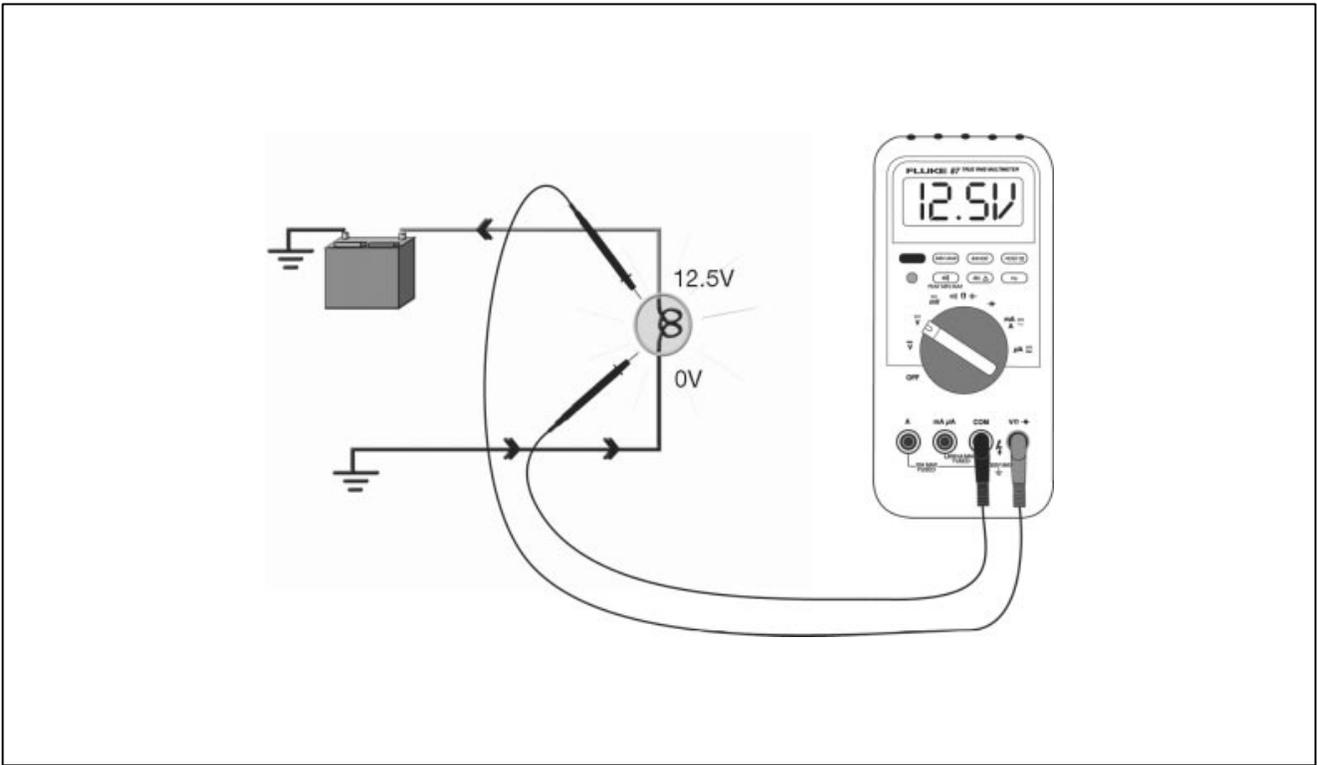


Section 1

Electrical Circuit Theory



- Learning Objectives:**
1. Review the basic electrical concepts of voltage, amperage, and resistance.
 2. Review the components of a basic automotive electrical circuit.
 3. Introduce basic wiring diagram symbols.
 4. Review the characteristics of voltage, amperage, and resistance in series and parallel circuits, showing how they are used when diagnosing electrical problems.
 5. Show how series-parallel circuits are used on the vehicle.
 6. Introduce the basic electrical diagnostic tools.



Notes

Introduction The first step in being able to effectively diagnose electrical problems is to have a good understanding of basic electrical principles. These concepts were covered in depth in the L623 course. In this course, we will be reviewing each of them with emphasis to their on-car applications and how these concepts are applied when you are diagnosing an electrical problem.

**Electrical
Circuit Diagnosis
Course L623**

Course L623 covered the “basics” of electrical. This course will expand on those concepts and apply them directly to the on-car diagnostic process.

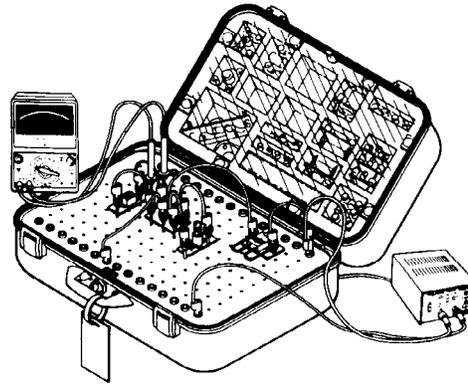


Fig. 1-1
L652f101

Voltage Simply put, think of voltage as **electrical pressure** or pressure differential. The difference in pressure that makes any hydraulic pump work is virtually the same for electrons. The pressure differential provided by the positive and negative terminals of the battery causes the electrons in a conductor to move when the two terminals are connected together.

This movement or flow of electrons is used to perform useful work. Whenever work is done, pressure is used up. We can measure where work is done in an electrical circuit by measuring where voltage is used up.

**Voltage
as Pressure**

Like the pressure/suction that a pump provides a fluid, a battery or alternator provides for an electrical circuit.

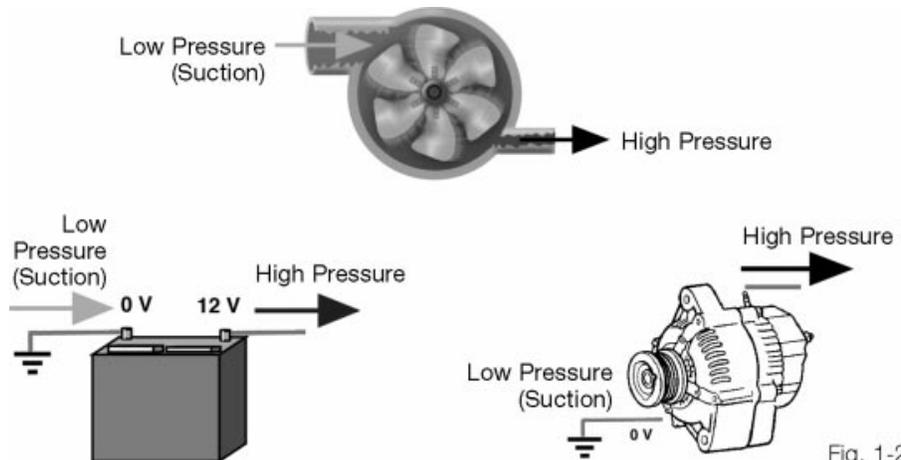


Fig. 1-2
L652f102

When working with on-car electrical problems, there are two different methods of voltage measurement. A Technician can either measure an open circuit voltage or a voltage drop. **Open circuit voltage** is measured when there is no current flow through the circuit. A **voltage drop** is measured dynamically while there is current flow through the circuit. Both open circuit voltage and voltage drop testing have their place in the diagnostic process. Information from each measurement can be helpful if used appropriately. These two measurements will be discussed in more detail in the **Electrical Diagnostic Tools** section of this course.

Measuring Open Circuit Voltage

This measurement tells you if there is voltage present at a terminal. It cannot tell you if there is any circuit resistance up to that point.

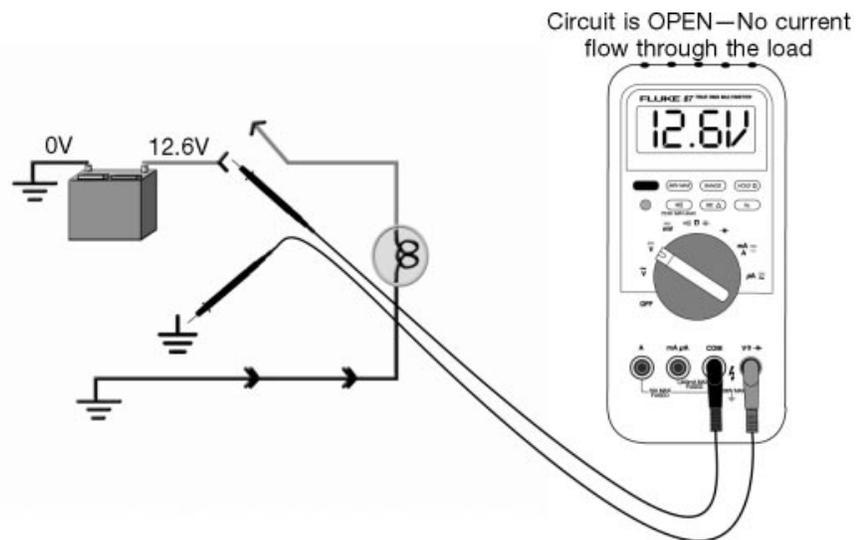


Fig. 1-3
L6521103

Measuring Voltage Drop

This measurement can only be done if there is current flow in the circuit. It accurately tells you how much voltage is actually available at the load, or the amount of voltage lost across connections or wiring on either the ground or power side of the circuit.

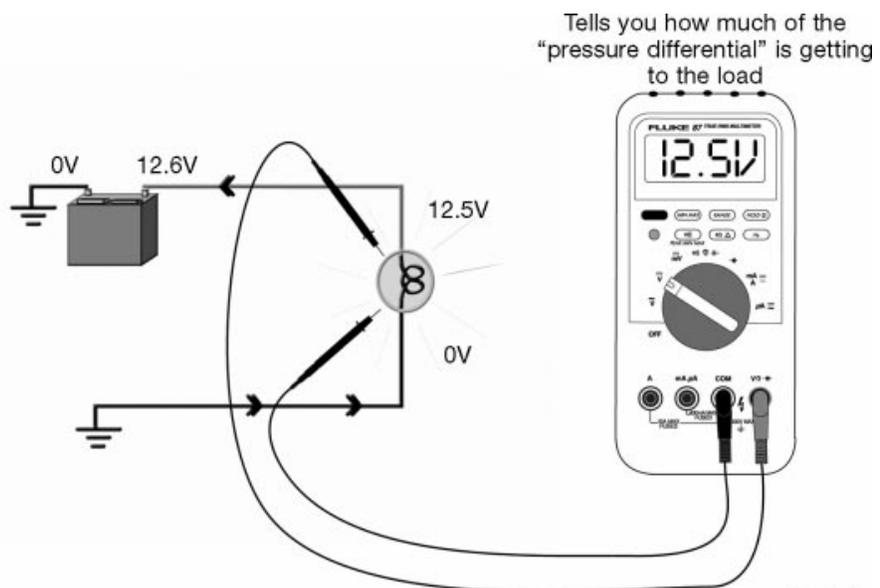


Fig. 1-4
L6521104

Voltage Drop Whenever current passes through any component, voltage is used up. The voltage used up is called Voltage Drop (ΔV).

NOTE

Δ is the Greek letter delta. The symbol delta means “change in”. When we use the abbreviated DV it indicates “change in voltage” or Voltage Drop.

