Basics of Automotive Electrical Systems

For Restoration and Fabrication

Overview

This is an overview to present a basic understanding of automotive electrical systems followed by an introduction to the fabrication of a wire harness.

What is the main source of electrical power?

The generator or alternator when driven by the engine at sufficient speed.

What is the difference between a generator and an alternator?

Both produce AC and convert to DC. The generator uses brushes and a commutator to convert AC to DC. The alternator uses diodes to make this conversion. An alternator generates more heat but also produces more electrical power when the engine is idling than a generator.

What is the function of the battery?

To supply electrical power to the starter motor and the automobile before the engine is running. The battery also supplies electrical power when the generator or alternator voltage output drops below the battery voltage.

What is meant by the term electrical ground?

Ground is one pole of the battery. It can be thought of as the universal return path of the current to the battery. It is usually the metal of the automobile body and engine block, supplemented by ground wires or straps. Insure an electrical connection is uninterrupted by insulating materials such as painted metal joints, rubber and plastic. Electrical problems on an old car are often caused by a poor connection to ground.

What are the four primary functional groups of an automobile's electrical system?

1. The charging system (e.g., generator or alternator, and its controller or regulator).
2. The starting system, including the starter motor, ignition switch, solenoid and battery.
3. The ignition system and a step-up transformer of voltage (e.g., ignition coils).
4. Lighting and HCV systems plus various electrical accessories.

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Wire Harness Fabrication

A new wire harness should be obtained or fabricated and installed in restored cars or fabricated hot rods. The reason for this recommendation is that insulation gets brittle with time and heat cycling, and eventually it disintegrates, possibly causing a short circuit and sometimes enough heat to cause a fire, often in a difficult to find, obscure location. Old and poor condition of automotive wiring is one of the two leading causes of fires, fuel system faults being the other. Corrosion of connections at terminals and grounding screws, and fading of color codes, will cause more problems with electrical systems than component failure. These old age problems will make fault finding very difficult and frustrating. We will cover harnesses below after some fundamental concepts and a few observations are introduced.

Most automobiles employ either a 12 volt or a 6 volt electrical system. Six volt systems require heavier gauge wires because they have to conduct more amperage to compensate for lower voltage. One analogy used by many people is that electricity is like water in a closed-loop plumbing system, meaning no open drains. Voltage is pressure, and amperage or current is rate of flow. A more light hearted analogy used by British car enthusiasts substitutes smoke for water. It is the job of the insulation to keep the smoke from escaping. But more seriously, electricity is used to power something, be it to re-charge the battery, drive a motor, a switch (relay), heat a glass surface, or illuminate a reflector, etc. These jobs require electrical power which is called watts, a product of volts times amperage. One horse power is equal to 740 watts. In other words, one horsepower can be delivered by 740 volts pushing one amp, or by one volt flowing 740 amps, or any combination with a product of 740.

However, since the voltage in an automobiles system is constant, the system's ability to deliver more power is limited to increasing amperage, or current flow. Thicker or heavier gauge wire is required to carry more current. If the wire is too small in cross section, or has too few strands, it will add resistance to the circuit and heat up. Therefore it is imperative that each circuit, or family of circuits, consist of the same and proper gauge of wire and be powered through a fuse of the appropriate size.

Also, a rule of thumb to keep in mind is that old automotive circuit designs could have benefited from more fuses, and more relays, the latter principally to reduce the current load on switches on the dash board. Therefore, some thought should be given to useful minor modifications, such as adding more fuses which can be easily hidden, the inclusion of relays to extend the life of switches, and more ground wires and straps to improve the conductivity of the system in a car which will probably have a lot more insulating primer and paint than the original car ever had.

Now back to the wire harness. Removing the old harness requires simple tools, a box of small labels, a sharp pencil and some markers, an enlarged wiring diagram, a comfortable cushion from a lawn chair for your back when working under the dashboard, and patience. But first disconnect the battery! The wire harness can be divided into several main sections: The under the dashboard bundle (always the biggest), one branch to each side of the engine compartment and the front lights and horn, one branch to the back of the car for lights and usually the gas tank, and small branches to various parts of the interior.

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First determine whether you can obtain a correct replacement harness. Preferably take the advise of a fellow enthusiast who has successfully used a particular source for replacement wire harnesses. A new wire harness ranges in price from a couple of hundred to almost a thousand dollars. However if you are working on a rare car for which no off-the-shelf harness is available you will have to make every effort to avoid cutting your old harness during the removal process. This is because you will need to trace wires from one end of your harness to another using a volt/ohm meter or a simple continuity tester as you map out your harness for building a new one from scratch.

Begin under the dashboard by removing one wire at a time, number a label and attach it (covering the label with a small piece of clear tape is a good idea to protect it), mark this number at the proper location on you wiring diagram, and if you are at all uncertain about remembering any details about the routing, function, or notice any color code inconsistencies of this wire, note this label number with descriptive text and a sketch in your note pad. In this manner proceed to remove the wires from all the instruments and switches, either by disconnecting or cutting the wire. As an added precaution you may also want to mark the terminal location on each instrument with this label number.

If the fuse block is located inside your car, you should most likely plan on extracting the wire harness from underneath the dashboard. If on the other hand your fuse block is located in the engine compartment (a great place for corrosion to wreak havoc) you should plan to extract your wire harness into the engine compartment. Where wires, usually bundled as a loom pass through the body, rubber grommets are used as an edge guard. These also age and harden over time. Before you pull a harness through a sheet metal panel, remove by cutting or tearing these grommets to give yourself some additional clearance and wiggle room. Label and save these for obtaining replacements. If you still have difficulty extracting the harness (even after staggering connectors to reduce the diameter of the “snake”, you could as a last resort cut the harness all the way through. After the complete harness is removed you can simply tape the loom together again (not the individual wires) to retain a good dimensional sample.

For many cars built before the mid 1960s (or pre-plastic connectors) you can make your own replacement wire harness buy buying the materials required in bulk from a supplier. You start by painting a 4x10 feet sheet of plywood white or some other handy color suitable for marking. Take your old harness and lay it out on this board (looped where there are long runs without wires sticking out). Attach it loosely to this board using big house wiring staples. Use smaller staples to spread out the bundles of connectors at the ends. Make a general tracing of your harness and label all runs and terminal ends as to their location and function. With your notes and wiring diagram in hand label all connector ends. Note in your notebook the style of connector, color code and exact length for each wire. This list of lengths, gauges, connectors and color/tracer of wires is your shopping list for supplies.

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Remove the old harness from the board and start stringing your new wires, cut to a generous length, through the staples and again label each. When all the wires are in place, zip tie them into the harness bundles, and begin to attach connectors. In locations like under the dashboard where space is tight and the wires are many, do not attach the connectors until you are certain as to the exact length of wire you need to make a tidy installation. Wires without connectors at one end also help when installing a bundle of wires through a panel with a grommet. Looming or packaging of bundles of wires was done by the OEM in two different ways, depending on the age and less so the manufacturer. Most commonly recent looms were wrapped with vinyl tape which you can purchase and loom yourself. Older harnesses were actually loomed with thread, kind of like making a tube sock. You can have this done by several suppliers in the U. S. by sending your zip tied bundle of wires to them, after marking it with tape to indicate where to start and stop the loom on each run of a bundle of wires.

