Close

Basic Electrical Theory

By Paul Bindon
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Electronic devices are run by smoke. When they become damaged or fail, the smoke escapes and they no longer work.

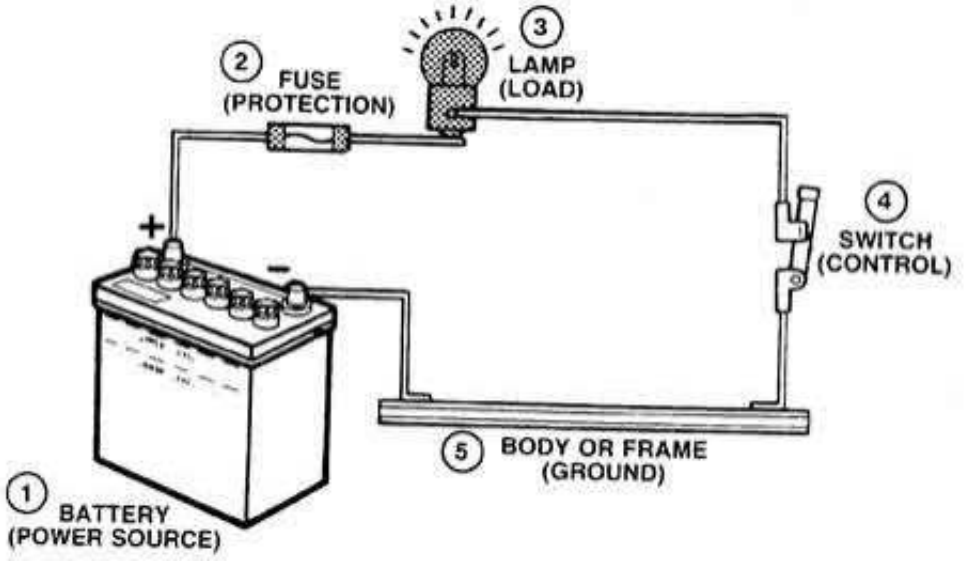
This explanation of how electricity works may seem comical, but it highlights the mystery surrounding electricity as something we cannot see. The results of electricity at work are obvious to us; the lights turn on, the motor turns and the stereo plays music. In contrast, the flow of electricity through wiring becomes somehow mysterious or even frightening when high voltages are considered.

The use of high voltage in transportation has caused some uneasy or wary approaches to vehicles involved in collisions. When considering hybrid vehicles, high-voltage orange wires come to mind. *"Don't touch the orange wires"* has been the most common message that has been relayed to first responders during hybrid training. *Why should you not touch the orange wires?* When asked this question, most first responders I have talked to reply with either *"because they are high voltage"* or *"because they will shock or kill you."* This basic message of caution is the reason many responders may hesitate or delay the approach to patients when hybrid vehicles are involved in a motor vehicle accident (MVA). This article will help you gain a basic understanding of electrical theory as it applies to transportation use; the goal is to dispel some of the mysteries associated with electricity.

DC Circuits

All batteries operate direct current (DC) circuits. This is true of small watch batteries all the way up to 800-vold (V) hybrid bus batteries. Current in a 12-Volt DC circuit flows from the positive (+) terminal of the battery through the weakest link (fuse), through a load device (bulb), a control circuit (switch) to the chassis or frame, and then finally to the negative (-) terminal of the battery. This is considered conventional electrical theory. It is important to note that the vehicle's body or frame is used as part of the circuit. For low-voltage applications, this is perfectly safe and simplifies the wiring.

A simple example of a DC circuit is the 12-V circuit shown below (1).



(1)

1 The power source in this case is the conventional lead/acid 12-V battery.
2 The circuit has a weak link (fuse) that protects the rest of the circuit in the event of an overload.
3 The load device (bulb, radio, and so on) puts the power to work and is the visible indication of what the electricity actually does.
4 On/off switch or some type of circuit control.
5 Body or frame of the vehicle (ground). This is the return path for the electricity back to the power source.

AC Circuits

Wires in an alternating current (AC) circuit contain positive and negative voltage on the same wire. Typically, three wires are associated in a household 110-V circuit: black (hot), white (common), and bare (ground). AC circuits use terra firma or ground as part of the circuit. Anyone who has become part of a 110-V household circuit can tell you this is true (2).

(2)

Hybrid vehicles do not use terra firma "ground" for their AC circuits as household electrical circuits. Since the tires insulate the vehicle from the ground, they would require some type of connection to the "ground" to operate the same way. There obviously is no wire running behind the vehicle or hanging down touching the ground as it is being driven along. The vehicle AC circuit is self-contained and does not use the chassis or frame of the vehicle as part of the circuit.

(3) Household grounding wire

Voltage vs. Amperage

PSI vs. GPM

A stun gun is an example of a "high-voltage" device. It operates with between 100,000 to 1.5 million volts. The reason it is not lethal is that it does not provide enough amperage--high voltage certainly, but low amperage output (1 to 5 milliamps). Compare this example to a fire apparatus pushing water through a garden hose. High pressure (600 pounds per square inch) running low gallons per minute (gpm) because of the restriction of the small hose.

A 12-V car battery can produce 500 to 1,000 amps. This example is not lethal because the voltage is too low to overcome the naturally high resistance of our bodies. If you connect the terminals of a car battery with a piece of steel, however, the low resistance across the terminals will result in maximum current flow (lots of sparks). Compare this to a hydrant feeding a five-inch line; low pressure providing very high gpm.

Have you ever heard the expression, "It's the amps that kill you"? This statement is an oversimplification of the hazards associated with electricity. There has to be a threshold where the voltage *and* amperage become hazardous. The Society of Automotive Engineers (SAE) industry standard wire color for hazardous voltage is **orange**. This means that the voltage contained on an orange wire is more than **60 V and over 1 amp**. It could be 60 V or 800 V; the wire color is the same and should be considered potentially lethal.

High-voltage circuits in vehicles do not use the body or frame as part of the circuit. The DC high-voltage wiring (orange) includes the positive and negative cables. This is done to insulate the body of the vehicle from the high-voltage circuit.

(4) DC orange wires from high-voltage battery to inverter

The AC high-voltage wiring includes all three parts of the circuit. This is done to insulate the body of the vehicle from the high-voltage circuits.

(5) AC orange wires from inverter to traction motor

Safety systems are included to prevent the body or frame from becoming part of the circuit in the event of possible damage. Each high-voltage wire is wrapped in a layer that is monitored by the vehicle's computer. If the wire becomes damaged, the system is designed to cut the connection from the high-voltage battery and isolate the high voltage inside the battery. Other systems are designed to do the same thing in if a supplemental restraint system (SRS) or an airbag deploys. It is important to know that the high-voltage system is controlled by the 12-V system in the vehicle.

Understanding the basics of how electricity works can help dispel some of the myths surrounding high voltage in the transportation industry. Knowing that electricity is more than what we can see will help prevent hesitation when

dealing with the emerging technologies of today.

Paul Bindon is a research specialist for MGS Tech and an on-site trainer, and has completed extrication training at the Corona-X seminar. He is also an ASE certified master auto technician with more than 23 years experience in the automotive field. He has been employed with Lexus dealerships for the past 16 years; he has received master diagnostic specialist and hybrid certification through factory training in the latest automotive technologies.

- **More Vehicle Extrication**
