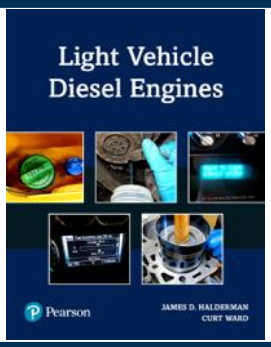
Light Vehicle Diesel Engines

First Edition



Chapter 17
Diesel Engine Electronics

LEARNING OBJECTIVES (1 of 2)

17.1 Prepare for the ASE Light Vehicle Diesel Engine (A9) ASE certification test content area "A" General Diagnosis and "F" Fuel System Diagnosis and Repair.

17.2 Explain the characteristics of electricity.

17.3 Differentiate between conductors, insulators, and semiconductors.

17.4 Explain the units of electrical measurement.

LEARNING OBJECTIVES (2 of 2)

17.5 List the parts of a complete circuit.

17.6 Discuss the types of electrical circuit faults.

17.7 Explain how to detect and measure electrical voltage, current, and resistance.

17.8 Discuss the purpose of terminals, connectors, relays, and switches.

17.9 Explain the operation of speed sensors and throttle position (TP) sensors.

INTRODUCTION

- **Electricity**
  - Difficult to learn for following reasons
    - It cannot be seen
    - Only results of electricity can be seen
    - It has to be detected & measured

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ELECTRICITY (1 OF 2)

- **Electricity**
  - Movement of electrons from one atom to another
  - Nucleus: Protons, neutrons, & electrons
  - **Automotive electricity** uses
    - **Conventional theory: electricity flows from positive to negative**
- **Magnets & Electrical Charge**
- **Electron Orbits**

Note: Example of relative sizes of parts of atom, consider that if atom were magnified so that nucleus were size of period at end of this sentence, whole atom would be bigger than a house

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Figure 17-1 In an atom (left), electrons orbit protons in the nucleus just as planets orbit the sun in our solar system (right).

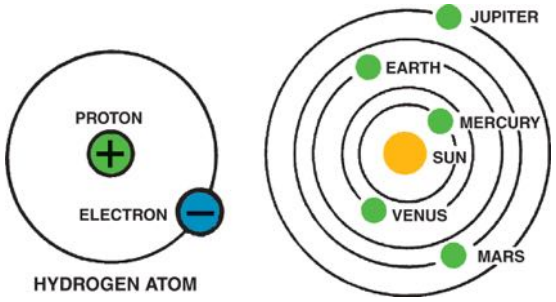

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Figure 17–2 nucleus of an atom has a positive (+) charge and the surrounding electrons have a negative (–) charge

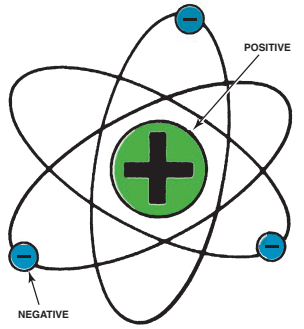

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FIGURE 17–3 shows a balanced atom. The number of electrons is the same as the number of protons in the nucleus.

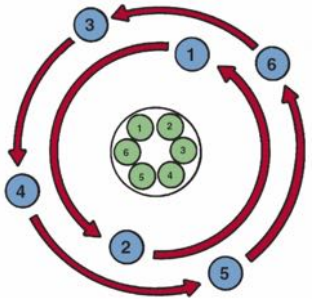

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FIGURE 17–4 Unlike charges attract and like charges repel.

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ELECTRICITY (2 OF 2)

- **Conductors**
  - Materials < 4 electrons in their atom's outer orbit.
- **Insulators**
  - Materials with > 4 electrons in outer orbit.
- **Semiconductors**
  - Materials with exactly 4 electrons in their outer orbit

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FIGURE 17–5 A conductor is any element that has one to three electrons in its outer orbit.

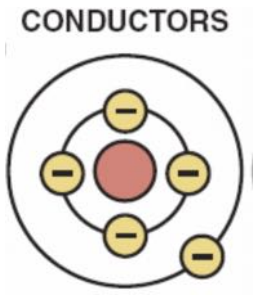

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FIGURE 17–6 Copper is excellent conductor of electricity because it has just 1 electron in its outer orbit, making it easy to be knocked out of its orbit and flow to other nearby atoms. This causes electron flow, which is definition of electricity.

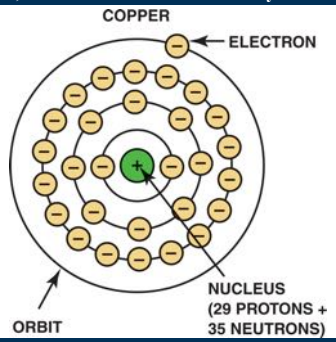

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Figure 17-7 Insulators are elements with 5 to 8 electrons in the outer orbit

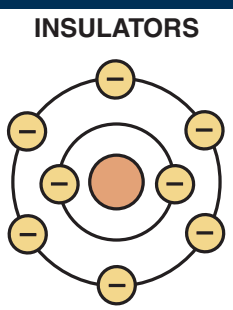

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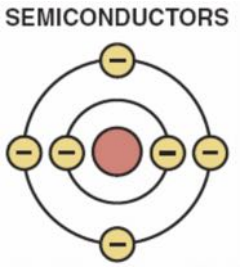
FIGURE 17–8 Semiconductor elements contain exactly 4 electrons in the outer orbit



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HOW ELECTRONS MOVE THROUGH CONDUCTOR

- **Current Flow**
  - **Conventional Theory**
    - **1 charge; moved from positive to negative**
      - **FIGURE 17–10**
  - **Electron Theory**
    - **From discovery of electron & its negative charge**
    - **Electron flow from negative to positive**

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FIGURE 17–9 Current electricity is the movement of electrons through a conductor.

