

# Typical Aircraft Electrical Systems

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#### Introduction

There are some important do's and don't's when considering the electrical system of an aircraft. Even in cases where the aircraft kit manufacturer has supplied the hardware for the electrical system in the kit, there is often a need to "customise" the system to better suit the individuals tastes, or the requirements of extra equipment.

# **Electrical Load**

Most aircraft builders/owners will possess a multi-meter, and will be familiar with how to measure the voltage at various points in the electrical system. A voltage measurement by itself does not however determine the LOAD at that point. To do this the *current* must be measured. Most multi-meters will do this, but to take the measurement, the circuit must be opened, and the multi-meter inserted in series with the circuit.

The electrical load must be known to build the electrical system from the correct materials. Wiring has a load rating normally quoted as a maximum number of AMPS. Switches and circuit breakers also have load ratings in their specifications.

#### IMPORTANT

It is vital that the components of your electrical system have load ratings which exceed the worst case electrical load which the components are expected to bear. If the electrical load draws 5 Amps, then the wiring must be rated above 5 Amps.

### Wiring

Wiring is usually described in terms of its "gauge". The most commonly used scale is American Wire Gauge (AWG). This scale has a corresponding electrical load rating. Before you can determine the appropriate AWG for the various lines in your electrical system, the length of each wire must be considered.

AC.43-13-1B is an advisor circular issued by the FAA, which has grown over the years to become a substantial book of how to repair most types of airframe. Section 13 describes the wiring needs for aircraft systems, and relates the electrical load a wire must bear, to the maximum length over which it is safe for that wire to carry such a load. It is possible for small wires to carry large currents for short lengths, the longer the length required the larger the wire gauge must become.

You need to consider:

What is the load on the wire ? What is the length of the wire ?

... and from this determine...

What should the gauge of the wire be ?



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#### Insulation

Electrical wire is clad in insulation. Most people will be familiar with conventional plastic insulation which is in common use in houses, cars, boats etc.

Aircraft present a unique situation which the above applications don't have. In the case of a fire, you cannot run away, you cannot follow an evacuation plan (unless you are wearing a parachute). You are forced to stay at the scene of the fire until you can land, or extinguish the fire.

Where there is fire there is smoke...

All things burn, it just depends on the required temperature. Once on fire, all things give off smoke or fumes. The smoke and fumes in most cases are toxic in concentrated quantities. If you are trapped in an enclosed cockpit at the scene of a fire, there is a serious risk of being asphyxiated by the smoke or fumes.

It is very important to select wire with an insulation which resists fire, does not support the spread of fire, and most importantly, does not give off smoke or fumes.

There are a variety of lesser known MIL-Spec wires which have been designed with very high fire ratings. Most comply with Military Specification M22759/16-xx where the xx is the AWG size of the wire. This wire spec is available in 10 colours including white.

#### **Colour Code**

Most General Aviation (GA) aircraft are wired with white wire. The wiring is typically labelled at regular intervals to make identification easy. The single colour option can save money, because you can order a larger quantity of just one part number, instead of small quantities of many part numbers.

Despite this, Microair recommends that you establish a colour code for your aircraft and stick to it. By the time you have finished wiring the instrument panel in a single colour you will be struggling to identify one wire from another.

Many Avionics manufacturers offer a colour code in their installation manuals. Microair recommends that you follow their advice. It can be very expensive in some cases to cross wires over, and then turn the unit on. We have a large number of sad stories on file, which have this scenario as a theme.

The most common of all colour codes is:

# **Red – positive** Black – negative



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#### Fusing

All electrical systems require protection from fault currents. High currents will cause heat, and possible fire, hence a safety device should always be used.

Aircraft fusing should first consider the output from the engines alternator to the instrument panel (not the starter motor). If the alternator can deliver approx 30A, then the primary or master fuse should be at least 30A.

The master fuse is installed in series with the master switch. If the master fuse blows, everything loses power!

From the master switch and fuse, the power is fed on to a bus (typically a brass or aluminium bar with thread terminal studs). From this bus, individual power feeds are run first to a circuit breaker, and then on to the application (eg ETC).

The rating of the circuit breaker should be determined by considering the maximum current requirements of the application. An ETC can draw up to 1.5A in operation. Fuses or circuit breakers are normally a minimum of twice the typical current draw. Hence the ETC would have a 5A circuit breaker.

Be careful when researching the maximum current requirements. A radio will draw only a few 100mA on receive, but can draw amps when transmitting. Transponders typically draw only 250mA, but their encoders can draw nearly an amp.

Be wary of two applications sharing the same fuse / circuit breaker. If one application faults and blows the fuse / circuit breaker, you lose both applications. Pairing up a transponder and encoder will not cause you any problem, but putting your radio and GPS together may not be a good idea.

Avionics require special attention. Avionic applications are typically split off on to their own power bus. It is very desirable for the power fed from the main bus to the avionics bus to pass through a power filter, and an avionics master switch. The switch allows the pilot to turn off all avionics before engine start up and shutdown. There are moments when the engine's electrical system can give out large voltage spikes which could damage your avionics.

Applications which should be powered from the avionics bus:

- Radio
- Intercom
- Transponder
- Altitude encoder
- GPS
- EFIS systems
- Autopilot

Applications which should NOT be powered from the avionics bus:

- ETC (and other gyro instruments)
- EMS systems
- Strobes
- Lighting
- Fuel pumps
- Electrical flap drives



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#### Terminations

The most important consideration when selecting a termination method, is **VIBRATION**. You should consider the type and size of the wire, the physical "weight" of the wire on the terminal, and the type of access you have to the terminal (can you reach it with a tool ?).

