Click here to go back to the normal view!

How Wires, Fuses and Connectors Work

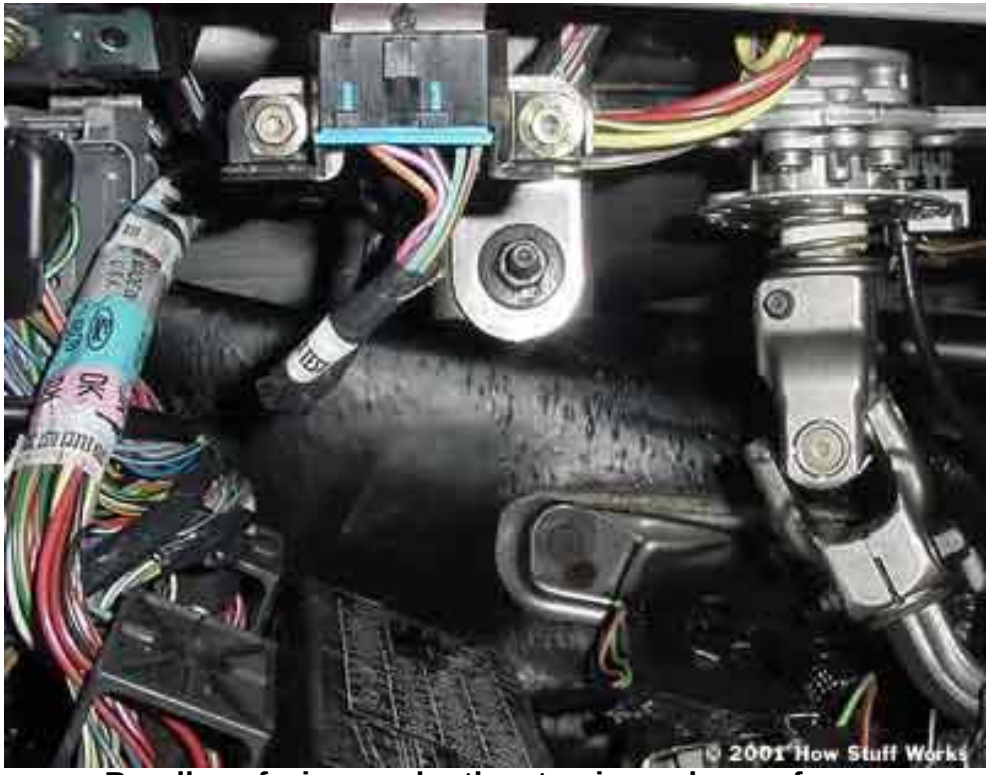
by Karim Nice

The mundane-sounding components of wires, fuses and connectors are found in every electrical device, and especially in cars. Many of the features we have come to expect in our cars are possible because of these elements, and their reliability has improved immensely in the last couple of years.

Along with increased reliability, the complexity of car wiring systems has increased dramatically. Cars now have literally thousands of circuits. In this article, we'll go through some of the key components in your car's wiring, starting with the wire itself. Then we'll discuss fuses and connectors and see how it all fits together.

Wire

A car's wiring has to distribute power from the battery to devices located all over the car. It also has to transmit data on a data bus, as well as a variety of digital and analog signals from switches and sensors.



Bundles of wires under the steering column of a car

This means that there are many different types of wires in your car. Some wires that transmit signals from switches or sensors carry almost no current. Those that provide power to large electric motors carry lots of current.

If too much current goes through a wire, it can overheat and melt. The amount of current that a wire can handle depends on its length, composition, size and how it is bundled. Let's take a quick look at how each of these properties affects the wire's current-carrying capacity:

- **Length** - Each type of wire has a certain amount of resistance per foot -- the longer the wire, the larger the resistance. If the resistance is too high, a lot of the power that flows down the wire will be wasted; the energy lost as heat builds up in the wire. Ultimately, heat build-up limits the current-carrying capacity of the wire, as the temperature must not get hot enough to melt the insulation.

