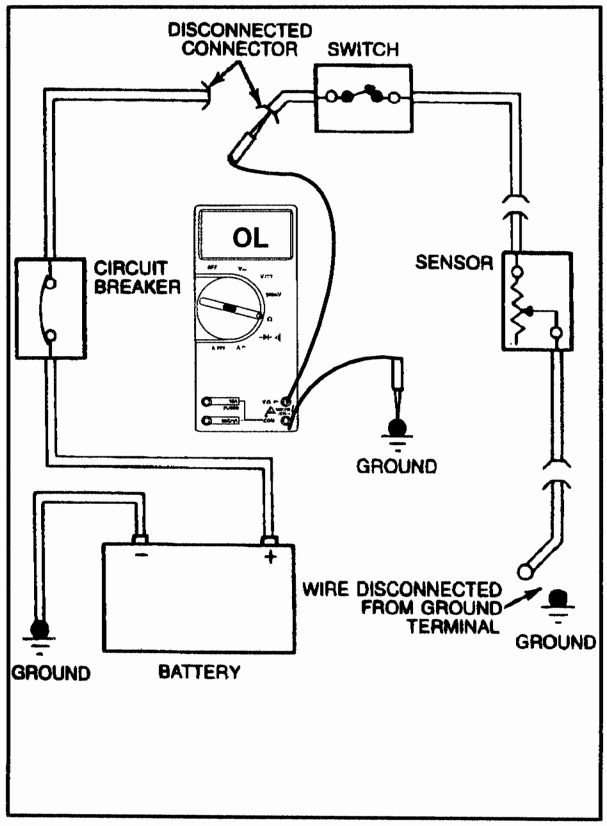

Figure 5.3–10 - Short Circuit Check Using An Ohmmeter

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TROUBLESHOOTING

Before beginning any troubleshooting, there are several important steps to be taken:

VERIFY THE PROBLEM

Operate the complete system and list all symptoms in order to:

- Check the accuracy and completeness of the complaint.
- Learn more that might give a clue to the nature and location of the problem.
- Analyze what parts of the system are working.

READ "ELECTRICAL OPERATION"

Read the electrical operation for the problem circuit (while referring to the circuit diagram). By studying the circuit diagram and the electrical operation, enough information about circuit operation should be learned to narrow the cause of the problem to one component or portion of the circuit.

CHECK THE CIRCUIT DIAGRAM

Refer to the circuit diagram for possible clues to the problem. Location and identification of the components in the circuit may give some idea of where the problem is.

The circuit diagrams are designed to make it easy to identify common points in circuits. This knowledge can help narrow the problem to a specific area. For example, if several circuits fail at the same time, check for a common power source or common ground connection (see POWER DISTRIBUTION AND GROUNDS). If part of a circuit fails, check the connections between the part that works and the part that doesn't work.

For example, if the low-beam headlights work, but both high-beam lights and the high-beam indicator do not work, then the power and ground paths must be good. Since the dimmer switch is the component that switches the power to the high-beam headlights, it is the most likely cause of failure.

CHECK FOR CAUSE OF THE PROBLEM

Diagnosis charts are provided for many of the common faults that may occur. Refer to these charts in each section. Follow the procedures in the chart until the cause of the problem is located.

If the particular symptom found in the problem circuit is not covered by a diagnosis chart, refer to the general electrical troubleshooting information provided under "Electrical Test Equipment" in this section.

MAKE THE REPAIR

Repair the problem circuit as directed in the diagnostic charts.

VERIFY THAT THE REPAIR IS COMPLETE

Operate the system and check that the repair has removed all symptoms, and also that the repair has not caused any new symptoms.

ELECTRICAL TEST EQUIPMENT

Various electrical testers have been developed over the years. A few of these are basic but necessary to perform an electrical diagnosis. These include:

- Jumper Wires
- Test Lights
- Voltmeter
- Ohmmeter
- Ammeter

All of these testers come in a variety of models and any working model will be adequate for simple tests. However, when the value of a reading obtained using a meter is critical to the diagnostic procedure, accuracy becomes important. Make sure any electrical test meter used is of sufficient quality and accuracy to make the measurements required in the electrical testing. The "Fluke 88 Digital Multimeter" (DMM) is the Navistar recommended meter and discussions of meter use in this manual will refer to that meter.