The voltage drop (ΔV) of a component is directly proportional to the resistance of the component. The greater the resistance the greater the voltage drop (ΔV). Low resistance components like fuses, switches, wires and connectors should have very low ΔV . As a general rule the maximum ΔV allowed for these components is less than 0.1V per component or connector.

Higher resistance components are usually referred to as loads. Loads use their resistance to convert current into work (light, heat, motion). This conversion causes voltage drop (ΔV) as the electrical pressure is used up. Typical loads include lamps, motors, relay coils and most sensors. Voltage drop (ΔV) is always proportional to resistance. The higher the resistance, the higher the ΔV .

In any electrical circuit, all the voltage will always be used up. Adding up all the voltage drops in a circuit will always equal source voltage.

Current Flow Current is the term used to describe the **flow of electrons** through the circuit. It is this flow of electrons that does the “work” in the circuit. The unit for measuring the amount of current flow is the Ampere or Amp (A). One Amp equals 628 billion billion electrons per second flowing through a circuit.

Current will only flow if there is a complete circuit between a source of higher voltage (power) and a lower voltage (ground). Voltage is the pressure that pushes the electrons through the circuit and Amperes is a measure of the number of electrons flowing.

The combination of amperage with voltage determines the amount of **power** that is being used at the load in the circuit. Power is measured in Watts (W). The amount of power that is being used by a load can be determined by multiplying the amperage through the load by the voltage drop across the load.

Current Flow

Measured in Amps (A) or milliamps (mA), current flow is caused when a voltage or pressure differential exists at both ends of a conductor.

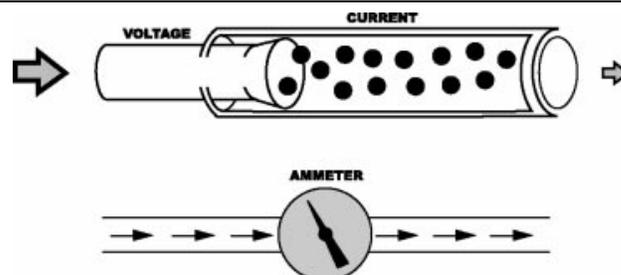
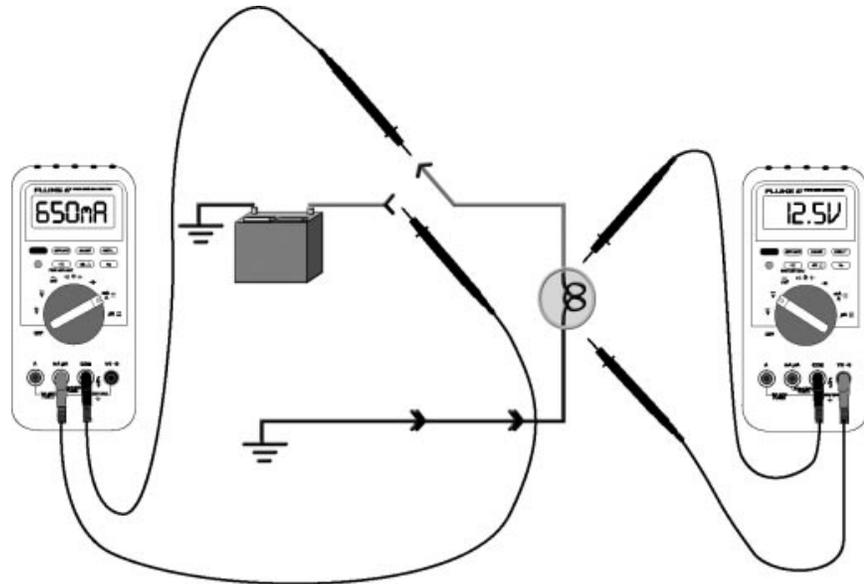


Fig. 1-5
L652f105

Measuring Amperage

Note that the ammeter is connected in series. The circuit must be "broken" so that the meter could be placed "in-line" with the circuit. The wattage of the light bulb can be determined by multiplying the amperage and the voltage drop.



Amps x Voltage Drop = Watts
 $0.650A \times 12.5V = 8.125W$

Fig. 1-6
L6521106

Resistance Electrical resistance describes how much something opposes current flow. This opposition to current is measured in Ohms (Ω) or in thousands of Ohms ($k\Omega$). In every circuit, resistance **regulates** current.

In a "perfect" circuit, the only resistance would be the load you are operating with the circuit. But even the best of conductors (materials which allow the flow of electrons) have a certain amount of electrical resistance. Materials which have an extremely high resistance are called *insulators*.

Resistance

Resistance is the opposition to current flow. Resistance determines the amount of current flow as long as the voltage stays constant. In theory, the load should be the only resistance in the circuit.

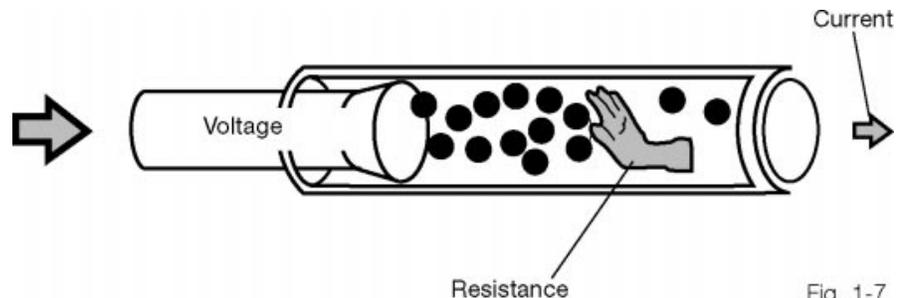


Fig. 1-7
L6521107

Using an Ohmmeter

When using an ohmmeter, disconnect the component from the circuit to isolate the measurement from other current flow paths or voltage sources. In this case, the ohmmeter does not measure the open circuit at the burned out light bulb.

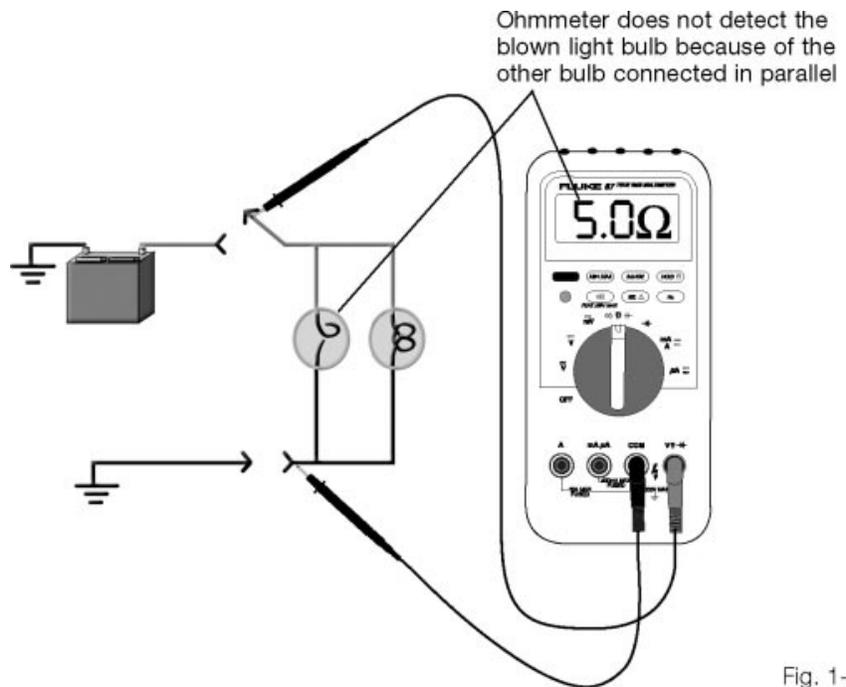


Fig. 1-8
L6521108

Ohm's Law In short, Ohm's law states that "current in a circuit will always be proportional to the voltage and resistance present." Voltage, amperage, and resistance in a circuit work in *proportion to each other*. Mathematically, we can always *predict* what electricity is going to do in a circuit, as long as we know what any two of the three values are.

So, for example, if you knew what the voltage and resistance were in a circuit, you could easily determine exactly how much current there would be in the circuit.

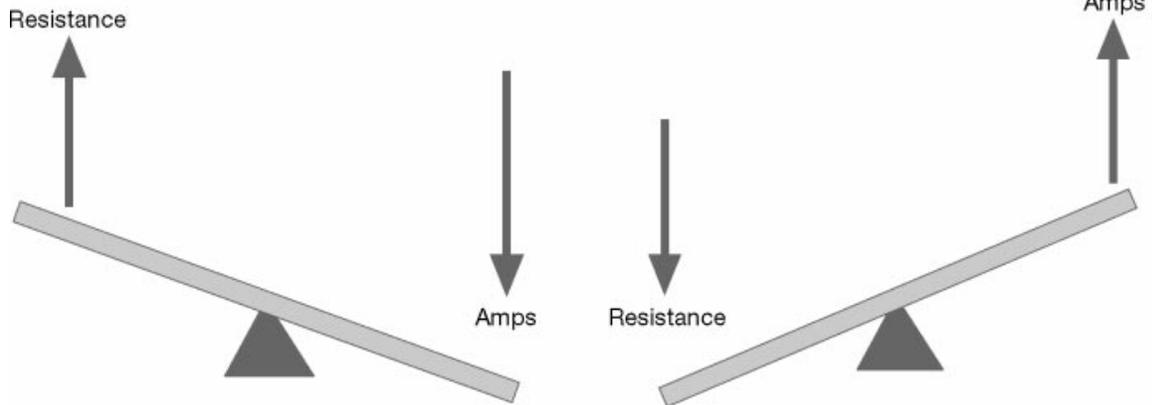
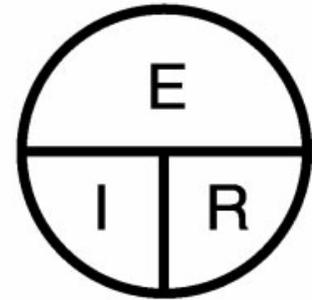
Ohm's Law Equation

The important fact about Ohm's law is that electrical systems and electrical problems are predictable. There is no magic to how electricity works!

$$\text{Voltage} = \text{Amperage} \times \text{Resistance}$$

$$\text{Amperage} = \frac{\text{Voltage}}{\text{Resistance}}$$

$$\text{Resistance} = \frac{\text{Voltage}}{\text{Amperage}}$$



When Resistance goes up, Current Flow goes down.
When Resistance goes down, Current Flow goes up.

