After talking to thousands of fellow homebuilders and giving many presentations at fly-ins around the country, I realized there was a need for information to design and build the newer, more complex electrical systems found in Experimental aircraft. This article is one in a series of excerpts from my new book entitled Aircraft Wiring Guide. For more information visit www.AircraftWiringGuide.com.

Installation Overview
Completing an electrical system is accomplished in five main steps. The most effort should be spent on the first step if you want to minimize issues later on. Following these steps will increase the likelihood of a trouble-free electrical system. It is recommended that you familiarize yourself with all five steps to better understand the scope of the project.

**Step 1: Planning**—Gather as much information as possible about the devices you want to install. Document and review all aspects of your electrical system.

**Step 2: Installation**—Select and install wires and devices.

**Step 3: Configuration**—Configure all of the avionics in the aircraft.

**Step 4: Ground Test**—Test as much as possible on the ground to minimize surprises in the air.

**Step 5: Flight Test**—Test everything to its safe limits.

Taking the time up front to carefully plan your electrical system will pay big dividends later on.

Steps to a successful electrical system installation.
Primary Power

The electrical system on your aircraft can be thought of as having two major sections: primary power and secondary power. The primary power section is the backbone of the electrical system. It includes the larger wires in the electrical system that tie together the battery, starter, alternator, and main power buses. It also includes the airframe, which is typically used as the ground.

The picture below shows a typical way to mount the contactors and alternator fuse. This example is from a Van’s RV-7, and your actual installation may vary. In aircraft with aft-mounted batteries, the master contactor is located in the back near the battery, and the starter and fuses are located in the front on the firewall.

The battery contactor (also known as the master relay, master contactor, or master solenoid) is a continuous-duty contactor and is essentially a big relay that allows a small amount of current to switch a large amount of current. This contactor is switched with a wire that comes from the master switch in the cockpit. The starter contactor allows the small starter switch in the cockpit to switch several hundred amps that are drawn by the engine starter.
The bus bars are copper strips that connect the contactors together electrically. Cable can be used as well, but tends to be more work to build and install. The ANL fuse is a specific type of fuse used to protect the main bus from any problems with the alternator or cable running to the alternator.

The primary power section can be configured several different ways. Here are some examples:

- Single bus, single battery, single alternator.
- Single bus, single battery, main alternator, and backup alternator.
- Single bus, dual battery, single alternator.
- Single bus, dual battery, main alternator, and backup alternator.
- Dual independent bus with cross-tie contactor (dual batteries, alternators, and battery contactors).
- Various permutations of the above.

This is an area where you want to keep things simple. Based on studying thousands of individual electrical designs and understanding modern avionics and engines, I recommend the following course of action that applies to 95%+ of Experimental aircraft:

Install a single bus, single battery, single alternator system in your aircraft and add to it as needed, noting the following:

- “Single battery” in this context means a single main battery and, if needed, a backup battery.
- The backup battery in this context is a small (4 amp-hour or so) battery used to back up the EFIS and/or other critical avionics in case of an emergency. It is not meant for starting the engine. Some avionics include their own backup battery system, or you can install a third-party backup battery system.
- There is rarely a need to install a second main battery and the associated contactors, switches, and wiring to be able to switch between two main batteries.
- “Single alternator” in this context means the primary or main alternator. You may, or may not, need a backup alternator, and we’ll address that in a future article.
- I’ll choose a backup alternator over installing a second main battery if redundancy is needed for a primary alternator failure condition. The reason is because you can fly indefinitely on a backup alternator, but a second battery has limited life. For clarification, a second main battery is different than a small backup battery for emergency power to avionics.
- A dual independent bus is used in certified aircraft because of redundancies needed for IFR flight, but not very often in Experimental aircraft. Because modern avionics include redundant power inputs, an emergency battery can often provide comparable levels of redundancy and safety.
- If you’re installing an automotive or turbine engine, there are specific requirements that are not covered here. You should follow the guidance provided by the manufacturer.

Secondary Power

The secondary power section includes the main bus and avionics bus, and the power wires needed for the avionics, lights, accessories, flap motor, trim motors, and other low-current loads. The bus bar is typically a strip of copper that electrically connects to all the circuit breakers, or it can be an automotive-style fuse block. A
modern option is to use an electronic circuit breaker system.