The Fluke 88 Multimeter, a digital meter, is recommended because it uses very little current to do its measuring. The digital meter has high impedance (resistance): 10 megohms.

ELECTRONIC CIRCUIT TESTING

Some of the devices in an electronic control system are not capable of carrying any appreciable amount of current. Therefore the test equipment used to troubleshoot an electronic system must be especially designed not to damage any part of it. Because most analog meters **(Figure 5.3–11)** use too much current to test an electronic control system, it is recommended that they not be used, unless specified.

ELECTRONIC CIRCUIT TESTING (Continued)

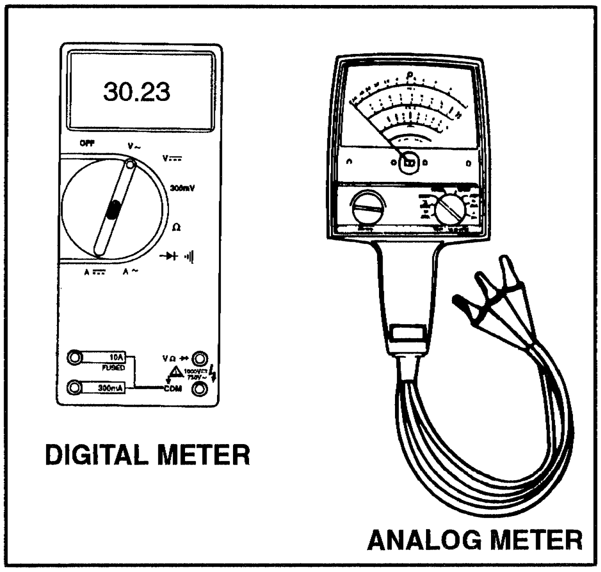

Figure 5.3–11 - Typical Meters, Digital And Analog

The use of any kind of battery-powered test light is not recommended when troubleshooting an electronic circuit, since it, too, could damage an electronic control circuit.

JUMPER WIRES

Jumper wires **(Figure 5.3–12)** allow "jumping" across a suspected open or break in a circuit.

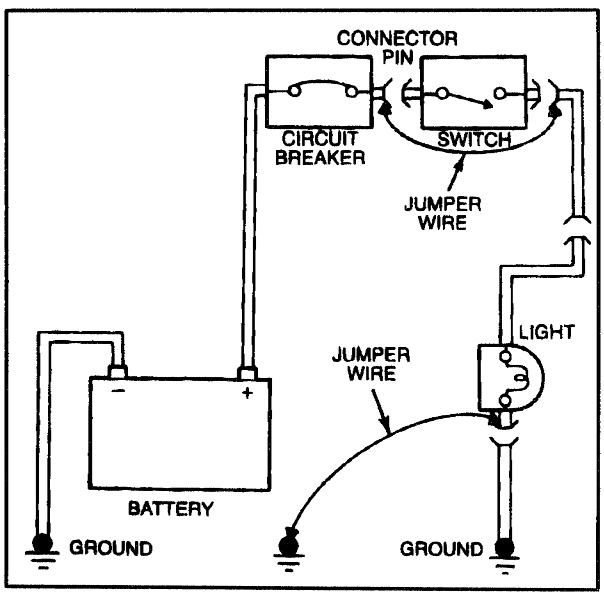

Figure 5.3–12 - Troubleshooting Using Jumper Wires

- If the circuit **(Figure 5.3–12)** works properly with the jumper wire in place, but does not work when the jumper wire is removed, the circuit has an open spot.
- A circuit without any opens or breaks has continuity (which means continuous) and needs no further testing.

Jumper wires are fitted with several types of wire tips. It will be helpful to have several jumper wires available with different tips **(Figure 5.3–13)**.