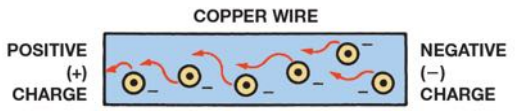

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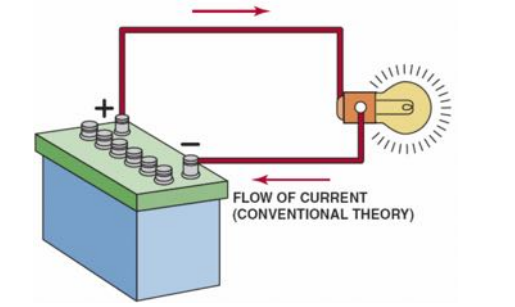
FIGURE 17–10 Conventional theory states that current flows through a circuit from positive (+) to negative (–). Automotive electricity uses the conventional theory in all electrical diagrams and schematics.



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UNITS OF ELECTRICITY (1 OF 5)

- 3 Fundamentals Of Electricity-related Units
  - Ampere, Volt, & Ohm
    - Ampere Measure Amount of Current Flow
    - Voltage Unit of Electrical Pressure
    - Ohm Unit of Electrical Resistance

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UNITS OF ELECTRICITY (2 OF 5)

- **Ampere** measures current flow
  - 6.28 billion billion electrons a coulomb: FIGURE 17–11
  - Like "gallons per minute" to measure water flow
  - Electrician Andrè Marie Ampére (1775–1836)
  - **A** & amps: abbreviations for amperes
  - Capital letter **I**, for intensity used in math
    - Amperes do actual work in circuit
    - Movement of electrons through light bulb or motor
    - Makes electrical device work FIGURE 17–12

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FIGURE 17–11 One ampere is the movement of 1 coulomb (6.28 billion billion electrons) past a point in 1 second.

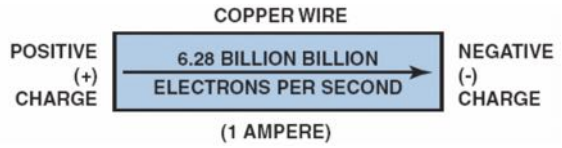

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FIGURE 17–12 Ammeter is installed in path of electrons similar to a water meter used to measure flow of water in gallons per minute. The ammeter displays current flow in amperes.

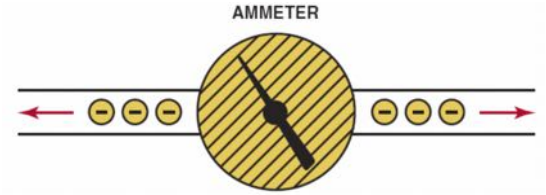

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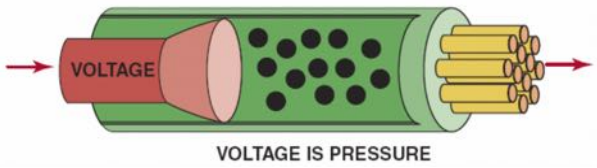
FIGURE 17–13 Voltage is electrical pressure that causes the electrons to flow through a conductor.



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UNITS OF ELECTRICITY (3 OF 5)

- **Volt: unit of measurement for electrical pressure.**
- **Electromotive force, abbreviated EMF**
  - Another way of indicating voltage
  - **V** is generally accepted abbreviation for volts
  - Symbol in calculations is **E**, for electromotive force
  - Volts measured by a voltmeter **SEE FIGURE 17–14.**

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FIGURE 17–14 digital multimeter set to read DC volts is being used to test the voltage of a vehicle battery. Most multimeters can also measure resistance (ohms) and current flow (amperes).

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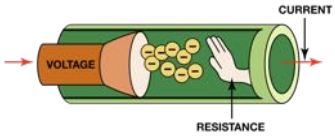
UNITS OF ELECTRICITY (4 OF 5)

- **Resistance to flow of current through conductor**
  - Measured in units called ohms, named after
  - ***Physicist George Simon Ohm (1787–1854)***
  - Resistance to flow of free electrons through conductor
  - Results from countless collisions electrons cause
    - Within atoms of conductor. **FIGURE 17–15**.



