

2 Electrical Circuits and Ohm's Law

REAL WORLD FIX

The Short-to-Voltage Story
A mechanic was working on a Chevrolet pickup truck with the following unusual electrical problems:

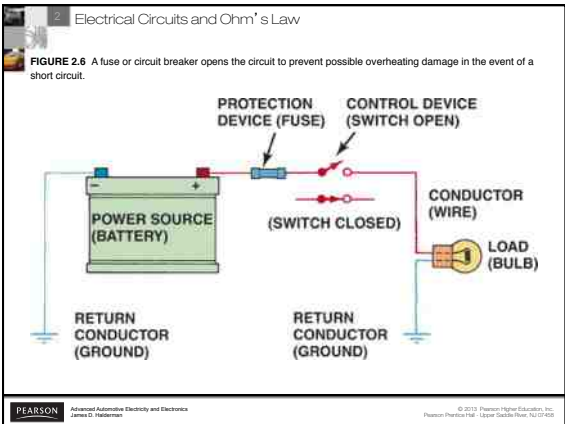
1. When the brake pedal was depressed, the dash light and the side marker light would light.
2. The turn signals (except all lights to come and the fuel gauge needle) to bounce up and down.
3. When the turn lights were on, the front parking lights also came on.

The technician noted all these strange electrical behavior and began to trace the circuit. He started at the origin (dash light and fuel gauge) and traced the circuit back to the battery. He found a short circuit in the wiring harness connecting all of the wires for circuits at the rear of the truck. The light that caused the indicator and caused most of the wires to touch. Whenever the circuit was activated (such as when the brake pedal was pushed), the current had a complete path to reverse other circuits. It was not too long before there was enough resistance in the circuits being energized, so the current in the circuit was too low to blow any fuses.

NOTE: Using a simple circuit bulb (such as a #1152) in the place of a dash-mount bulb (such as a #1152) usually also causes many of these same problems.

Because most of the trouble occurred when the brake pedal was depressed, the technician started to trace all the wires in the brake light circuit. The technician discovered the problem was the wrong resistor. It used 15 ohms in the original (the original) circuit but was replaced in the wiring harness with a resistor of 15 ohms for circuits at the rear of the truck. The light that caused the indicator and caused most of the wires to touch. Whenever the circuit was activated (such as when the brake pedal was pushed), the current had a complete path to reverse other circuits. It was not too long before there was enough resistance in the circuits being energized, so the current in the circuit was too low to blow any fuses.

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FIGURE 2.7 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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TECH TIP

Think of a Waterwheel.
A highway technician checked the positive terminal of the battery when the starter was cranking the engine slowly. When questioned by the shop foreman as to why only the positive post had been checked, the technician responded that the negative terminal was "only a ground." The foreman reminded the technician that the current, if incorrect, is dependent throughout a series circuit such as the starting motor circuit. If 200 amperes flow the positive end of the battery, then 200 amperes must return to the battery through the negative post. The technician could not understand how electricity can do work inside an engine, yet return the same amount of current, in amperes, as left the battery. The shop foreman explained that even though the current is constant throughout the circuit, the voltage (electrical pressure or potential) drops to zero in the circuit. To explain further, the shop foreman drew a waterwheel. **SEE FIGURE 2-6.**
As water drops from a higher level to a lower level, high potential energy (or voltage) is used to turn the waterwheel and results in low potential energy (or lower voltage). The same amount of water (or pressure) reaches the pond under the waterwheel as finished the fall above the waterwheel. As current (amperage) flows through a conductor, it performs work in the circuit. Hence the waterwheel while its voltage (potential) drops.

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FIGURE 2.8 Electrical flow through a circuit is similar to water flowing over a waterwheel. The more the water (amperes in electricity), the greater the amount of work (waterwheel). The amount of water remains constant, yet the pressure (voltage in electricity) drops as the current flows through the circuit.

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FIGURE 2.9 To calculate one unit of electricity when the other two are known, simply use your finger and cover the unit you do not know. For example, if both voltage (E) and resistance (R) are known, cover the letter I (amperes). Notice that the letter E is above the letter R , so divide the resistor's value into the voltage to determine the current in the circuit.

$I =$ AMPERES (CURRENT)
 $R =$ OHMS (RESISTANCE)
 $E =$ VOLTS (ELECTROMOTIVE FORCE)

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

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CHART 2.1 Ohm's law relationship with the three units of electricity.

| VOLTAGE | RESISTANCE | AMPERAGE |
|---------|------------|----------|
| Up | Down | Up |
| Up | Same | Up |
| Up | Up | Same |
| Same | Down | Up |
| Same | Same | Same |
| Same | Up | Down |
| Down | Up | Down |
| Down | Same | Down |

CHART 2-1

NOTE: Before applying Ohm's law, be sure that each unit of electricity is converted into base units. For example, 10 K Ω should be converted to 10,000 ohms and 10 mA should be converted into 0,010 A.

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FIGURE 2.10 This closed circuit includes a power source, power-side wire, circuit protection (fuse), resistance (bulb), and return path wire. In this circuit, if the battery has 12 volts and the electrical load has 4 ohms, then the current through the circuit is 4 amperes.

CLOSED CIRCUIT

BATTERY

RETURN PATH

FUSE

POWER SIDE

LIGHT BULB

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TECH TIP

Wattage Increases by the Square of the Voltage

The brightness of a light bulb, such as an automotive headlight or courtesy light, depends on the number of watts available. The watt is the unit by which electrical power is measured. If the battery voltage drops, even slightly, the light becomes noticeably dimmer. The formula for calculating power (P) in watts is $P = I \times E$. This can also be expressed as: **Watts = Amperes \times Volts.**

According to Ohm's law, $I = \frac{E}{R}$. Therefore, $\frac{E}{R}$ can be substituted for I in the previous formula resulting in $P = \frac{E}{R} \times E$ or $P = \frac{E^2}{R}$.

E^2 means E multiplied by itself. A small change in the voltage (E) has a big effect on the total brightness of the bulb. (Remember, fluorescent light bulbs are sold according to their wattage.) Therefore, if the voltage to an automotive bulb is reduced, such as by a poor electrical connection, the brightness of the bulb is greatly affected. A poor electrical ground causes a voltage drop. The voltage at the bulb is reduced and the bulb's brightness is reduced.

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FIGURE 2.11 To calculate one unit when the other two are known, simply cover the unknown unit to see what unit needs to be divided or multiplied to arrive at the solution.

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FIGURE 2.12 "Magic circle" of most formulas for problems involving Ohm's law. Each quarter of the "pie" has formulas used to solve for a particular unknown value: current (amperes), in the upper right segment; resistance (ohms), in the lower right; voltage (E), in the lower left; and power (watts), in the upper left.

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