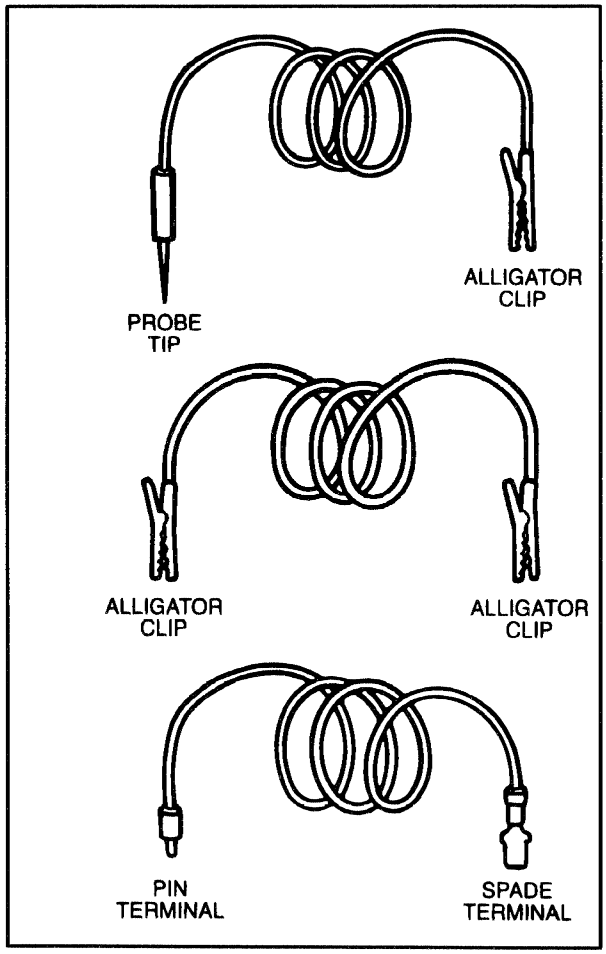

Figure 5.3–13 - Jumper Wires

In **(Figure 5.3–12)**, if bypassing the switch with a jumper wire causes the light to illuminate, but closing the switch does not, it indicates the switch has failed. If, with the switch closed, the light does not illuminate, and "jumpering" the switch doesn't cause the light to operate, but "jumpering" the light to ground causes the light to operate, then there is an open in the ground circuit.

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JUMPER WIRES (Continued)

The jumper wire can be used to check for open relay contacts, wire breaks, poor ground connections, etc.

12—VOLT TEST LIGHTS

The 12-volt test light tests for voltage in a circuit between the point being tested and ground **(Figure 5.3–14).** If there is no glow in the bulb, the circuit is open and no current is flowing.

Once a technician becomes familiar with the test light and the brilliance of the bulb in a normal circuit, high-resistance circuits can be recognized by the dimming effect that they have on the test light bulb. As the current drops in a high-resistance circuit, the bulb will glow less brightly. Although using a 12-volt test light cannot be used as a fool-proof test for high resistance, a less than normal brilliance of the test light is an indication of circuit high resistance. Further testing will verify the condition and locate the cause.

The 12-volt test light continuity tester depends on the vehicle battery to power the circuit under test. Twelve-volt testers are available with a variety of tips to permit touching them to connectors, bare wires, insulated wires or even wires within wiring harnesses **(Figure 5.3–15)**. To check the tester before use, briefly touch the clip to one post of the battery and the other to the opposite post. Twelve-volt testers are not sensitive to polarity and can be connected either way.

The 12-volt test light generally has a sharp probe tip so it can be inserted into connector terminals or through wire insulation for testing. It is important to keep the probe tip sharp to minimize damage to wire insulation. When the test is complete at a particular point, make sure to tape any holes made in wire insulation.