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UNITS OF ELECTRICITY (5 OF 5)

- **Resistance** can be:
  - Desirable when part of how circuit works
  - LIKE resistance of a filament in light bulb
  - Undesirable, such as corrosion in a connection
  - Restricting amount of current flow in circuit

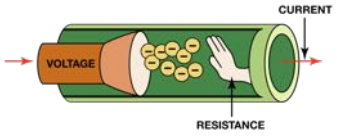

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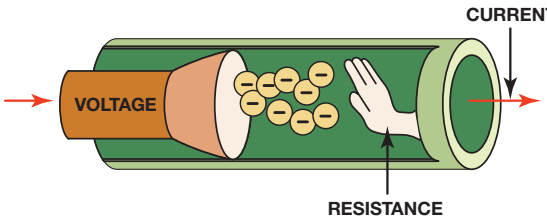
FIGURE 17–15 Resistance to flow of electrons through conductor is measured in ohms.



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ELECTRICAL CIRCUITS

- **All Complete Electrical Circuits Have:**
  - Power source, circuit protection device
  - Power-side wire or path, an electrical load
  - Ground return path & Switch or control device.
    - Circuit testers include test lights and fused jumper leads.

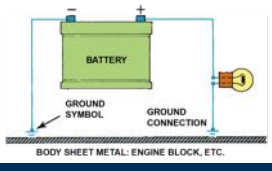

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Figure 17–16 The return path back to the battery can be any electrical conductor, such as a copper wire or the metal frame or body of the vehicle

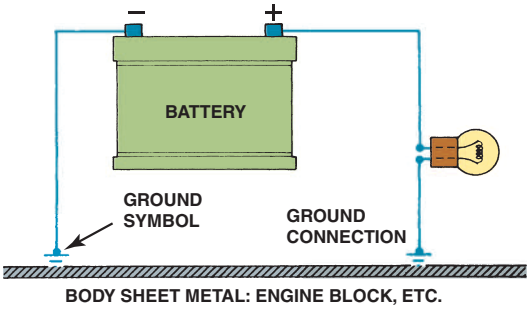

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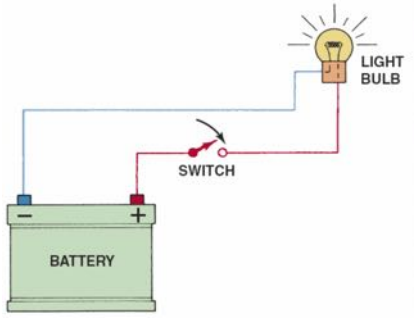
FIGURE 17–17 electrical switch opens circuit and no current flows. The switch could also be on the return (ground) path wire.



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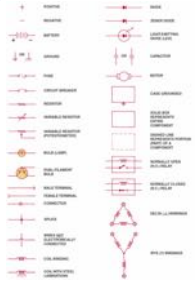
ELECTRICAL SCHEMATICS (1 OF 2)

- **All circuit schematics or diagrams include**:
  - Power-side wiring of the circuit
  - All splices
  - Connectors
  - Wire size
  - Wire color
  - Trace color (if any)
  - Circuit number
  - Electrical components



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ELECTRICAL SCHEMATICS (2 OF 2)

- **All circuit schematics or diagrams include**:
  - Ground return paths
  - Fuses and switches
- **Circuit information**
- **Wire size**
- **Open circuits**
- **Short-to-voltage**
- **Short-to-ground**
- **High resistance**

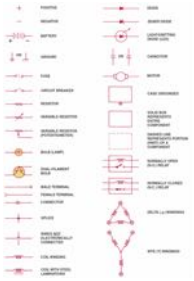

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FIGURE 17–18 The center wire is a solid color wire, meaning that the wire has no other identifying tracer or stripe color. The two end wires could be labeled "BLU/WHT," indicating a blue wire with a white tracer or stripe.

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FIGURE 17–19 Typical section of a wiring diagram. Notice that the wire color changes at connection C210. The "0.8" represents the metric wire size in square millimeters.

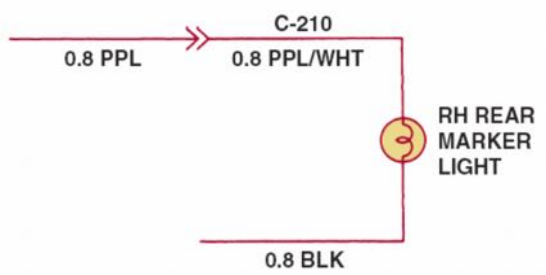

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FIGURE 17–20 Electrical and electronic symbols used in automotive wiring and circuit diagrams. Both the conventional and the global symbols are shown side-by-side to make reading schematics easier. The global symbols are used by many vehicle manufacturers.

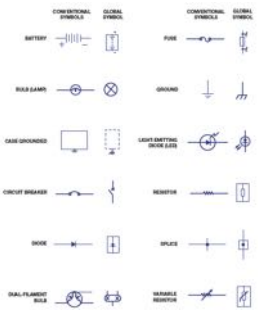

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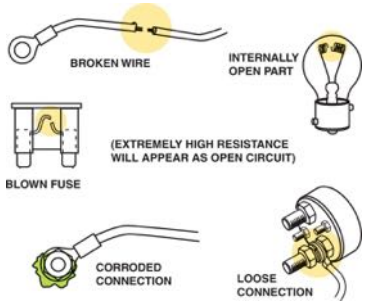
Figure 17-21 Examples of common causes of open circuits. Some of these causes are often difficult to find.