Fig. 1-9
L652f109

Basic Principles of Series/Parallel Circuits

Ohm's Law Formula

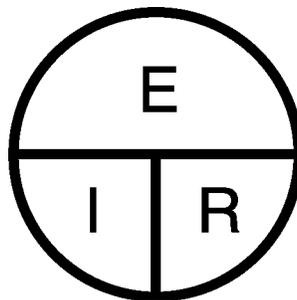
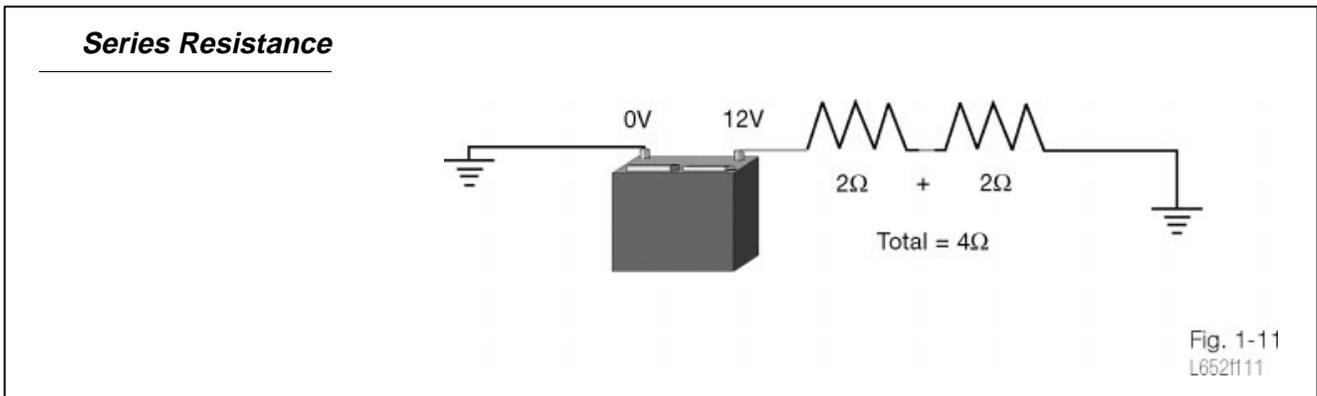


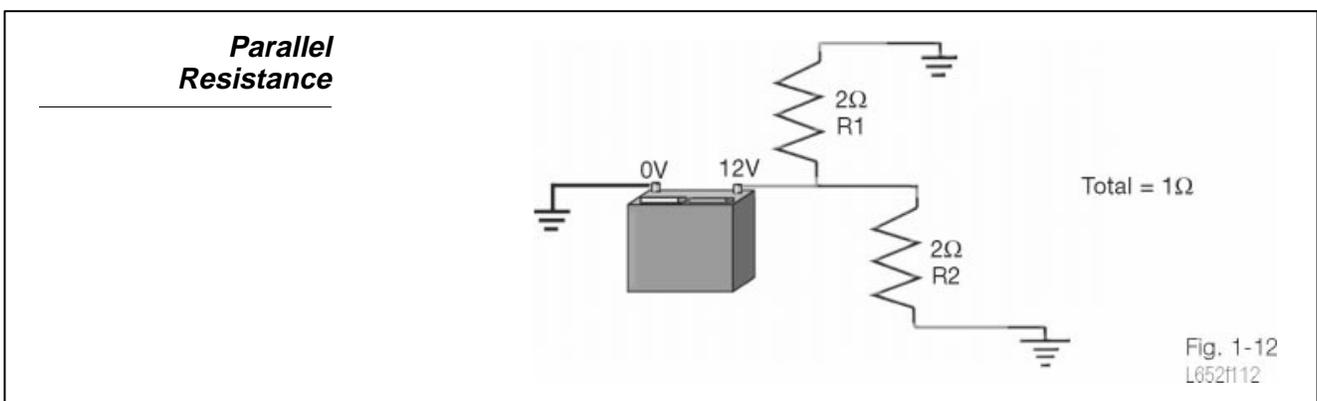
Fig. 1-10
L652f110

Series Resistance One of the more difficult concepts concerning Ohm's Law has to do with calculating resistance in a circuit. Series circuit resistance is probably the easiest concept to understand because it is simply an adding up of all the resistances in a circuit in order to get the total resistance. Figure 1-11 illustrates the method.



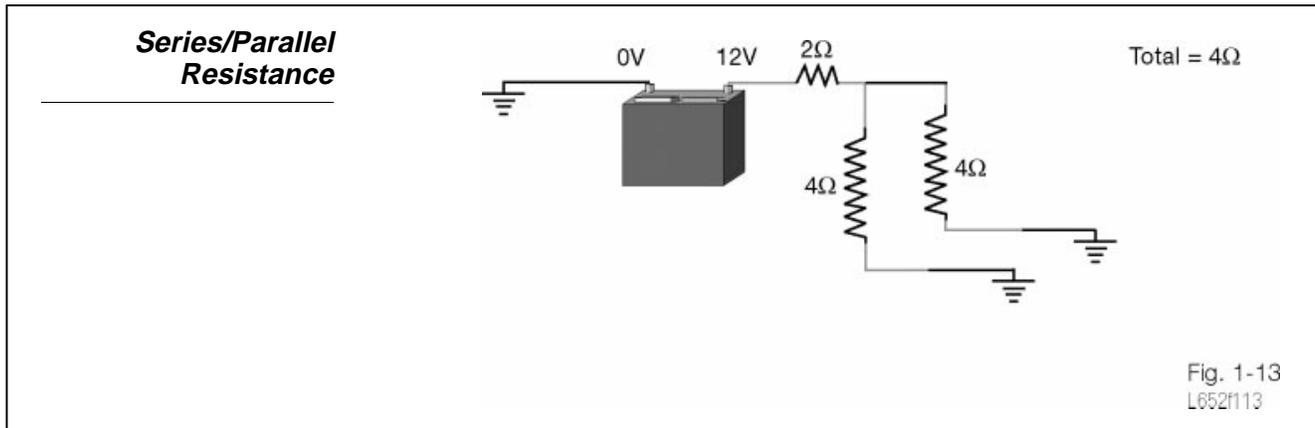
The total resistance is the sum of all resistances in the circuit. This resistance will affect the number of amps which can flow through the circuit. Ohm's Law says that amps can be found by dividing ohms into voltage. In this case: $12V$ divided by 4Ω equals $3A$.

Parallel Resistance In Figure 1-12, we have a parallel resistance rule at work. The total circuit resistance will always be less than the smallest resistance. To find total resistance you must treat each branch as an individual series circuit. $12V$ divided by 2Ω equals $6A$ current per branch. Adding the branch currents, $6A$ plus $6A$ equals $12A$ total current. Dividing $12V$ by $12A$ equals a total parallel circuit resistance of 1Ω . Notice that this number is smaller than the smallest branch resistance.



Series/Parallel Resistance

Series/parallel circuits are the most difficult calculation.



The first step is to calculate the total resistance of the parallel portion of the circuit. The formula is:

$$\frac{1}{\frac{1}{R1} + \frac{1}{R2}}$$

Using values from the example:

$$\frac{1}{\frac{1}{4} + \frac{1}{4}} = \frac{1}{0.25 + 0.25} = \frac{1}{0.5} = 2\Omega$$

Adding the total resistance of the parallel portion, 2Ω ohms, to the 2Ω from the series portion equals 4Ω total circuit resistance.

Why Does It Matter?

Knowing the formulas which arise out of Ohm's Law is not necessarily helpful for repairing automobiles. A person can know theory, but not know how to apply it in the real world. However, a knowledge of the relationships between these elements is essential to a Technician. You need to be able to predict what **should be** as opposed to **what is** in a problem vehicle. We are going to use the concept of voltage drop in this class to make this kind of diagnosis quicker and easier. Later, as you become more familiar with electrical theory and concepts, there may be an opportunity to do more advanced calculations like the ones we have discussed here.

On-Car Applications of Ohm's Law

The “math” side of Ohm’s Law is important if we are designing a circuit. But because we are in the business of repairing electrical problems, what we need to know about Ohm’s law can be summarized. Since most circuits (and basically all body electrical circuits) work on what is called 12V power (which is actually more like 12.6 - 13.6V) we will look at Ohm’s law with the voltage held constant. Assuming this fixed voltage, we can summarize Ohm’s law as: **“When resistance goes up, current goes down. When resistance goes down, current goes up.”** This is the heart of Ohm’s law when it comes to servicing a vehicle.

Knowing the principle of Ohm’s law plays an important role when diagnosing an electrical problem. However, a Technician will rarely use a calculator to fix an electrical problem. The importance of Ohm’s law is that it provides the foundation for being able to **understand and predict** how an electrical circuit will respond.

- If a circuit is **inoperative**, and there is no current in the circuit, it means that there is an infinite amount of resistance or an **open** somewhere in the circuit.
- If the circuit is **partially working** (such as when a bulb is dim), and the load is not receiving full battery voltage, it is probable that there is **excessive resistance** in the circuit. The excessive resistance can be located either in the circuit itself or in series somewhere in the circuit. Or, the battery may not be delivering 12V.

HINT

If the battery voltage is low, more than one circuit will be affected.

- If a 20A **fuse is blown**, we know that a lot of current must have been flowing in the circuit. In order to get a 20A fuse to blow at 12V, there must be very little resistance (0.6Ω) in the circuit. This condition is caused by too many loads connected to the fuse, aftermarket accessories or a possible **short-to-ground**. Shorts-to-ground provide a no or very low resistance to path to ground **before the load**, allowing current to flow unregulated. In this case, the resistance of the load has been removed.

Because of Ohm’s law the actual circuit does not need to operate in order for us to know how much current (if any) there will be or where it is going to flow. Ohm’s law makes current predictable. So instead of checking *every component, connector or wire* on the vehicle, a Technician can use the *System Circuit Diagram* to determine where current flow should be, and which specific area could be causing the problem. This type of diagnosis eliminates unnecessary checks during the repair process. **It saves the Technician time.**

General Electrical Rules

- Current can only flow when there is a complete path between power and ground (or between a higher voltage and a lower voltage). No complete path = “open” circuit = 0 current.
- The resistance of the load limits current in the circuit and converts current into work. In a perfect circuit the only resistance would be the load.
- Whenever current flows in a circuit voltage drops (ΔV) will happen. Voltage drops happens anywhere there is resistance. The larger the resistance the larger the voltage drop.
- Every circuit will use up all the source voltage (total ΔV will always equal source voltage).

Series Circuit Principles

In a **series circuit**, regardless of the number of loads in the circuit, there is only one path for current. There are not many circuits on the vehicle that precisely fit this description. The Lexus radiator fan circuit, shown in fig. 1-14, is a good example of a “true” series circuit. In general, the term “series” is used to describe any **in-line connection** between electrical components. Control components in the circuit, such as a resistor or a switch, as well as *circuit problems* are always in series. The term “series” is also used when describing the connection of test equipment, such as an **ammeter**.

An Application of Series Circuit Principles

On a typical Lexus Electric Radiator Fan Circuit, the fan motors are connected in series to get a low speed. Note all of the connections, switches and relay contacts that are connected in series with each other. Reference the “Radiator Fan and Condenser Fan” circuit in the EWD, System Outline, “Low Speed Operation” for a complete description.