- **Composition** - Automotive wire is usually composed of fine copper strands. Generally, the finer the strands, the lower the resistance and the more current the wire can carry. The type of copper used has an effect on the resistance of the wire, too.

- **Wire gauge** - The wire gauge, or size of the wire, also determines how much resistance the wire has. The larger the wire, the less resistance. The smaller the gauge, the larger the wire -- so a 16-gauge wire is bigger than a 24-gauge wire. Wire gauges go all the way down to zero, which is also called 1/0 (one aught). Even bigger than 1/0 is 00 (2/0, or two aught), and so on. The diameter of a 4/0 (four aught) wire is almost half an inch (1.27 cm).

- **Bundling** - The way a wire is bundled affects how well it can dissipate heat. If the wire is in a bundle with 50 other wires, it can carry a lot less current than if it were the only wire in the bundle.

(See also this Question of the Day for a good explanation of current, voltage and power.)

You can see how important it is to choose the correct wire size. The job is made even more difficult by the number of wires in a car, which continues to grow each year as new features are added to even the most basic automobiles.

Fuses

The main job of the fuse is to **protect the wiring**. Fuses should be sized and located to protect the wire they are connected to. If a device like your car radio suddenly draws enough current to blow the fuse, the radio is probably already toast. The fuse is there to protect the wire, which would be much harder to replace than the radio.

Most cars have two **fuse panels**. The one in the engine compartment holds the fuses for devices like the cooling fans, the anti-lock brake pump and the engine control unit -- all of which are located in the engine compartment. Another fuse panel, usually located in the dashboard near the driver's knees, holds fuses for the devices and switches located in the passenger compartment.

Engine-compartment fuse panel

Interior fuse panel

We saw in the last section how the heat build-up in the wire depends on the resistance and the amount of current flowing through the wire. Fuses are really just a special type of wire in a self-contained connector. Most automotive fuses today have two blade connectors and a plastic housing that contains the conductor. There are also some fuses that are in the wiring of the car, called **fusible links**.

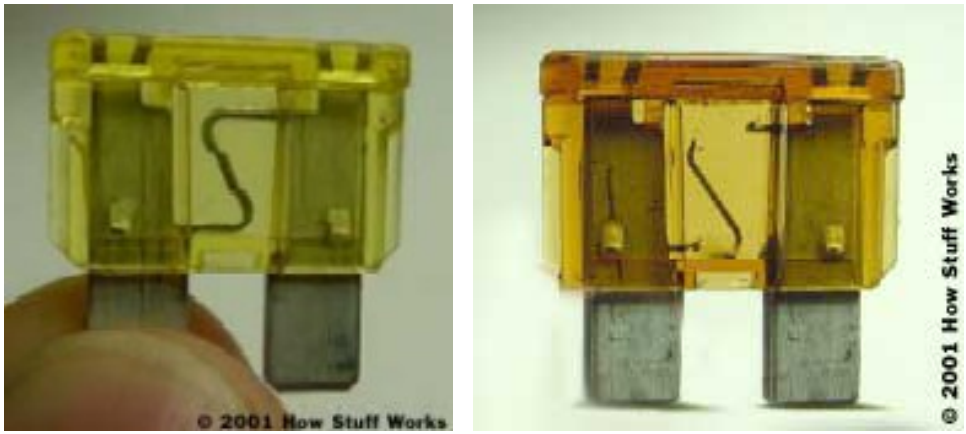
An assortment of automotive fuses

The **conductor** inside the fuse is made of a metal similar to solder. It has a lower melting point than the wire itself. The size of the conductor is calibrated very carefully so that when the rated current is reached, enough heat is generated to melt the conductor and so break the circuit.

When a fuse is blown, it must be replaced before the circuit will work. A blown fuse must be replaced with a fuse of the same amperage.