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TYPES OF CIRCUIT FAULTS (1 OF 2)

- **Open Circuit**
  - **Circuit not complete**, or lacks continuity
    - **Such as a broken wire**
- **SHORT-TO-VOLTAGE**
  - Power side of one circuit is electrically connected
  - TO power side of another circuit

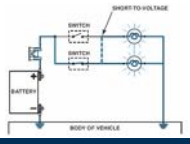

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FIGURE 17–22 A short circuit permits electrical current to bypass some or all of the resistance in the circuit.

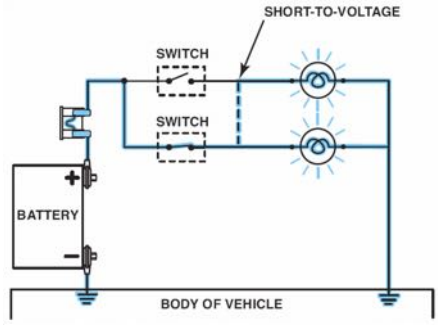

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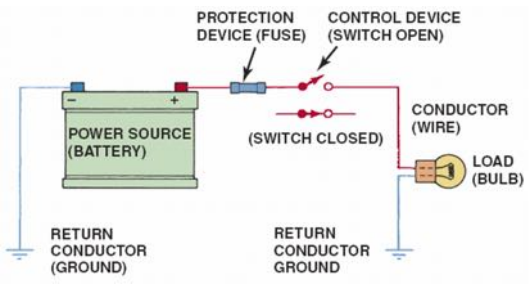
FIGURE 17–23 A fuse or circuit breaker opens circuit to prevent possible overheating damage in event of a short circuit.



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TYPES OF CIRCUIT FAULTS (2 OF 2)

- **SHORT-TO-GROUND**
  - Short circuit that occurs when current bypasses
  - Part of normal circuit & flows directly to ground
  - High resistance is resistance higher
    - Than normal circuit resistance.

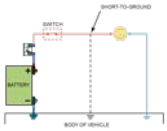

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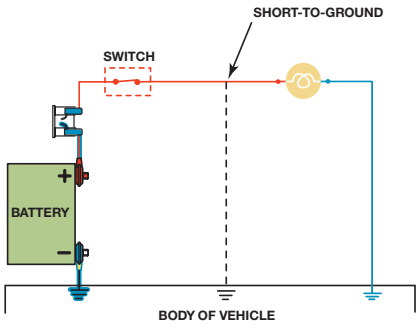
FIGURE 17–24 A short-to-ground affects the power side of the circuit. Current flows directly to the ground return, bypassing some or all of the electrical loads in the circuit. There is no current in the circuit past the short. A short-to-ground will also cause the fuse to blow.



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FUSED JUMPER WIRE

- **Purpose & Function**
  - Check Circuit By Bypassing Switch/Provide Power
    - Or Ground to Component
  - Fuse
  - Alligator clip ends
  - Good-quality insulated wire

CAUTION: Never use fused jumper wire to bypass any resistance or load in the circuit. Increased current flow could damage wiring and blow fuse on the jumper lead. Be very cautious when working on or around any computer circuit. Permanent damage to computer or electronic module could result if power or ground goes to wrong circuit.

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FIGURE 17–25 A technician-made fused jumper lead, which is equipped with a red 10-ampere fuse. This fused jumper wire uses terminals for testing circuits at a connector instead of alligator clips.

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TEST LIGHT

- Non-powered test light
- Use of a 12-volt test light
  - Electrical power
  - Grounds

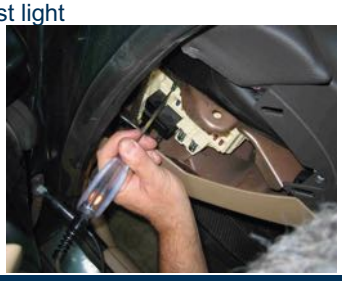

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FIGURE 14–26 Testing a fuse with a test light. If the fuse is good, the test light should light on both sides (power side and load side) of the fuse.

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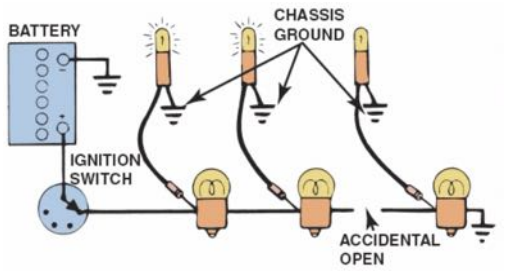
FIGURE 17–27 A test light can be used to locate an open in a circuit. Note that the test light is grounded at a different location than the circuit itself.



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DIGITAL MULTIMETERS (1 OF 9)

- **Digital multimeter (DMM)**
  - **Digital volt-ohm-meter (DVOM)**
    - **Terms commonly used to describe digital meters**

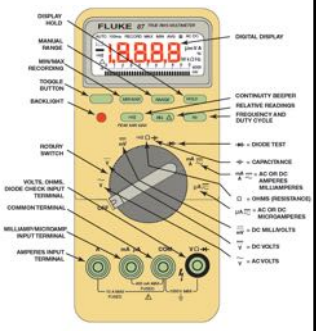

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CHART 17-1 Common symbols & abbreviations used on digital meters.