RADIATOR FAN AND CONDENSER FAN

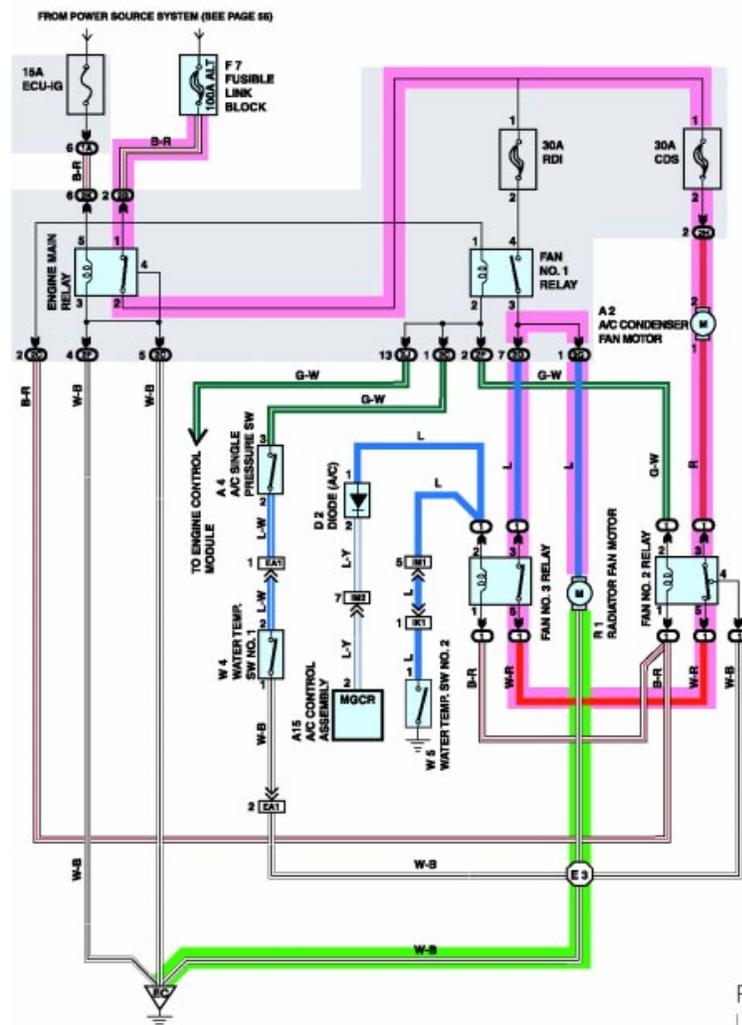


Fig. 1-14
L6521114

Voltage The voltage provided by the battery or power source will divide proportionally between all of the resistances in the circuit. The resistor with the largest value, relative to the other resistance in the circuit, will have the largest voltage drop. If we measure all of the voltage drops in the circuit and add them together, we will always find that the sum of all drops will equal source voltage.

Resistance and Current The resistance in a series circuit **add up** to the total circuit resistance. Assuming a fixed 12V power supply, the current in the circuit is determined by **total circuit resistance**. Since there is only one path, current will be the same at every point in the circuit. The placement of excessive resistance in the circuit, either before or after the load, does not change its affect on current. The resistance can be on either the “power” or “ground” side of the load and still cause the same reduction in current that leads to circuit problems.

Resistance In Series Decreases Current Flow Everywhere in the Circuit

The use of resistors in series decreases the amperage in the circuit. With the combination of the 3 resistors and a unique switch design, a one speed blower motor can have 7 different operating speeds.

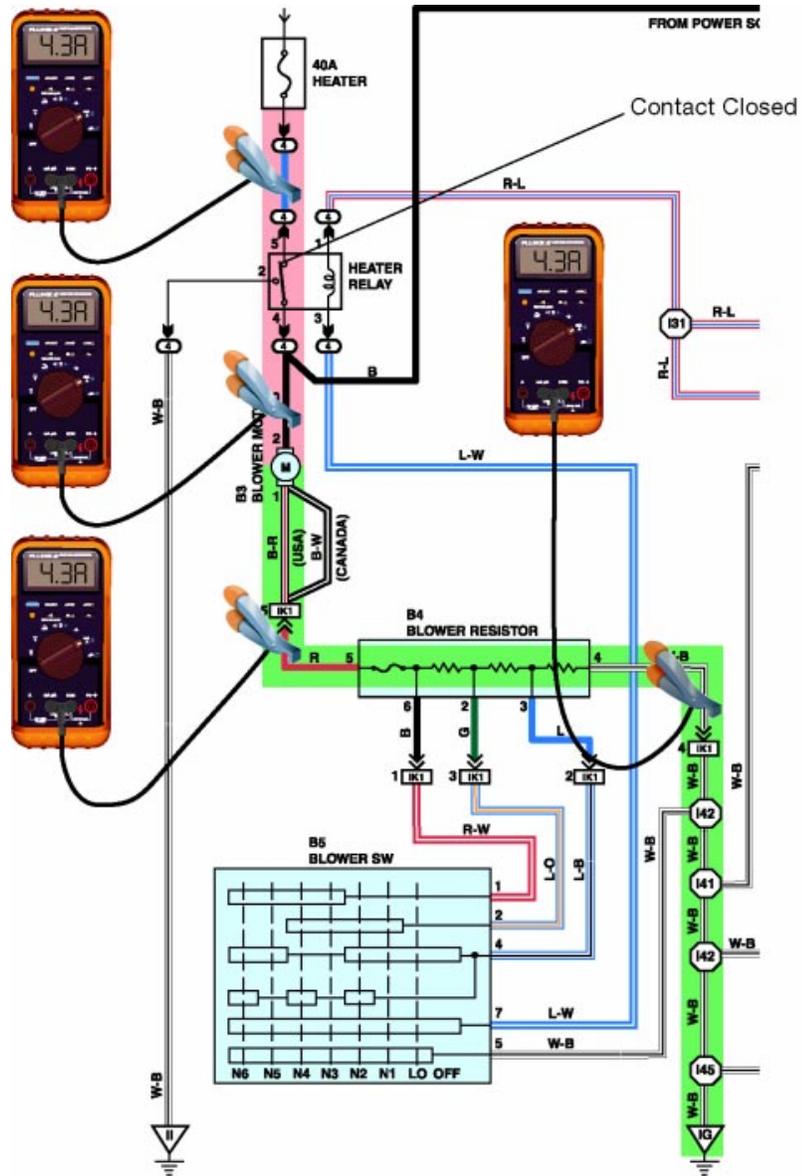


Fig. 1-15
L652f101

**Series Circuit
General Rules**

- A true series circuit has only one current path regardless of the number of loads in the circuit.
- If there is only one load in the circuit, all the voltage drop will be in that load.
- If there are two, or more, loads in a circuit voltage drops will be divided accordingly to the resistance of the loads.
- The loads with the highest resistance will have the highest voltage drop. The load with the least resistance will have the least voltage drop.
- Current is the same everywhere in the circuit. An ammeter can be connected anywhere in the circuit in order to measure current.

**On-Car
Application of
Series Circuit
Principles**

1. In a “perfect” automotive circuit, the **voltage drop at the load** would be exactly **the same as battery/source voltage**. Because of series resistance in the circuit from connections, control devices and conductors, the voltage drop at the load will **always be less than source voltage**, but not much.
2. If there is a **high resistance problem** in the circuit, it will **decrease the voltage drop at the load**. Because we know that the voltage drop in the circuit must add up to source voltage, we can use a voltmeter to track down and isolate the problem, by measuring voltage or voltage drops at various points in the circuit.
3. A **circuit problem anyplace in the circuit** (even if it is after the load) will reduce current in the entire circuit. Poor connections, nicked wires, or a loose ground point will affect the entire circuit.

Using Voltage Drops To Troubleshoot High Resistance Problems

By connecting the voltmeter in parallel, you can determine the location of any high resistance problem in a circuit.

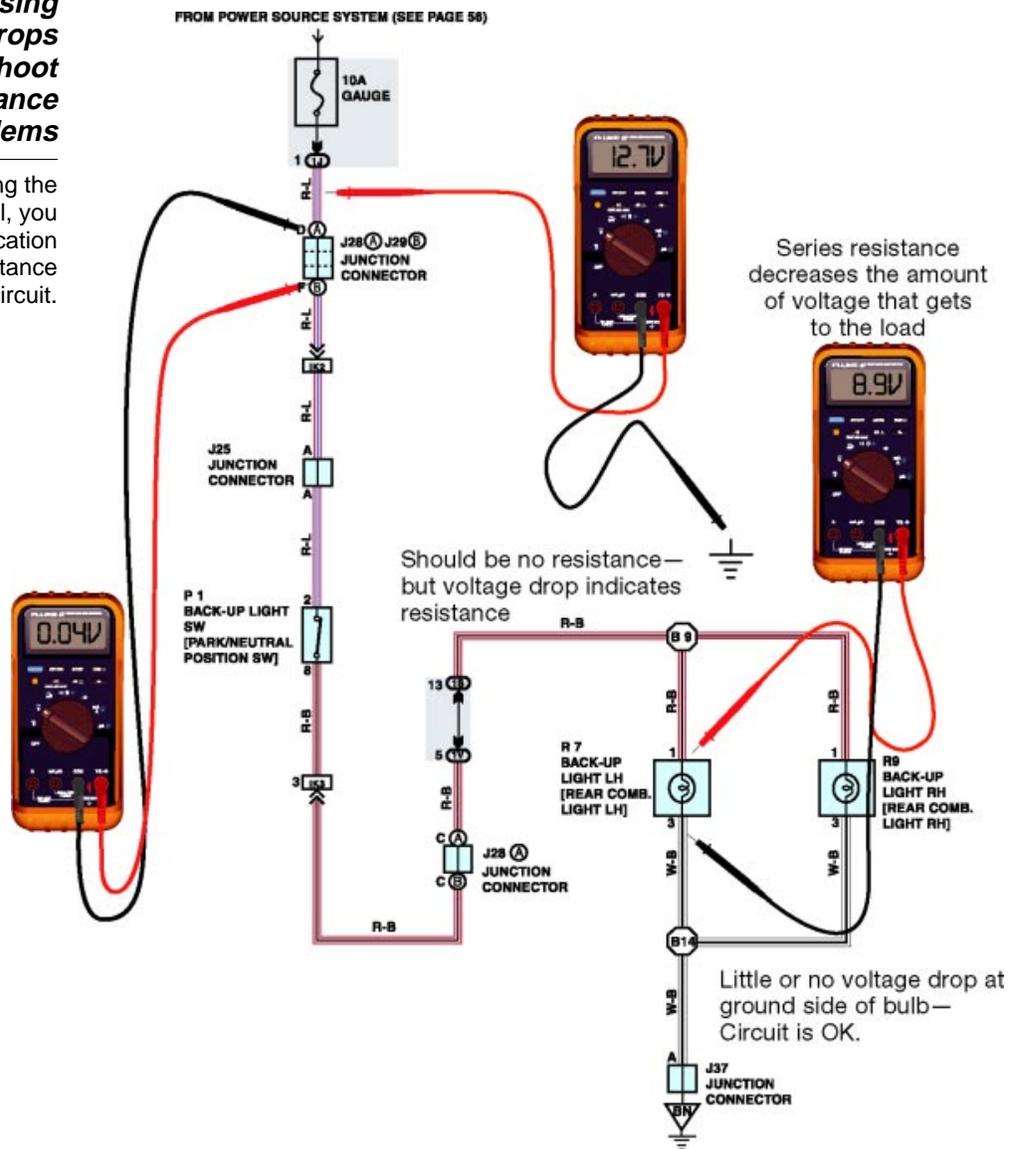


Fig. 1-16
L6521116

Parallel Circuit Principles

A parallel circuit has multiple loads that are connected to both the power source and ground in individual branches. Each branch provides its load with power and ground paths that are independent of other loads. There are very few “true” parallel circuits in automobile electrical systems. However, since automotive circuits are a combination of series and parallel circuits, understanding both series and parallel circuit principles is crucial to understanding automotive electrical systems.