**Wire Sizes and Circuit Protection**

The table above shows wires sizes versus loads for a typical homebuilt airplane. The wire size can be larger than necessary but should not be smaller. Circuit breakers (or fuses) are there to protect the wiring, not the device. If the breaker is too large, then the wire may overheat and fail. If the breaker is too small, then the breaker or fuse may trip because the device draws too much current.

Most kit aircraft and avionics companies provide recommendations for sizing wires and breakers. You can use these recommendations, or you can use an ammeter to measure the current draw of each electrical device and then determine the sizes yourself.

There are some devices that need a higher breaker value (and larger wire) than you’d normally expect. For example:

- An HID light draws only 3 amps (at 14 volts) at steady state. But at startup, the light draws about 8 amps then slowly declines to about 3 amps over about 25 seconds. You’ll need a 10-amp breaker rather than a 5-amp breaker. Because you are using a 10A breaker, you should use 18 AWG wire (the wire is sized for the breaker, not for the load). The breaker must protect the wire.

- A radio may only draw 2 amps while receiving. As soon as you transmit, it might draw 6 amps. Therefore a 5-amp breaker won’t work.

- The flap motor may only draw 1 amp on the ground. But in the air, it has to work harder to overcome the air loading, and therefore draws 4 amps while in flight.

When you know the current draw for each device, use the chart to size the power wires. Note that this is a conservative guide to sizing wires, and you may find instances where wires are smaller than recommended.

Be sure to use aircraft-grade Tefzel 22759/16 wire. Do not use automotive wire. The insulation on the Tefzel wire has a higher temperature rating and the...
same gauge wire for Tefzel has a smaller diameter, so it takes less room.

**Conductors**

A conductor is a wire within a bundle of shielding or other wires. For example, a 4-conductor shielded wire has four wires wrapped together and covered with shielding and outer insulation. The wires are usually spiral wound within the outer sheathing.

**Wire Labeling and Color**

Tefzel is available in a variety of colors from most avionics shops and parts dealers. White is commonly used because it can be labeled using a laser label machine. However, laser labeling is not practical for homebuilders so other methods are employed.

Below are some ways to mark the wires. I recommend putting a label at both ends of a wire.

- Print labels with your printer, cut them out, then wrap around the wire and cover with clear heat-shrink tubing.
- Using a black fine-point Sharpie pen, write on light-colored heat shrink tubing before you shrink it around the wire.
- Use a special heat-shrink tubing printer that prints labels on heat-shrink tubing.
- For temporary labels, use tape wrapped sideways around the wire (looks like a flag).

**Tip:** Put the label on before crimping the terminal on the wire!

Here are recommendations for choosing wire color. The color of the wire has no bearing on its performance; the color is simply to help the builder identify wires.

- **White:** Can be used for anything
- **Red:** Power
- **Black:** Ground
- **Yellow:** Panel light dimming power
- **Green:** 24 AWG used from shield to chassis on shielded wire

**Special Wires**

In addition to standard single wires, you will also have to strip and crimp terminals on special types of wire such as the ones below. The Internet is a great source for videos and further instructions.

**Heavy-gauge wire:** This is 00 to 8 AWG size, used in the primary power system to connect batteries, starters, buses, and alternators. Use a special crimp tool for heavy-gauge wire—do not use pliers or a vise. Also note the rotational direction of the terminal before you crimp it, as the heavy-gauge wire does not twist easily.

**Shielded wire:** This is wire that has a metal braid around an inner core of one or more smaller wires. The shielding is used to reduce radiated emissions from the wires or to insulate the wires from outside interference. Shielded wire is typically used for wires that carry data between avionics boxes.

**Coax cable:** This is used to connect radios with antennas, and typically RG58 and RG400 (preferred) is used in homebuilt aircraft. Cutting the various layers of coax cable and crimping on the terminal requires special tools and a good amount of practice. If you have not done this before, plan on having a few extras for training purposes.

**Conclusion**

Those are the basics to help you get started. I’ll provide more information in future articles, and pick up a copy of the Aircraft Wiring Guide online.

Marc currently flies an RV-7 he finished building in 2006. He was founder and president of Vertical Power and has served as an EAA Director since 2011. He flew with the U.S. Navy as a Naval Flight Officer on board the P3-C Orion. He lives in California with his wife and three children.