SYMBOL	MEANING
AC	Alternating current or voltage
DC	Direct current or voltage
V	Volts
mV	Millivolts (1/1,000 volts)
A	Ampere (amps), current
mA	Milliampere (1/1,000 amps)
%	Percent (for duty cycle readings only)
Ω	Ohms, resistance
kΩ	Kilohm (1,000 ohms), resistance
MΩ	Megohm (1,000,000 ohms), resistance
Hz	Hertz (cycles per second), frequency
kHz	Kilohertz (1,000 cycles/sec.), frequency
Ms	Milliseconds (1/1,000 sec.) for pulse width measurements

CHART 17–1

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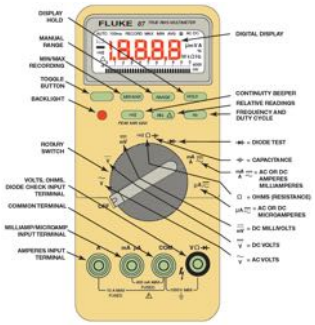
FIGURE 17–28 digital multimeter. The black meter lead always is placed in the COM terminal. The red meter test lead should be in the volt-ohm terminal except when measuring current in amperes.



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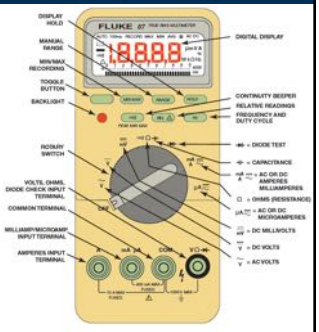
DIGITAL MULTIMETERS (2 OF 9)

- **Measuring Voltage**
  - Voltmeter measures pressure
  - Potential of electricity in volts
  - Voltmeter connected to circuit in parallel



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DIGITAL MULTIMETERS (3 OF 9)

- **Voltage Measured**
  - Selecting either AC or DC volts
  - **DC volts (DCV):**
    - Most common setting for automotive use
    - Battery voltage, voltage to lighting and accessory circuits

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FIGURE 17–29 Typical digital multimeter (DMM) set to read DC volts.

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DIGITAL MULTIMETERS (4 OF 9)

- **Voltage Measured**
  - **AC volts (ACV):**
  - Check for unwanted AC voltage
  - From alternators and some sensors
  - **Range**: Automatically set for most meters
  - Can be manually ranged

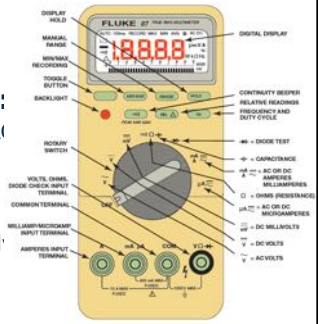

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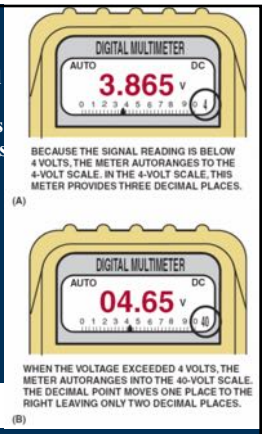
FIGURE 17–30 autoranging DMM automatically selects proper scale to read voltage being tested. Scale selected usually displayed on meter face. (a) Display indicates "4," meaning that this range can read up to 4 volts. (b) range is now set to 40 volt scale, meaning that meter can read up to 40 volts on scale. Any reading above this level will cause the meter to reset to a higher scale. If not set on autoranging, meter display would indicate OL if a reading exceeds limit of scale selected.



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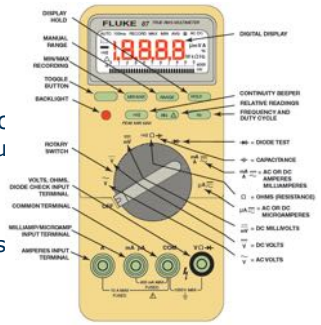
DIGITAL MULTIMETERS (5 OF 9)

- **Measuring Resistance**
  - Ohmmeter measures resistanc
    - Component or circu section
    - No current flowing through
    - Connected in series with component
    - or wire being measured



PEARSON

Figure 17–31 Using a DMM set to read ohms (Ω) to test this light bulb. Meter reads resistance of filament

PEARSON

DIGITAL MULTIMETERS (6 OF 9)

- **Measuring Resistance**
  - When connected to component
  - Current flows through leads
  - Voltage drop between leads measured as resistance
  - 0 ohms means no resistance between test leads
    - Indicates continuity for current to flow in closed circuit

PEARSON

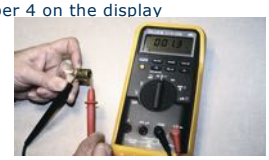
DIGITAL MULTIMETERS (7 OF 9)

- **Measuring Resistance**
  - Infinity means no connection, or open circuit
  - Ohmmeters have no required polarity
  - Even though red & black test leads used
  - Meters have different ways of indicating infinity
  - Resistance, or reading higher than scale
    - **OL, meaning over limit or overload**

PEARSON

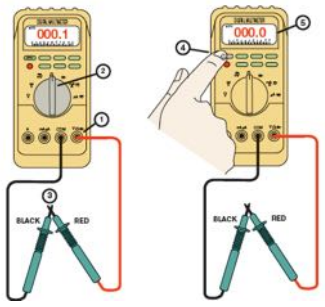
DIGITAL MULTIMETERS (8 OF 9)

- **Measuring Resistance**
  - Meters have different ways of indicating infinity
  - Resistance, or reading higher than scale allows
    - Flashing or solid number 1
    - Flashing or solid number 3 on left side of display
    - Flashing or solid number 4 on the display



PEARSON

FIGURE 17–32 Many DMM can have display indicate zero to compensate for test lead resistance. (1) Connect leads in v and COM meter terminals. (2) Select 2 scale. (3) Touch 2 meter leads together. (4) Push "zero" or "relative" button on meter. (5) Meter display will now indicate zero ohms of resistance.