Voltage Source voltage is applied to every branch of a parallel circuit. The number of branches in a parallel circuit will have no effect on the voltage applied.

The term **parallel** is also used to describe how to connect a voltmeter into a circuit to make a **voltage drop test**. Backprobing the connector in parallel doesn't break into the operating circuit, it simply allows a path for additional current in the circuit. This small amount of current (due to high meter impedance) is used by the voltmeter to determine voltage drop between the two test leads.

Application of Parallel Circuit Principles

The branches of a parallel circuit operate independently of each other. A parallel connection to the battery/charging system delivers "12V" to all the electrical components on the car.

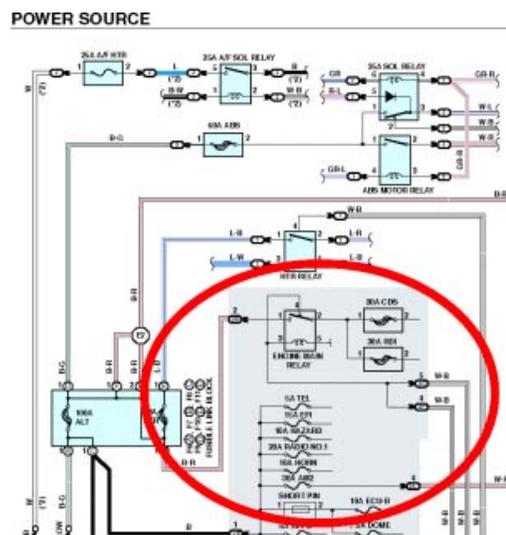


Fig. 1-17
L652117

Backprobing a Connector

Here is an example of the parallel connection of a meter. This set up can measure voltage drop or show available voltage. Probing from the front of the connector can do a lot of damage if not done VERY CAREFULLY!

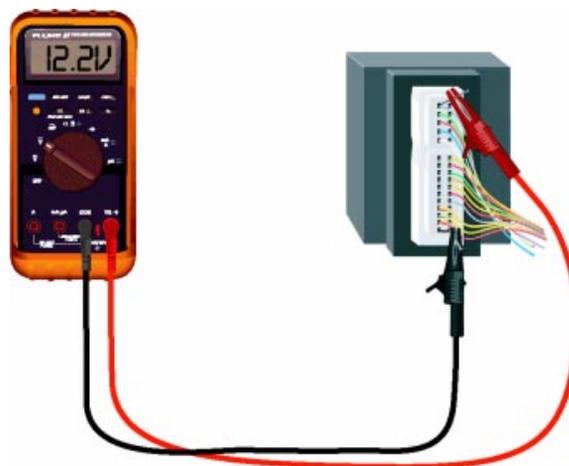


Fig. 1-18
L652118

Voltage in a Parallel Circuit

The voltage in each branch is the same as the source voltage. (There is an inconsequential drop at the load.)

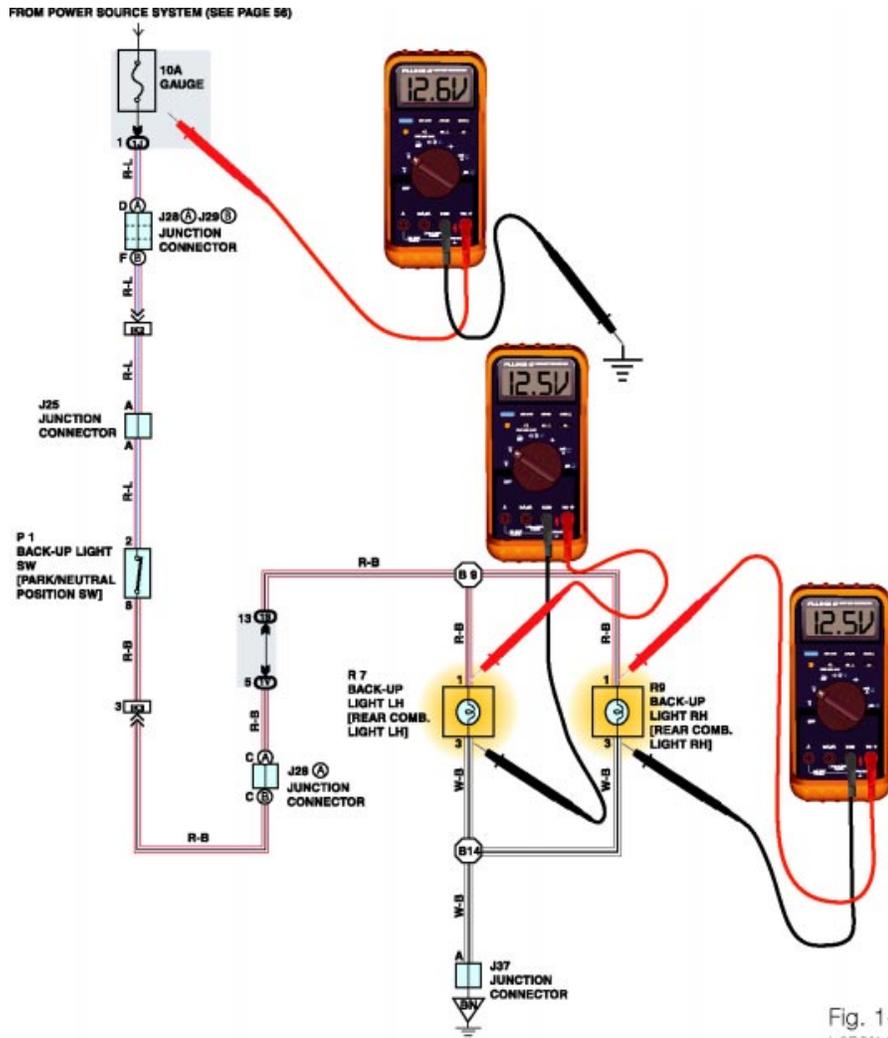


Fig. 1-19
L652f119

Resistance and Current

The resistance rule for parallel circuit is one of the most difficult concepts in every basic electrical course. In parallel circuits, total circuit resistance is always less than the smallest individual resistor. To help understand this principle, keep the relationship between resistance and current in mind.

- As demonstrated by Ohm's Law, when voltage is held constant, resistance and current are inversely proportional. If resistance goes up then current will go down and if resistance goes down, current goes up.
- Total parallel circuit current is the sum of all the branch currents. Adding a branch to a parallel circuit increases total current. The only way for total circuit current to increase is for total circuit resistance to decrease.

Determining Resistance in a Parallel Circuit

There are formulas to determine this resistance. On cars, we tend to look at parallel circuits in terms of the amount of AMPERAGE used, and not in terms of the total circuit resistance.

$$\text{Resistance} = \frac{\text{Voltage}}{\text{Amperage}}$$

$$\frac{12.8\text{V}}{4\text{A}} = 3.2\Omega$$

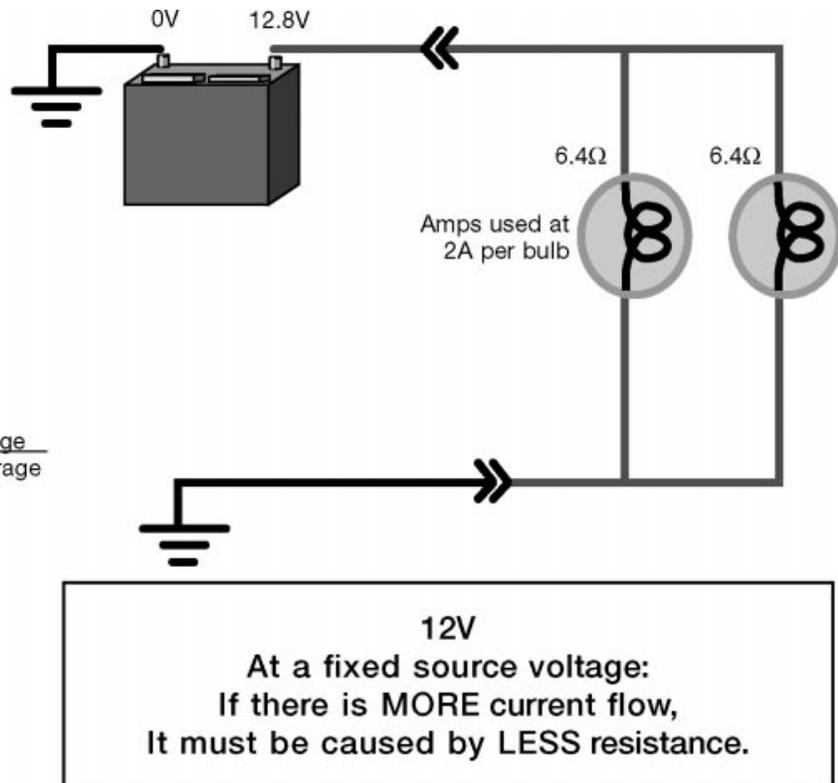


Fig. 1-20
L6521120

NOTE

As long as you understand how voltage and amperage “work” in a parallel circuit, understanding the resistance concept may fall into the category of “nice to know” but not critical when it comes to on-car diagnosis.

Parallel Circuit General Rules

- Parallel circuits have more than one path for current.
- Source voltage is applied to all branches.
- Current in each branch is determined by that branch’s resistance.
- Total current is the sum of all the branch currents.
- Total circuit resistance decreases as branches are added. Adding a branch increases total circuit current and if current goes up it must be because resistance went down.
- Total circuit resistance will always be less than the lowest branch resistance.

Applying the Parallel Circuit Current Flow Principles

By figuring how much amperage increased when an accessory is turned on, will tell you how many amps the one component is using, even if there are other accessories in operation.