Vibration undoes things with remarkable skill, and in a very short space of time. Vibration can also break wiring which is not adequately supported, by flexing it up and down.

General electrical terminations are usually crimp or solder. Crimping is by far the most common termination in aircraft. Solder joints are limited to multi-pin connectors (typically for avionics).

Another group of terminations are coaxial. These are special connectors used to terminate coaxial cable. For most aircraft applications the BNC type connector is used. Some applications require N-series connections because of the amount of power involved. GPS antenna connections can be either BNC or TNC types.

The BNC, TNC, and N Series connectors are all available in crimp and clamp types. The crimp types all require a specialty tool. The clamp types however can be terminated without any special tooling. It is very important to get the strip lengths right for coaxial termination, and to assemble the connector in the right order.





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# Crimping

The universal crimp tool is of course the pliers. Working up the quality scale, there are a variety of crimp tools available.



Always opt for the crimp tool which crimps the entire terminal. Most will squash squeeze or worse crush the crimp. In the art of crimping more is not better, and it is possible to cut the wire off completely inside the crimp.





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Some pins can only be crimped with a speciality tool. Don't negotiate this one. It can be a considerable job to take the panel apart again to repair broken wires. Getting replacement pins can also be difficult.





The important issues to keep in mind with crimping are:

- Use the correct size crimp for the wire size your are using
- Strip the wire to the correct length
- Ensure the wire is correctly positioned in the crimp
- Use the correct crimp tool
- Ensure that all of the crimp is engaged





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#### Soldering

Soldering is used for multi-pin connections such as DB-15's. The wire should be accurately cut to length to ensure that there is no excessive load on the solder joint when the wire is bundled up into a harness. The end should be stripped and test fitted into the pin. The pin and the stripped end are then tinned, and a small piece of heatshrink slid over the end. The wire is then soldered into the pin, with the heatshrink sliding down into place over the soldered joint. The heatshink is shrunk into place with a small hairdryer or a cigarette lighter.



#### Shielding

For most avionics, the use of shielded wire is the best option to ensure reliable operation, and reduces the instance of electrical induction.

Shielded wire has one or more inner wires, all separately insulted from each other. All of the inner wires are then covered by a wire mesh to provide an electrical shield.

The shield is typically used as the power ground to or from the avionic device, and the positive and other signal lines are carried by the inner wires.





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### Grounding

Much attention is normally paid to the positive side of the electrical system, with fusing, circuit breakers and distribution. The same attention is also required for the negative side of the system.

The ground system can be a great source for noise into the electrical system which can adversely affect the performance of avionics, and even cause damage.

The first thing to consider in the earth system is a single primary earth point. This is normally a termination point located on the firewall adjacent to the aircraft's battery. All ground lines should trace back to this point, directly wherever possible.

Behind the panel, all electrical applications are typically individually grounded to an earth bus beside the power bus. The bus itself should be wired directly back to the primary earth point.

### **Ground Loops**

Ground wires (and power wires) should be run as short as possible, to reduce the instance of electro-magnetic induction (EMI) from "inducing" noise into the electrical system. Avoid wherever possible creating coils in the wiring of the electrical harnessing. Coils act like antennas to EMI, and will make induction easier.

Radio wiring can be very vulnerable to ground loops, and they are easy to create without realising. A good example of a ground loop would be the headphone and mic lines to the pilot and copilot headset jacks. Look at the case where the jacks are located on each side of the panel. Each set of wires is run with a ground wire from the radio. The body of the jacks form the ground for the plug, and they are set into an aluminium panel.



The panel now joins the pilot and copilot jacks together, and forms a very large "loop" on the ground circuit. The loop acts like a big antenna to any EMI, and pipes it straight back to the radio. The larger the loop the better the EMI pick up gets.

A good clue to listen for... does the noise level and tone rise and fall with your engine revs ? If it does, there is a good chance that your electrical system is picking up EMI noise.



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## Filtering

Most aircraft electrical systems are not "smooth". The DC voltage supplied to the instrument panel often has a "ripple" on it, and it can be punctuated by the occasional spike.

The ripple can be discerned as a whine or low frequency tone in the headphones.

Voltage spikes can be discerned in the headphones as popping or sharp crackling sounds.

The best solution is a line filter to supply power to sensitive avionic equipment such as radio, GPS and transponder.



Strobe systems can create a special brand of noise due to the pulse nature of their operation. The high voltage sudden discharge creates emissions at radio frequencies. These emissions are so loud that the radio can "hear" them via the antenna.

The best way to combat this type of noise is to "suppress" the sudden discharge, by installing a high voltage capacitor across the trigger and ground lines coming from the power supply to the strobe light.

Note that the capacitor for this application must be a high voltage type (typically 0.01 uF / 3 KV).









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#### **Cable Ties**

The world these days seems to be held together by plastic cable ties. They are a very effective way of binding wiring together into harness, and to hold harnesses to the airframe.

Caution: Plastic cable ties can exert considerable pressure on the wiring. For some wiring such as coaxial cables, this pressure will distort the cable. This distortion will affect the cable's performance by increase the loss.

Use wider cable ties on wiring like coax cable, and tension sufficiently to hold in place, and not to strangle it.

Always cut away the surplus plastic tail !

### References

From the FAA web site [http://www.airweb.faa.gov/Regulatory\_and\_Guidance\_Library/rgAdvisoryCircular.nsf] AC.43-13-1B Chapter 11 Electrical Systems AC.43-13-1B Chapter 12 Avionics Systems