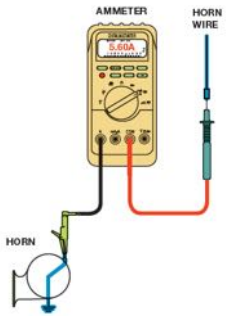
PEARSON

DIGITAL MULTIMETERS (9 OF 9)

- **Measuring Amperes**
  - Ammeter measures flow of current
  - Through complete circuit in amperes
  - Ammeter installed in circuit (in series)
  - So it can measure all current flow in circuit

PEARSON

FIGURE 17–33 Measuring the current flow required by a horn requires that the ammeter be connected to the circuit in series and the horn button be depressed by an assistant.



PEARSON

"Fuse Your Meter Leads!" 1

TECH TIP

Most digital meters include an ammeter capability. When reading amperes, leads of meter must be changed from volts or ohms (V or) to amperes (A) or milliamperes (mA). A common problem may then occur next time voltage is measured. Although you may switch selector to read volts, often leads are not switched back to volt or ohm position. Because ammeter lead position results in 0 ohms of resistance to current flow through meter, meter or fuse inside meter will be destroyed if meter is connected to a battery. Many meter fuses are expensive and difficult to find. To avoid this problem, simply solder an inline 10-ampere blade-fuse holder into one meter lead. FIGURE 17–34.

PEARSON

FIGURE 17–34 Note blade-type fuse holder soldered in series with one of meter leads. A 10-ampere fuse helps protect internal meter fuse (if equipped) and meter itself from damage that may result from excessive current flow if accidentally used incorrectly.

PEARSON

"Fuse Your Meter Leads!" 2

TECH TIP

Do not think that this technique is for beginners only. Experienced technicians often get in hurry and forget to switch lead. A blade fuse is faster, easier, and less expensive to replace than meter fuse or meter itself. Also, if soldering is done properly, addition of an inline fuse holder and fuse does not increase resistance of meter leads. All meter leads have some resistance. If meter is measuring very low resistance, touch 2 leads together and read the resistance (usually no more than 0.2 ohm). Simply subtract resistance of leads from resistance of the component being measured.

PEARSON

INDUCTIVE AMMETERS

- **Inductive Ammeters**
  - Do not make physical contact with the circuit
  - Able to read much higher amperages than 10 amperes.
  - Sensor detects strength of field surrounding wire
  - Carrying current
  - Uses strength of magnetic field measure current

PEARSON

FIGURE 17–35 inductive ammeter clamp is used with all starting and charging testers to measure the current flow through the battery cables.

PEARSON

FIGURE 17–36 typical mini clamp-on-type digital multimeter. This meter is capable of measuring alternating current (AC) and direct current (DC) without requiring that circuit be disconnected to install meter in series. The jaws are simply placed over wire and current flow through circuit is displayed.

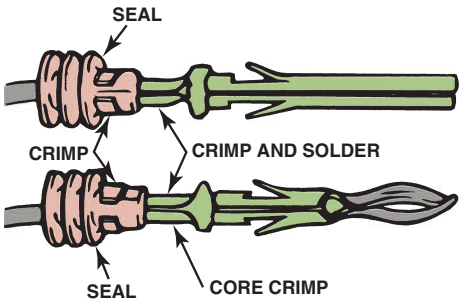
PEARSON

TERMINALS & CONNECTORS

- **Terminal**
  - Metal end of a wire
- **Connector**
  - Plastic housing for terminal
- **Servicing Terminals**

PEARSON

Figure 14–37 Some terminals have seals attached to help seal the electrical connections

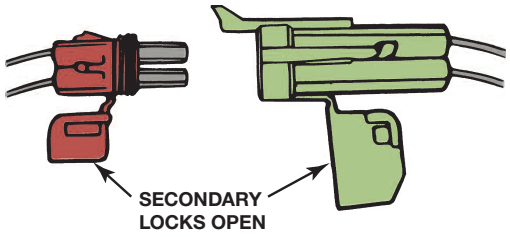


PEARSON

FIGURE 17–38 Separate a connector by opening the lock and pulling the two apart.

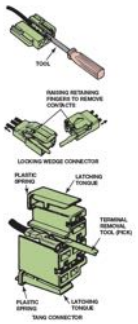
PEARSON

FIGURE 14–39 The secondary locks help retain the terminals in the connector.



PEARSON

FIGURE 17–40 Use a small removal tool, sometimes called a pick, to release terminals from the connector.