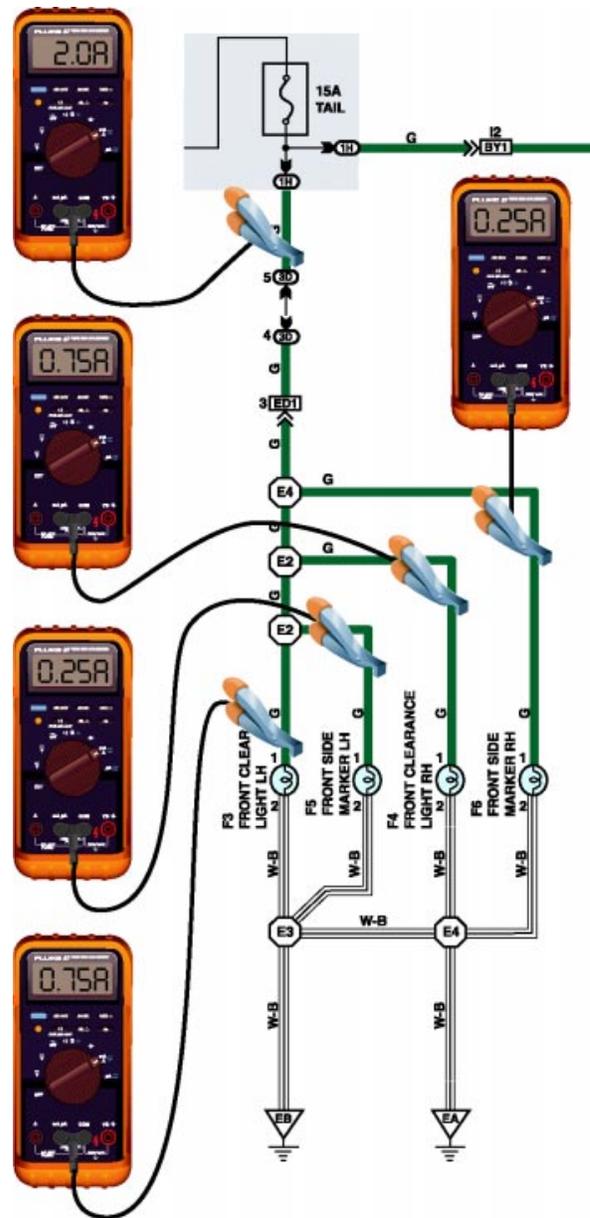


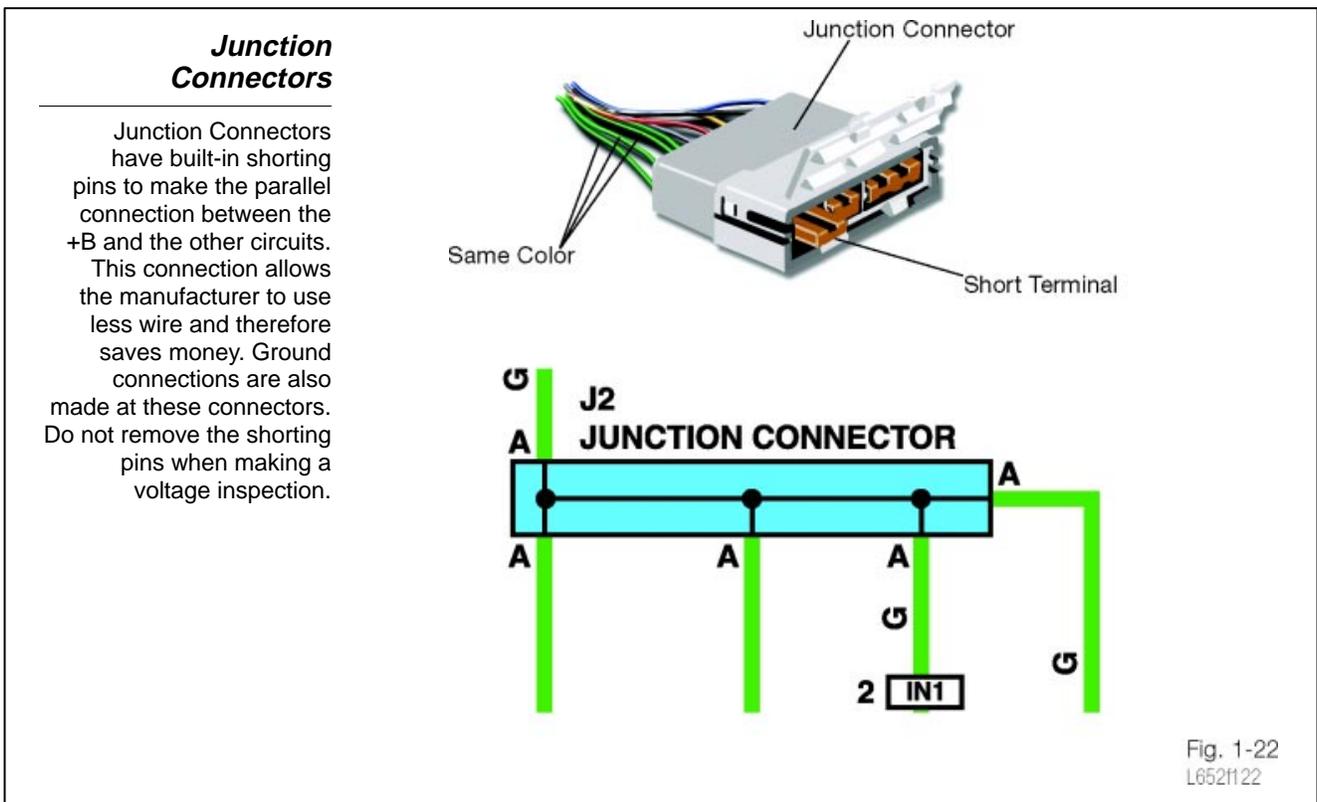
Fig. 1-21
L6521121

Series-Parallel Circuits

Series-parallel circuits are combinations of series circuit elements and parallel circuit elements. Most Lexus electrical circuits are a variation of the classic series parallel circuit. A typical Lexus automotive circuit will have the power supply and sometimes a control device in series with parallel connections to multiple loads. Series connection for power and control allows designers to simplify and lighten the electrical system. Parallel connections to multiple loads allow components to receive full source voltage for maximum efficiency. A classic series-parallel circuit has a load in series connected to multiple loads in parallel. In this type of circuit, the load in series causes a voltage drop so the parallel loads receive less than full source voltage.

When analyzing series-parallel circuits remember that the series portions of the circuit will follow series circuit rules. The parallel portions of the circuit will follow parallel circuit rules.

Junction blocks, junction connectors and splices are used to create the transition between the series and the parallel portions of series-parallel circuits.

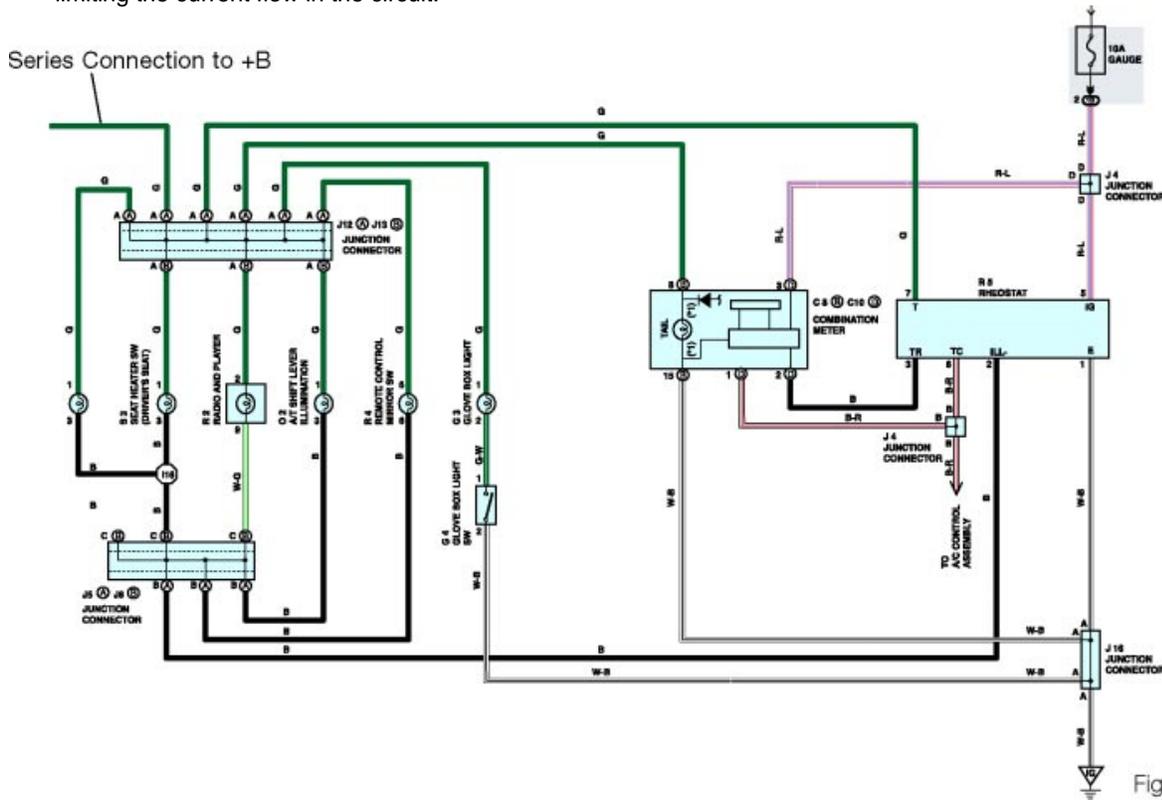


Series-Parallel General Rules

- Problems in the series portion of a series-parallel circuit will affect the entire circuit. If every load in a series parallel circuit is inoperative, the problem is most probably in the series parts of the circuit.
- Problems in a parallel branch of a series parallel circuit will affect only that branch. If only one tail lamp is inoperative, the fuse and switch in the series part of the circuit are not the problem.

Application of Series-Parallel Principles

Virtually every circuit on the vehicle has a series element (a switch) and a parallel element (multiple loads in a circuit). The rheostat in this circuit is in series with the bulbs, controlling the bulbs' intensity by limiting the current flow in the circuit.



On-Car Electrical Circuits

Every electrical circuit on the vehicle contains the following:

- Load
- Voltage source and ground
- Over-current protection
- Control device
- Conductors
- Connectors

