



# ALL ABOUT AVIONICS

## THE ELECTRIC AIRPLANE

**The modern homebuilt is volt-intensive. Here's how the smarties plan for an all-electric world.**

BY STEIN BRUCH

**Experimental airplanes** built through the late-1990s had systems and instrumentation that closely followed their counterparts in store-bought designs. You'd see three pneumatic gyros in their little 3.125-inch holes, spun up by a vacuum pump and bracketed by old-school pitot-static systems; if you saw a 1990 Piper, you saw a 1990 RV-6A. Likewise, a typical 1990s homebuilt probably had a single-bus, 12-volt electrical system with an engine-driven alternator. The groundbreaking types might have a specialty battery in place of the heavier, expensive aviation item, but otherwise, tradition ruled.

Then a funny thing happened. Electronic instruments waltzed in, and the unreliable vacuum systems were being shown the door. Suddenly, the electrical system needed more than a cursory "that'll do" design phase, because it now had to carry all of the critical systems, not just part of them. It's imperative

when designing to keep in mind the reliability and performance of each system that depends on electricity. For this discussion we'll divide the topic into two main groups: airframe and avionics first, then engine-centric electrical theories and philosophies.

### **Airframe and Avionics**

Perhaps the most common questions relating electrically advanced aircraft are: 1) How many batteries do I need, and what size should they be? 2) How many alternators do I need, and what size should they be?

Of course, there is no single answer that will cover every aircraft. Each one depends significantly on a number of variables. The easiest place to start is determining whether you intend your plane to be used for VFR or IFR, so let's begin there.

If you don't intend to fly your airplane great distances or will stick to VFR con-

ditions, then it's logical to decide on a simple electrical system. In this case you probably will have only simple flight instruments (perhaps an EFIS or engine monitor), a radio, transponder, maybe a handheld GPS and a few other goodies installed in the panel.

Yep, you're saying: "Are you nuts, Stein? EFIS in a VFR airplane?" Believe it. We get queries all the time from pilots who never intend to enter clouds who still want an EFIS, in part because the good ones are lighter and more reliable than conventional gauges.

With this setup you should be fine with a single alternator and a single battery. Even if the alternator were to fail—and they still do from time to time—the battery should provide power long enough to get on the ground safely. You don't need multiple buses or an "emergency" bus. If you intend to fly at night, it might be wise to consider a small backup battery for your EFIS or gyros;

if no attitude gyros are installed, then you ought not be flying at night. (Yes, I know it's legal to do so, but the first time you fly over the empty countryside on a moonless night, you'll know why I insist on having attitude reference.)

### Dancing in the Clouds

On the other hand, if you intend to fly the airplane in an IFR environment or even, in my view, cross-country, then it's wise to design your electrical system with a bit more "robustness" than your day/VFR brethren's. This doesn't automatically mean you need two batteries or two alternators, but it does mean that you need more than a simple "no backup of any kind" installation. (Feel free to disagree with me here. Many builders have flown their aircraft extensively cross-country without backups, but the potential is always there for a failure that puts you on the ground away from home. Robustness buys you flexibility as well as safety.)

Now we're into fault tolerance: Which equipment can you afford to lose and still complete the flight safely? If you have one and only one attitude reference and it goes down, you are well and truly out of luck. Traditional instrument panels had some components powered by electricity and some by vacuum, separate power systems and, for that matter, separate components. Yes, a failure of the vacuum pump would render both the attitude indicator and directional gyro stupid, but you still had the trusty turn coordinator or, better, a turn-and-bank instrument. Lose electrical and the vacuum system should not be affected.

If your flight

instruments are 100% dependent on electrical power, it's essential that you provide those instruments some sort of alternative and backup electrical power. Luckily, most of the EFISes you can purchase now include the option of a backup battery. This is good. You can design a simple electrical system with one battery and one alternator, and have backup instrumentation running on its own internal batteries, and you'll be just fine. However, if your EFIS does not have an internal battery, then it's wise to provide it with another source of power.

Remember that though the main aircraft battery is your first backup, it also has to share its remaining storage capacity with everything in your airplane that is consuming current. This includes relays (even though small, they still eat amps), lights, ignitions, fuel pumps, flaps, trim systems, autopilots, radios, transponders and more.

When calculating the size of a primary or backup battery, it's important to do a load analysis of every item in your plane that consumes current.

Then you decide which items are critical for flight

It's the modern all-electric panel—not a vacuum device to be found. This is a single-bus system with one 60-amp B&C alternator and one battery. It's old school in that switch/breakers are used.

and, using the total current draw from those items, you can determine how much battery capacity you need.

The scenario where you might need either two batteries or two alternators (or both) would be if you installed flight instruments that don't have an internal battery. Each method has its own benefits. Let's take a look at each scenario.

### A Battery of Backup

Installing two batteries (primary plus backup) has the benefit of allowing you (if you wire it as such) to use either one or both of the batteries for starting the aircraft. It also may allow you to create two or more independent buses for driving avionics and other equipment in the plane. (Some EFISes have the capability for multiple independent power inputs and automatically select which source is appropriate.) A second battery also allows you to design your system so that you can power up some equipment on the



A high-tech example of prefabbed system architecture is the Vertical Power setup, which uses a centralized power-management box controlled by a computer. Turn on the nav lights, Hal.