PEARSON

WIRE REPAIR

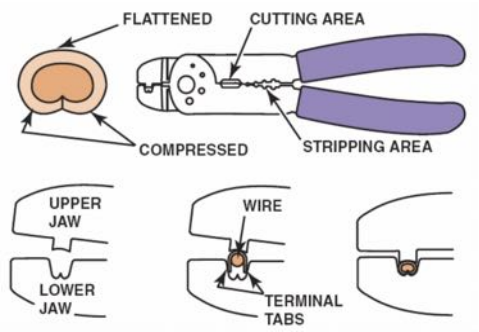
- Soldering
  - Many manufacturers recommend that
  - All wiring repairs be soldered. **Why?** **Page 197**
- What is soldering procedure?
- Crimping terminals
- Heat shrink tubing
- Crimp-and-seal connectors

PEARSON

FIGURE 14–41 Always use rosin-core solder for electrical or electronic soldering. Also, use small-diameter solder for small soldering irons. Use large-diameter solder only for large-diameter (large-gauge) wire and higher-wattage soldering irons (guns).

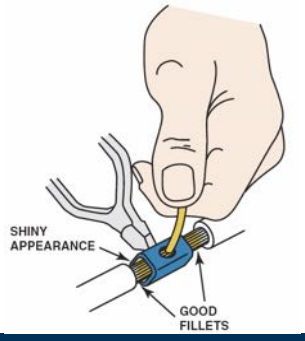
PEARSON

FIGURE 17–42 Notice that to create a good crimp, the open part of the terminal is placed in the jaws of the crimping tool toward the anvil or the W-shape part.



PEARSON

FIGURE 17–43 A ll hand-crimped splices or terminals should be soldered to be assured of a good electrical connection.



PEARSON

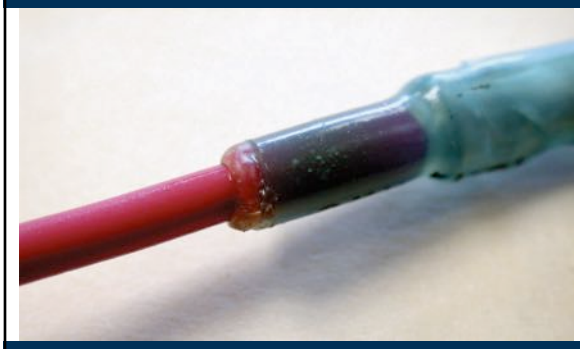
FIGURE 17–44 butane torch especially designed for use on heat shrink applies heat without an open flame, which could cause damage.

PEARSON

FIGURE 17–45 typical crimp-and-seal connector. This type of connector is first lightly crimped to retain ends of wires and then it is heated. The tubing shrinks around wire splice, and thermoplastic glue melts on inside to provide an effective weather-resistant seal.

PEARSON

FIGURE 17–46 Heating the crimp-and-seal connector melts the glue and forms an effective seal against moisture.



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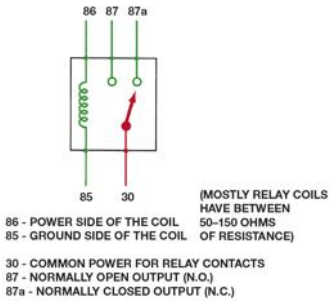
RELAYS

- **Relay**
  - Magnetic switch that uses a movable armature
  - Control a high-amperage circuit
  - Using low-amperage electrical switch
  - **Terminal identification**
    - Coil
    - Other terminals used to control load current

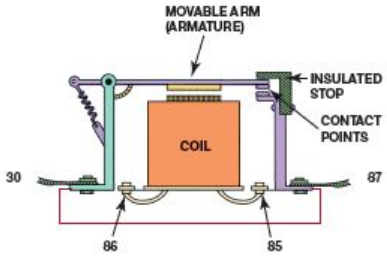
PEARSON

FIGURE 17–47 A relay uses a movable arm to complete a circuit whenever there is a power at terminal 86 and a ground at terminal 85. A typical relay only requires about 1/10 ampere through the relay coil. The movable arm then closes the contacts (#30 to #87) and can often handle 30 amperes or more.



PEARSON

FIGURE 17–48 cross-sectional view of typical four-terminal relay. Current flowing through coil (terminals 86 and 85) causes movable arm (called armature) to be drawn toward coil magnet. The contact points complete electrical circuit connected to terminals 30 and 87.

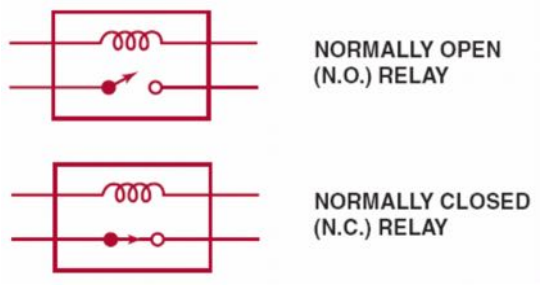


PEARSON

FIGURE 17–49 typical relay showing schematic of wiring in relay.

PEARSON

FIGURE 17–50 All schematics are shown in their normal, non-energized position.