Checking Fuses

The most foolproof way to check a fuse is to pull it out of its receptacle and hook up a **continuity tester** to both blades of the fuse. But if you do this while the fuse is plugged in, you could get continuity through a path other than the fuse (for instance, both sides of the wire may be grounded when you check the fuse). You can usually tell if a fuse is blown by a visual inspection:



A good fuse (left) and a blown fuse (right)

Now let's move on to connectors.

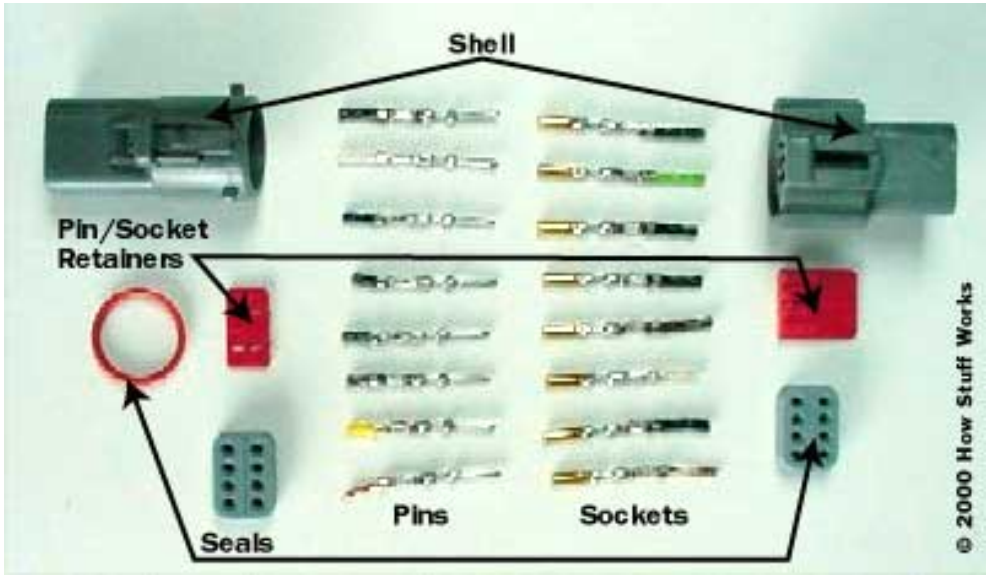
Connectors

Connectors are critical to today's cars. Without them, it would be nearly impossible to build or service a car. Whenever a bundle of wires passes through or attaches to a component of the car that might have to be removed, there must be a connector there to allow for that removal. A single connector can have more than 100 wires.

The connector on the engine control unit has more than 100 wires.

In the past, unreliable connectors have been the source of many electrical problems. Connectors have to be waterproof (modern connectors have several seals to keep out moisture), corrosion proof and provide good electrical contact for the life of the vehicle.

The connector pictured below is an eight-terminal connector -- it connects eight wires to each other.



The parts of a typical automotive connector: Everything on the left connects to everything on the right.

To make this connection, there are a total of 23 separate parts. The main parts are:

- The **shell**
- The **pins and sockets**
- The **pin retainer**
- The **seals**

The Shell

The shell is an intricate piece that has a complicated shape. There is a locking clip on the outside that holds the two halves of the connector together. There are holes for the pins, and there are special barbs that lock the pins in place once they are inserted. There are numerous grooves to hold seals

and make sure things fit together tightly. All of these features are molded into the piece when it is made.