Timesavers such as the EXP bus can simplify wiring but also limit flexibility.

ground—radio for clearance delivery, weather briefing, GPS flight plan loading, etc.—without draining the battery used for engine start.

Builders might choose a second battery that is of smaller amperage (current capacity) to save weight, an acceptable practice. Make sure you have a way to keep the batteries isolated electrically when need be, so that if one battery or its specific bus fails, it doesn't drain the other. Even so, you still need a way to keep the second battery charged. This can be accomplished with bus tie switches, relays and/or diodes. A downside to installing multiple batteries is simply maintenance and upkeep. See Figure 1 for a simple example of an installation depicting two batteries and one alternator.

### Supplementary Amps

The next option is to install a single main battery, a single main alternator and supplement it with a standby or backup alternator. Currently the most popular backup alternators are made by B&C Specialties and are available in 8-amp or 20-amp models. Our experience has shown that the SD-8 permanent-magnet 8-amp model is marginal for well-equipped panels, though it ought

Critical, absolutely critical, are good ground paths for all electrical components. There are many ways to accomplish the task, but getting all grounds as close as possible to a central location is best.

to be fine for keeping a nav/com, GPS and transponder working. If your load survey shows the airplane needing close to 8 amps on essential equipment, this alternator is not the best choice.

Our experience with the 20-amp model (SD-20) has shown a capable and reliable alternator. Wiring is relatively simple, and while the unit isn't cheap (about \$1000 with the required regulator), the long-term benefits can't be ignored. The SD-20 mounts on the vacuum pump pad of Lycoming or Continental engines. The required external voltage regulator provides over-voltage protection.

The benefits to having a secondary alternator are twofold. First, it obviously weighs less than a battery, and the associated wiring is less; secondly, it can't be run down, as long as the

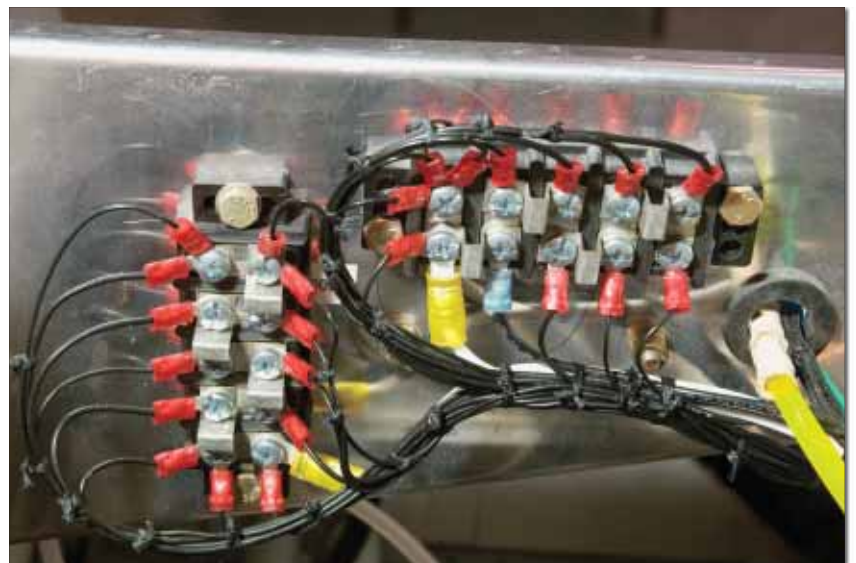


A workaround for a true dual bus system is to provide independent backup power for flight-critical instruments. The TruTrak ADI (attitude direction indicator) can be wired for an external battery.

engine is turning. Typically the setup for the secondary alternator is to use it as a supplement to the main bus and/or to power a standby or emergency bus in addition to or in conjunction with the main alternator. The downside is that you can't use it on the ground or as an aid to starting, but the benefit of a constant current flow is a good thing. With a current capacity of 20 amps continuous, the SD-20 gives you a bit more flexibility for a longer period of time in the case of a main alternator failure. See Figure 2 for a simple example of an installation depicting one main battery and two alternators.

### Seeing Double Double

The most popular way to supply the higher-end modern glass-cockpit-equipped aircraft with reliable and redundant electrical supplies has been to install







fuel from the tanks to the cylinders. But most have electric boost (or backup) pumps that need to be considered in any electrical-system design. The odds of having an electrical-system failure at the same time that the engine-driven pump fails are low, but not, theoretically, zero. In addition, some designs use electric pumps to move fuel from auxiliary tanks to the mains; lose all electrical, and that fuel becomes unusable. I would argue that these transfer pumps be considered part of your essential equipment.