**A Basic
Automotive
Electrical Circuit**

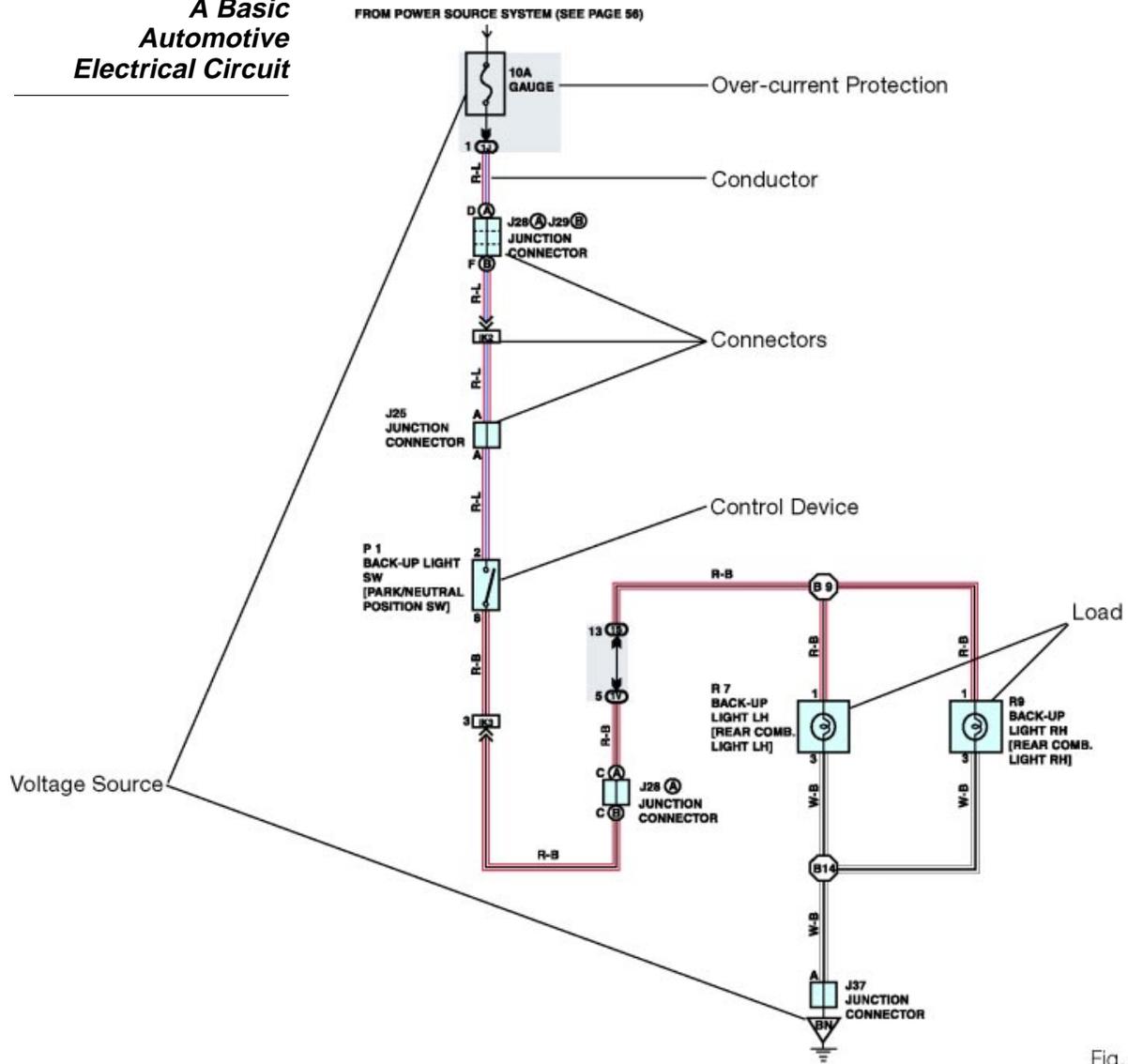


Fig. 1-24
L652f124

Load Every circuit is built around the load. The load in a circuit does the actual work: a light bulb, a motor, a solenoid, a computer or a heating resistor.

Typical Loads

A load can be as simple as a light or motor, or a more complicated ECU.

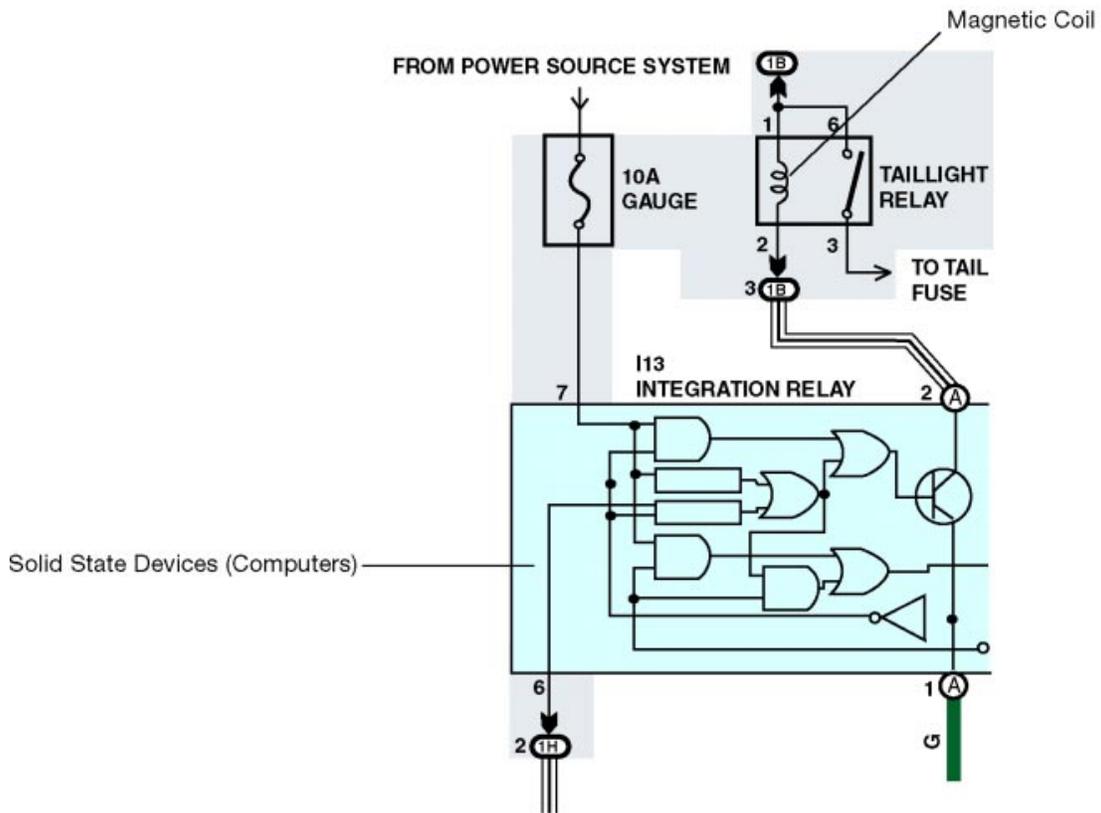
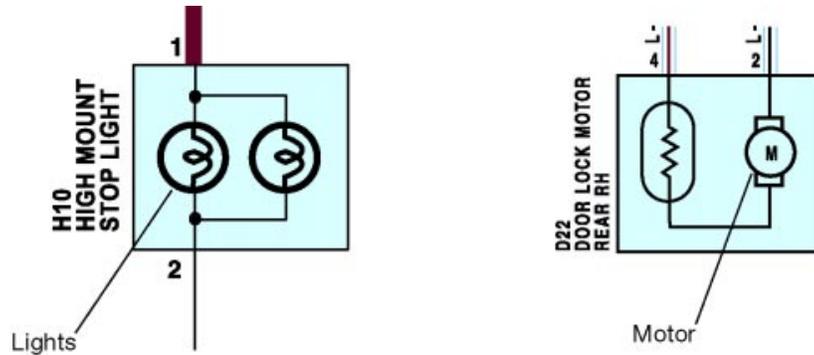


Fig. 1-25
L652F125

Voltage Source The voltage source is the “electron pump” that provides the pressure differential in the circuit. This pressure differential gets the electrons moving within the conductors. On the vehicle, voltage is provided by the battery and the alternator. In many cases, the voltage inside the component (such as an ECU or ECM) is maintained temporarily after the key is turned off or power removed through the use of a capacitor.

Voltage Sources

The battery and the alternator provide voltage to the electrical system. A capacitor acts as a voltage “accumulator”. The symbol for each of these is also shown.

Fig. 1-26
L6521126

Other Voltage Sources

Sensors used in ECU controlled systems such as TCCS and ABS produce an AC voltage that the ECU uses to determine RPM, or other operating conditions. Noise filters are capacitors which act as voltage “accumulators” to dampen sudden voltage changes. The ignition coil uses magnetic induction to step up the 12V battery voltage into the KV necessary to fire the spark plug.

Fig. 1-27
L6521127

Over-Current Protection

Fuses , circuit breakers, and fusible links are built into every automotive circuit to prevent damage from excessive current. An over-current condition can be caused by a lack of aftermarket accessories. A short to ground condition allows current to flow to ground before it reaches the load. Since the load is bypassed there is nothing to limit current in the circuit. Without a fuse in the circuit, wires and connectors would be damaged by excessive current. The maximum load to a single fuse is designed to never exceed seventy percent of the fuse’s rating.

Over-Current Protection Devices

Fuses, circuit breakers, and fusible links quickly open the circuit when too much current flow occurs.

Illustration	Symbol	Part Name	Abbreviation
		Fuse	Fuse
		Medium Current Fuse	M-Fuse
		High Current Fuse	H-Fuse
		Fusible Link	FL
		Circuit Breaker	CB

Fig. 1-28
L6521128

Control Devices

Most circuits on the vehicle are **switched** off and on to control when they operate. This switching is done through the use of relay contacts, transistors, and of course, mechanical switches.

To limit or control the amount of current in a circuit a **series resistor** can be used. Examples of this are found in some A/C blower motor circuits and in fuel injector circuits on cars equipped with low resistance injectors.

There are several circuits on the vehicle that are designed to be “ON” at all times. These include Theft Deterrent Systems, and components that have an electronic memory such as radios, clocks and ECMs (Engine Control Modules). Circuits which are “ON” all the time create parasitic loads which draw current from the battery even when the engine is off and the vehicle is parked.

Control Devices

Circuit control is done using switches, resistors, relays, and transistors.