The Pins and Sockets

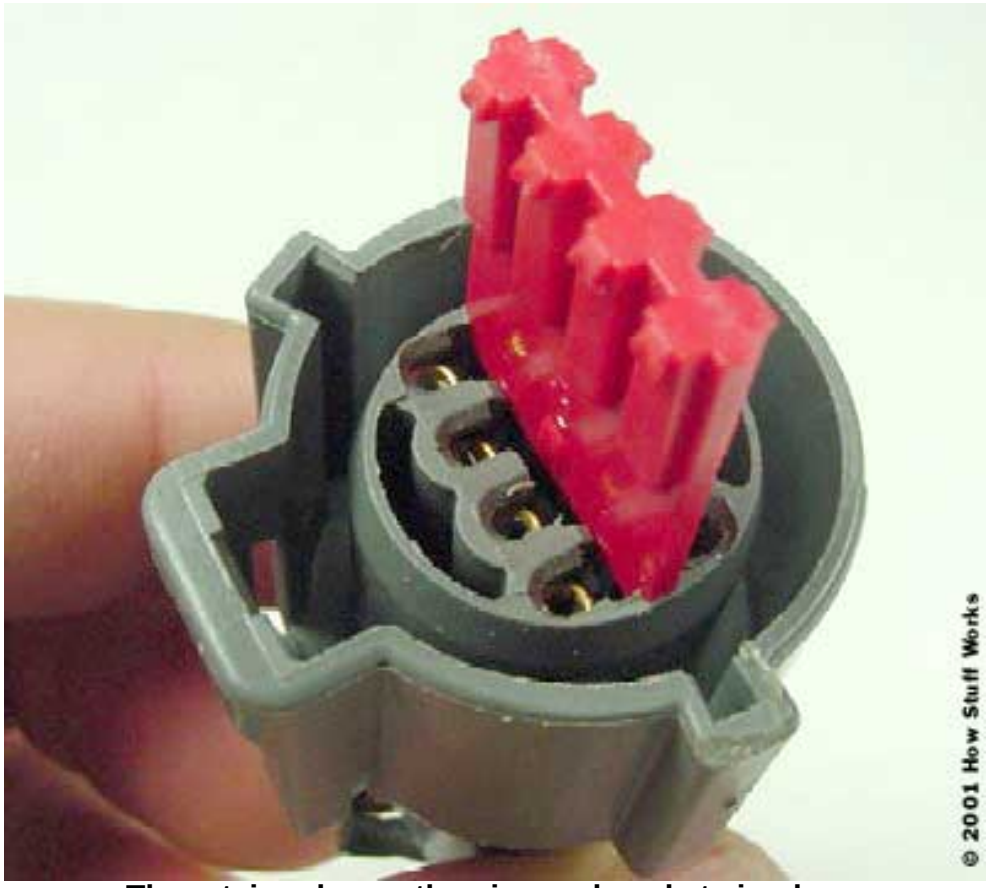
The pins and sockets are responsible for conducting electricity from one half of the connector to the other. These are made very precisely so that the pins and sockets fit together with just enough force to ensure a good connection, but not enough force to make connecting and disconnecting too difficult.

A socket (left) and a pin (right)

The pins are crimped to the wires using a special crimping tool. Part of the pin wraps around the bare wire, while another part clamps onto the insulation. This makes it harder to pull the wire away from the pin.

The Pin/Socket Retainer

The pin/socket retainer is a piece of plastic that slides into the connector from the front. It wedges against all of the plastic locking barbs so they can't release. This piece makes it nearly impossible for the pins and sockets to work their way loose.



The retainer keeps the pins and sockets in place.

The Seals

The seals prevent water from entering the connection once the connectors are locked together. Each connector has a rubber seal through which all of the wires are fed. This seal fits firmly into the back of the connector. One side of each connector has a round seal that keeps water from entering the space between the connectors once they are locked together.

The wires pass through a rubber seal on the back of each connector (the seal, seen on the right, has been pulled out for this picture).

For more information on wires, fuses, connectors and related topics, check out the links on the next page.

Lots More Information

Related HowStuffWorks Articles

- How Batteries Work
- Inside a Power-Cube Transformer
- How Electric Motors Work
- How Car Computers Work
- How Car Engines Work
- How Relays Work

- What are amps, watts, volts and ohms?

More Great Links

Click here to add your site to this list

- Automotive 101: The Electrical System
- Introduction to Electricity - illustrated
- DC Circuits and Components
- Are today's automobiles more prone to electrical/electronic system failure?
- Smart Continuity Tester
- Autoweb: Owning and Maintaining Your Vehicle