Modern homebuilts are likely to have something beyond the traditional dual-magneto ignition system, too. (The whole point of using mags is that they're electrically independent of the airframe—except for those needing electrical power for starting purposes—but the majority of traditional engines today have impulse-coupled mags that are independent of the airframe electrical.) If you're using electronic ignition, consider how to power such a system reliably. Sure, most builders opt for one mag to back up the electronic ignition, but a total electrical-system outage puts you back to a single-point failure mode; lose that mag, and you're gliding.

All of the modern electronic ignition systems come with their own set of unique requirements, and builders have suffered various headaches and maladies from each and every company. To reduce

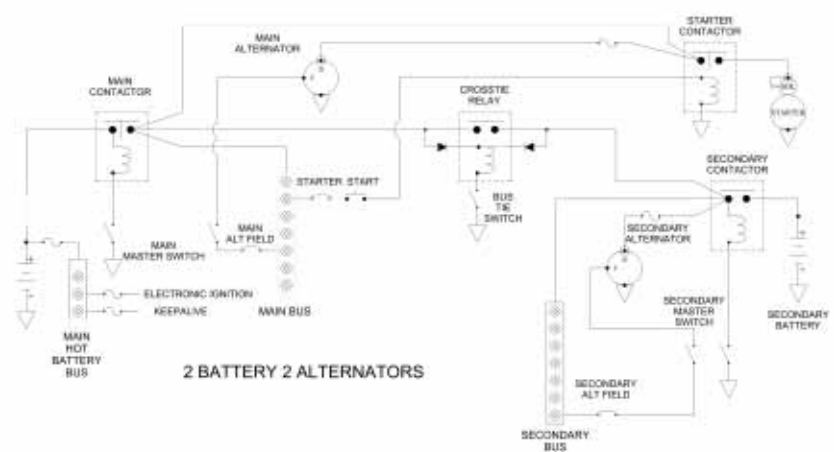


Figure 3: two main batteries and two alternators.

the likelihood of problems from these systems, it's imperative that you follow the manufacturer recommendations for installation and power supply.

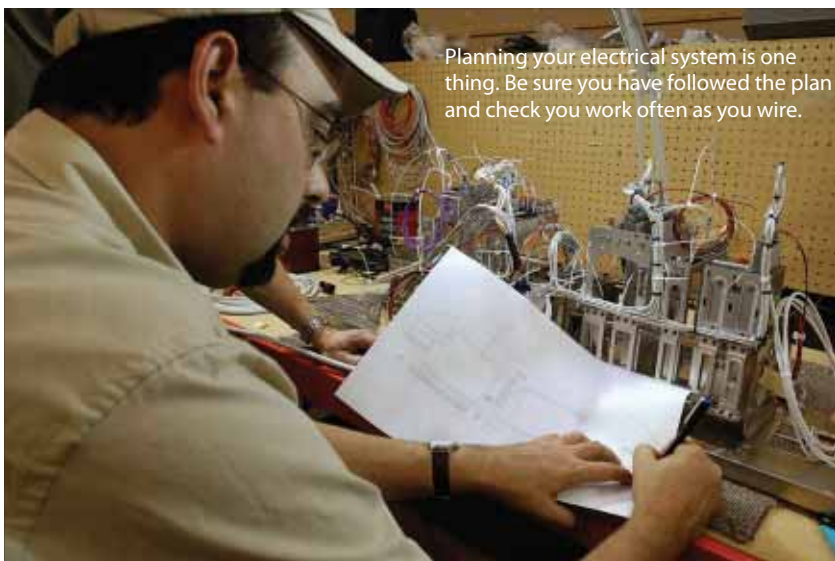
### Stein's Three Rules for Electrical Systems

**Rule Number One:** Thou shall not make your electrical system any more complex than it need be. Sure the DC-9 you fly at work may have 12 buses in it, but that doesn't mean you need it for your homebuilt VFR day fun flier. Even if your airplane is a high-end IFR machine with multiple EFISes, GPSes, radios and other widgets, keep the electrical design simple and robust. The less complicated you make your design, the more reliable, user friendly and safer your plane will be. More switches may look cool,

but when you have an emergency, sometimes less is better.

**Rule Number Two:** Thou shall not fly IFR, install dual electronic ignitions, dual electronic fuel pumps or any other engine critical items that rely 100% on electrical power without installing some sort of alternate electrical power supply. At the very least install a secondary small battery or standby alternator to supply power to critical engine and fuel systems. The same goes for the attitude indicator; if you only have one, then it should either have its own backup battery or a secondary power supply. Of course, having two attitude indicators is preferred!

**Rule Number Three:** Thou shall take the time to prepare a spreadsheet or document listing all of the electrical loads for the airplane—the load analysis we talked about earlier. This seemingly simple task will save you many hours down the road and greatly simplify the planning, purchasing, wiring and maintenance of your aircraft. Read the manufacturer's specs for the units you intend to use and study their power requirements. You'll be happy you did, and you'll have a much deeper understanding of your airplane when you finish it.



Planning your electrical system is one thing. Be sure you have followed the plan and check your work often as you wire.

*If you have specific questions for author Stein Bruch, or have certain projects you'd like us to cover, email us at [editorial@kitplanes.com](mailto:editorial@kitplanes.com) with "About Avionics" in the subject line. †*