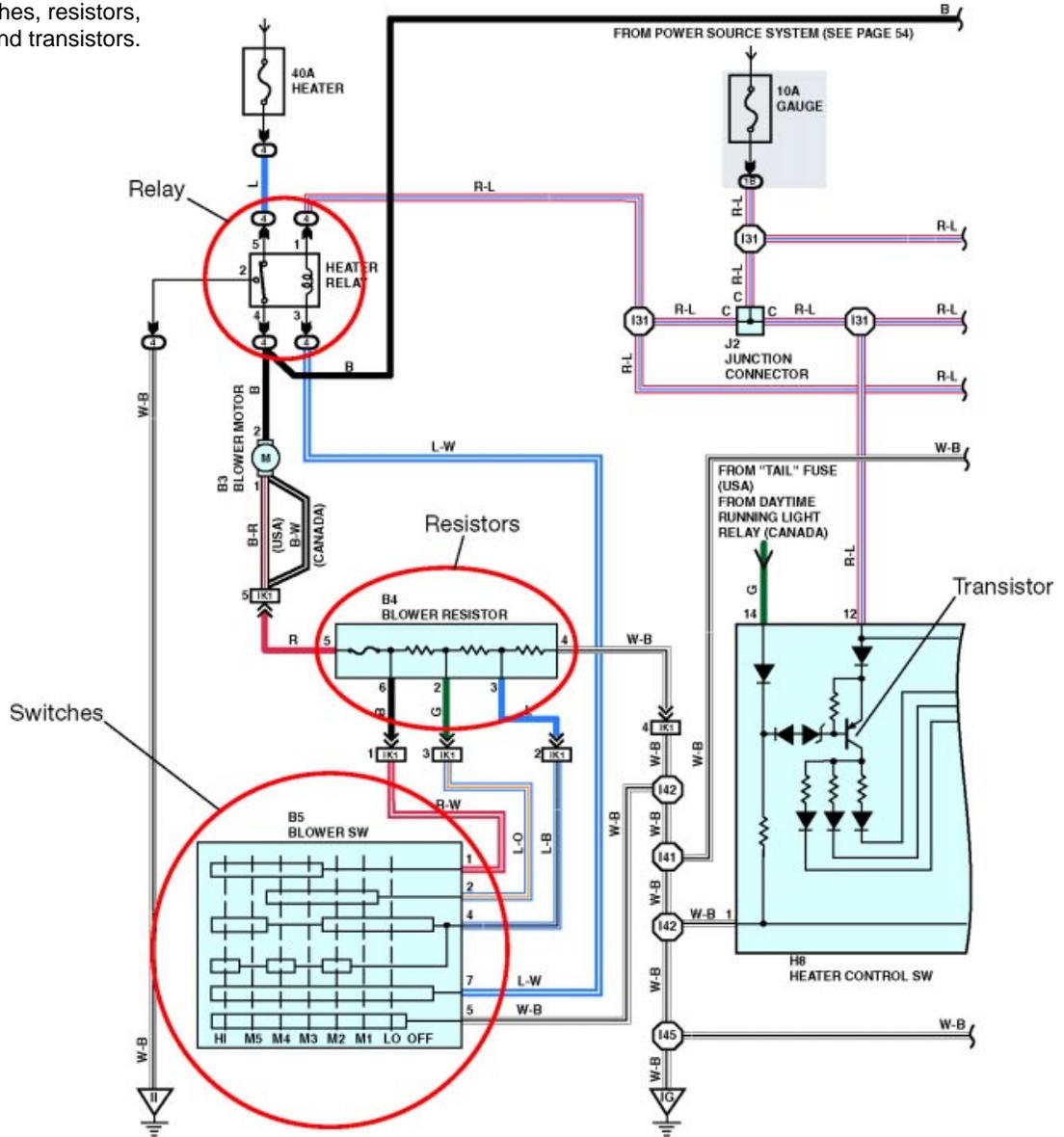
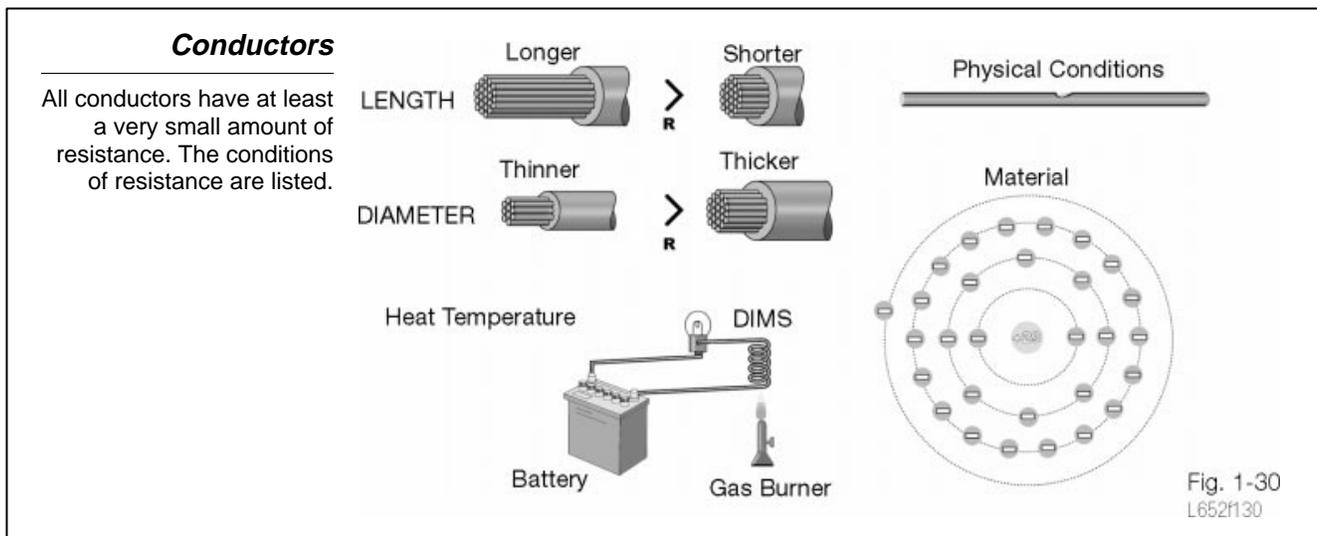


Fig. 1-29
L652f129

Conductors A **conductor** provides a low resistance pathway for current. All conductors have a certain amount of resistance. The resistance is determined by the conductor's:

- **Diameter** - Larger area has less resistance.
- **Length** - Shorter wire has less resistance.
- **Material** - Some materials conduct better than others.
- **Temperature** - Heat increases the resistance in the conductor.
- **Physical Condition** - Corrosion or nicks in the wire increase resistance.

Current flow will occur through the conductor any time there is a connection between the positive and negative terminals of the voltage source.



Connectors Given a relatively fixed voltage in an automotive electrical system (12 volts) the current in the circuit is determined by the amount of resistance in the load and in the conductors and connections in the circuit.

Terminals, connectors and splices are used throughout the electrical wiring harness to aid in the assembly and service of the vehicle, any connection in a circuit provides an area where problems could occur. Typical connector problems include:

- Disconnected connector
- Terminal backed out
- Terminal corrosion
- Terminal spread too wide
- Improperly made splice

The Lexus Wire Harness Repair Kit SST contains a selection of terminals that are used in the wiring harness. Additional terminals and connectors are also available through the parts system.

Lexus Wire Repair Kit

Contains frequently used terminals and wire repair tools. The manual supplied with the kit provides the part number for a large number of terminals and connectors.

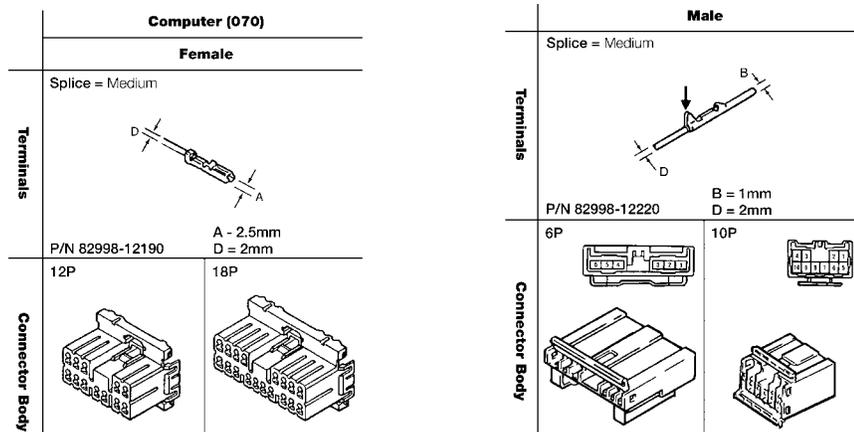


Fig. 1-31
L652f131

Basic Diagnostic Tools

When diagnosing an electrical problem there are a number of “tools” available to help find and repair the problem. While using these tools can help in locating electrical problems, *mastering their use* is the key to being able to perform the job in the shortest amount of time.

Electrical Wiring Diagram

The **Electrical Wiring Diagram (EWD)** is your #1 source for Lexus electrical system information. This manual contains detailed information about the entire electrical system, both body and engine control. There are two keys to being able to use the EWD effectively:

1. **Knowing where to find the information you want.** There is a lot of information packed into this manual. The ability to locate everything is very important.
2. **Understanding basic circuit theory.** The EWD does not “talk” a technician through the diagnostic process. We must take the problem symptoms, apply them to the System Circuit Diagram, trace the paths of current flow, and create a diagnostic plan **on our own, without prompting from the manual.**

NOTE

Be aware that there may be specifications from other countries in certain EWDs.

Electrical Wiring Diagram

Make certain that you correctly identify the appropriate wiring diagram. Some diagrams which are listed are written for cars sold in other countries. (Canada or Brazil)

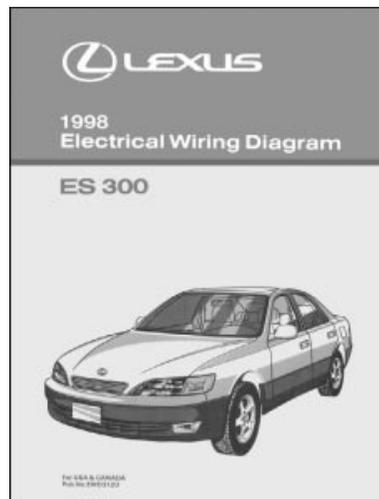


Fig. 1-32
L6521132

Repair Manual

The **Repair Manual (RM)** contains body electrical information that is formatted differently from the EWD. Its key advantages are:

- **Troubleshooting charts will guide you through specific inspections step-by-step.**
- **Contains Diagnostic Trouble Codes** for every system with self-diagnostics. This makes it the first place to look whenever you are working with systems such as the Supplemental Restraint.

Toyota Repair Manual

The BE and DI sections in the Repair Manual are the best resources to use when diagnosing a system that has self-diagnostics. The Repair Manual explains how to test values or connectors. The "Theory of Operation" is also covered in the manual. Use these sections in conjunction with the EWD.

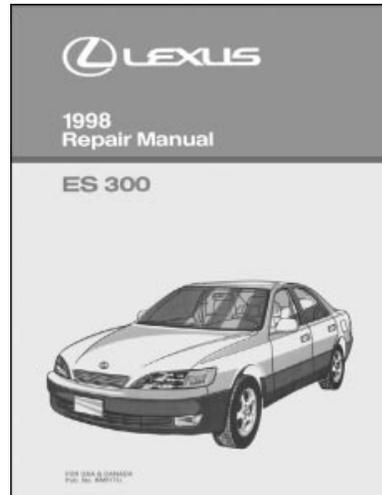


Fig. 1-33
L6521133

Digital Multimeters In L623, we learned how to use both *analog* and *digital* multimeters. In this course, we will concentrate on using the digital multimeter (DVOM). While analog meters have their uses, the DVOM provides many advantages:

- **Highly accurate** even on low-current solid state circuits.
- **Additional features** such as "min-max," peak hold.
- Some models **can read rapidly changing voltages**. This can help when looking for intermittent problems.

Digital/Analog Multimeters

The best measurement tool for body electrical. In recent years, DVOM prices have fallen, and new, useful features have been added. The analog meter is less expensive but more difficult to work with in automotive applications.



Fig. 1-34
L6521134

Test Lights The **test light** is one of the oldest electrical tools we have, and it can be useful, but only in limited ways.

- It can tell you if a wire is “hot,” but like an open circuit voltage inspection, it cannot tell you how much voltage is actually present.
- Bulb intensity varies from test light to test light.
- Can be used as a load in place of the fuse when diagnosing a short-to-ground problem, but has severe limitations. (These will be covered in Section 5 of this handbook).

Because of the complexity of body electrical circuits now, and the future complexity we expect to see, the test light is nearing the end of its usefulness. So in this course, we will be working exclusively with DVOMs. There will be a lot of hands-on worksheets later in this course to help you to master it’s use.

***Test
Lights/Jumpers***

A test light is useful in limited ways, but inconsistent. Cannot accurately test for voltage drop. Will indicate only presence of voltage. Jumpers can allow us to take current flow across suspect areas (control devices, grounds)

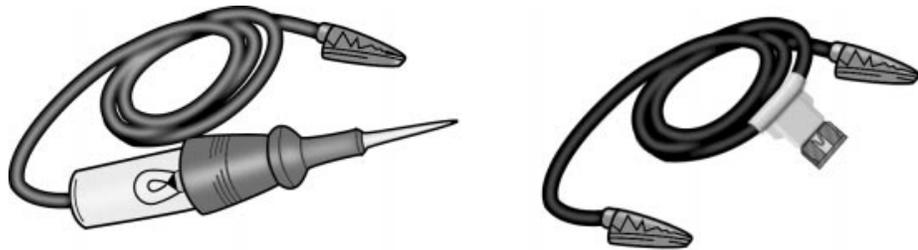


Fig. 1-35
L6521135