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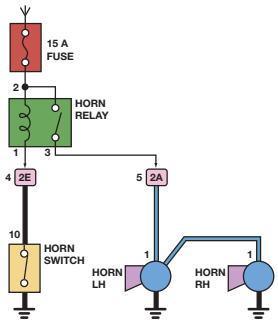
SWITCHES

- **Electrical Switch**
  - Opens circuit no current flows
  - Could also be on return (ground) path wire.
- **Ohmmeter checks**
- **Voltmeter checks**

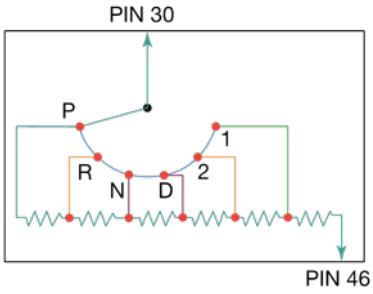
PEARSON

FIGURE 17–51 typical horn circuit. Note that relay contacts supply heavy current to operate horn when horn switch simply completes low-current circuit to ground, causing relay contacts to close.



PEARSON

FIGURE 17–52 typical transmission range switch is also similar to the circuit used for electronic transfer case switches. In this example, power, usually 12 volts, is applied at pin 30 and pin 46 is an input to PCM. Change in voltage at pin 46 indicates how much resistance circuit has, which is used to detect gear selected.



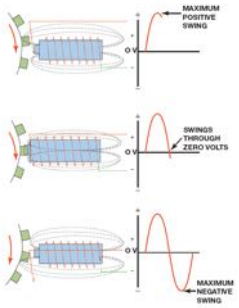
PEARSON

SPEED SENSORS

- **Magnetic Sensor Consists**
  - Notched wheel and a coil consisting
  - Iron core wrapped with fine wire.
  - Notched wheel causes magnetic strength changes
  - Enough to create usable varying AC voltage signal.
- **Speed Sensor Tests**

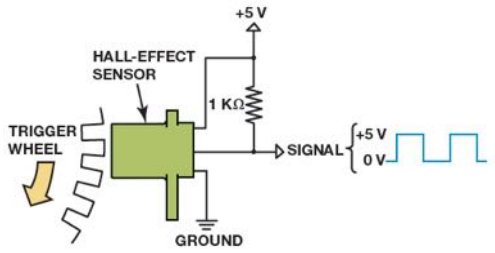
PEARSON

FIGURE 17–53 magnetic sensor uses permanent magnet surrounded by a coil of wire. The notches on rotating shaft create a variable magnetic field strength around the coil. When a metallic section is close to sensor magnetic field is stronger because metal is a better conductor of magnetic lines of force than air.



PEARSON

FIGURE 17–54 Hall-Effect sensor produces an on-off voltage signal whether it is used with a blade or a notched wheel.



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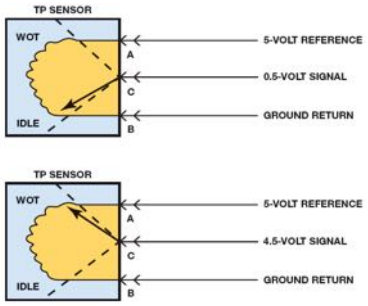
THROTTLE POSITION (TP) SENSORS

- **TP Sensor Input**
  - Determine amount of throttle opening
  - Rate of change to determine shift points
  - Of an automatic transmission OR engine management.
- **Parts and operation**
- **Testing a TP Sensor**

PEARSON

FIGURE 17–55 The signal voltage from a throttle position increases as the throttle is opened because the wiper arm is closer to the 5-volt reference. At idle, the resistance of the sensor winding effectively reduces the signal voltage output to the powertrain control module (PCM).



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SUMMARY (1 OF 4)

- Electricity is the movement of electrons from one atom to another.
- In order for current to flow in a circuit or wire, there must be an excess of electrons at one end and a deficiency of electrons at the other end.
- Automotive electricity uses the conventional theory that electricity flows from positive to negative.
- The ampere is the measure of the amount of current flow.
- Voltage is the unit of electrical pressure.
- The ohm is the unit of electrical resistance.

SUMMARY (2 OF 4)

- All complete electrical circuits have a power source (such as a battery), a circuit protection device (such as a fuse), a power-side wire or path, an electrical load, a ground return path, and a switch or a control device.
- A short-to-voltage involves a copper-to-copper connection and usually affects more than one circuit.
- A short-to-ground usually involves a power path conductor coming in contact with a return (ground) path conductor and usually causes the fuse to blow.
- An open is a break in the circuit resulting in absolutely no current flow through the circuit..

SUMMARY (3 OF 4)

- Circuit testers include test lights and fused jumper leads.
- Digital multimeter (DMM) and digital volt-ohm-meter (DVOM) are terms commonly used for electronic test meters.
- Ammeters measure current and must be connected in series in the circuit.
- Voltmeters measure voltage and are connected in parallel.
- Ohmmeters measure resistance of a component and must be connected in parallel with the circuit or component disconnected from power.

SUMMARY (4 OF 4)

- A terminal is the metal end of a wire, whereas a connector is the plastic housing for the terminal.
- All wire repair should use either soldering or a crimp-and seal connector.
- All switches and relays on a schematic are shown in their normal position, either normally closed (N.C.) or normally open (N.O.).
- A typical relay uses a small current through a coil (terminals 85 and 86) to operate the higher current part (terminals 30 and 87).

PEARSON