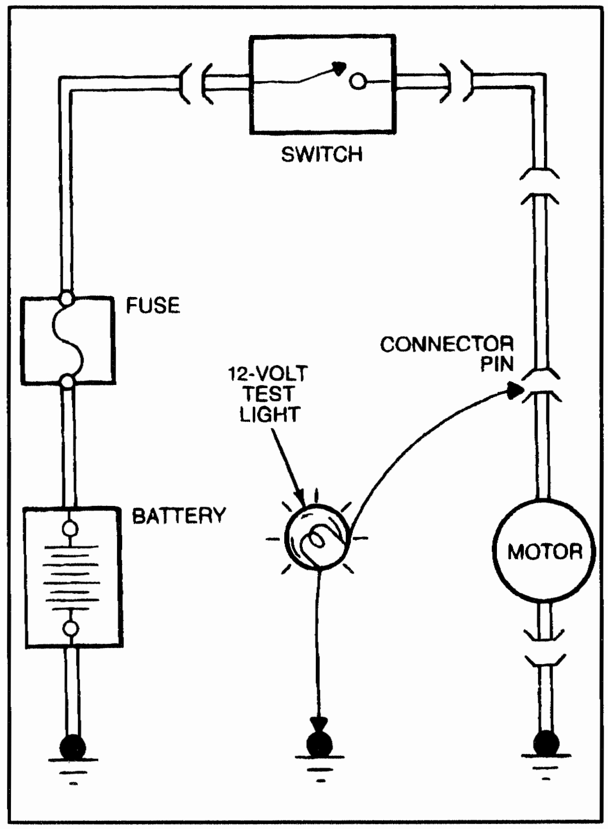

Figure 5.3–14 - Troubleshooting Using 12-Volt Test Light

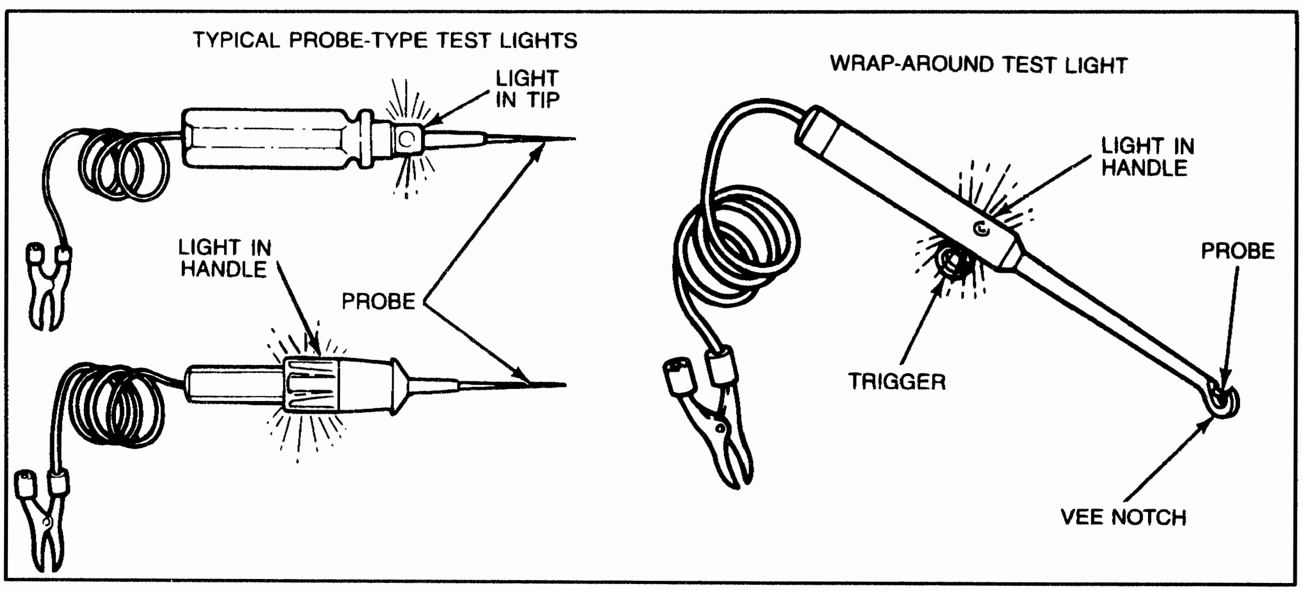

Figure 5.3–15 - Typical 12-Volt Test Lights

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