

Making Connections- Terminating the Wiring

Shortcuts (no pun intended) can lead to wire failure. These can result from, among other things, the press of time or contortions from working in confined workspaces.

For example, when removing insulation from any wire for connection or termination, nicking the conductor is all too possible, and it has serious consequences.

There are enough problems with connections (that's where nearly all open circuits occur). Why cause a problem because the connection to the connection is poorly made?

Stripping The Insulation

In its worst case, a wire-stripper may actually remove a strand or two along with the insulation, leaving a shortage of conductors at the termination.

What happens is that, for example, only five of seven strands have to carry all the current. This creates a bottleneck, overburdening the surviving conductors and making them prone to failure with possibly intermittent strands - all of which can produce extra heat, circuit noise, and/or changes in resistance.

With vibration or even a small amount of stress, a "mere" nick can develop into a crack which may break and fail, almost always long after the connection has been made. While stranded wires will "bottleneck," as described above, a solid conductor may open completely! NOTE: There is no such thing as a "mere" nick.

You cannot "fix" a nicked or broken conductor; cut it off and start fresh. And when you do, be sure to use tools which will sever only the insulation, staying clear of the conductor below.

How do you assure this? After all, insulation materials are generally a lot softer than copper, and sometimes you just can't tell by feel that you have "touched bottom."

Stripping Tools

Here's a review of some of the tools found in common use:

1. Thermal strippers are the kindest to the wire and will soften most insulation materials. Available in hand-operated or bench types.

2. Motorized hand and bench strippers have a spinning collet, which receives the wire. Adjustable blades can be set to a uniform insulation depth and will slice and then remove the "slug" of insulation without damage to the conductor. Some of these are very precision tools. And some are very expensive, but worth it, for production situations.

3. Pliers-like mechanical strippers, with one or a range of slots for different AWG diameters, are inexpensive, handy, and perform well - provided the correct slot is chosen, the wire is well centered in the slot, and the cycle is smoothly performed. Counterbored die-type blades help greatly in centering the wire.

4. Inexpensive stripping pliers may also have one or more sharpened notches, often V-shaped - a poorer choice, requiring considerable care - and some means of limiting their closure. Experience is vital - and yours may already have steered you away from this tool.

5. Diagonal cutters are always handy but a poor choice, relying on just the opposing edges (usually dull and better at holding than cutting insulation) and considerable skill. Diagonals grab and stretch the insulation to the breaking point in order to remove it - kind of an "all thumbs" approach. This process also leaves the length of the strip rather unpredictable due to the stretching. This tool is truly designed for simply cutting wire, but even so, it is inferior (for that purpose) to cable cutters which scissor-cut a nice squared-off end instead of mashing the wire.

6. Razor blades. Nice cut, but control can be a problem. Actually, with skill and care a razor blade can prepare the insulation for removal with diagonal cutters, or even by hand. A razor blade is best used to "circumcise" or score the insulation part-way to define its breaking point. This can result in a rather precision length of strip and, in fact, may be necessary in the absence of more sophisticated tooling. It's not uncommon to use a razor blade to help in the stripping of coaxial cables.

7. Pocket knives are fine for whittling.

So, given a variety of tools, we recommend not leaving this delicate task to the inexperienced.

Further, as with any "tools of the trade," quality is never a poor investment, and maintenance is a necessity. A dull anything is actually a comment on the technician's concern for quality performance.

About "Gas-Tight"

Gas-tight means sealed against the possible penetration of air molecules, as well as any "tag-along" airborne contaminants. Metal-to-metal gas-tight connections are those where oxides or other surface contaminants are absent or removed, if necessary, by mechanical or chemical means.

Hermetic sealing is molecular, impenetrable, and gas-tight, usually employing insulators, such as glass or ceramic, which are heated in order to flow around and seal a metallic conductor. Examples include ceramic-package semiconductors, light bulbs, mercury-wetted or dry-reed relays, and the feed-thru connectors incorporated in PIC Quad group connector arrays. There are no plastics which can effect a true hermetic seal.

This is not so say that excellent protection is impossible without glass-to-metal sealing. It is the constant goal of designers to defy the pressures of the environment. Many excellent sealants and techniques are available to "prevent" [i.e., delay] leakage of corrosive gases; however, in the strict sense, they are not hermetic.

Before the impression is given that there is no practical means of defeating corrosion, it should be understood that the connection itself is readily made to be gas-tight. That is, creating an inter-metallic bond is the first step. The second step is surrounding the exposed metal with enough protection to keep the environment from causing enough corrosion to damage the current path.

Professionalism and aircraft system reliability demand meticulous attention to detail. Choosing and using the best available tool for the job, double-checking everything, and performing careful inspection before completing the termination will help assure the long-term quality of installation.

Gas-Tight Connections

The enemies of electrical continuity are purely physical. Chemical corrosion is the most insidious, because it doesn't appear until some time after the connections are made, tests are performed, and the installation is pronounced successful.

This is a serious problem, but there are solutions.

In corrosive atmospheres, considerable effort is required just to protect the connection against exposure. This involves seals or enclosures or "goops," but underneath it all there must be a gas-tight bond between the wire and its termination. Only a true hermetic seal can provide absolute protection of an exposed connection.

Making Sound Connections

It is not difficult to make a gas-tight connection. Even amateurs do it inadvertently - yet even professionals can fail unless certain precautions are taken.

There are many ways to terminate a wire: soldering; crimping; under the head of a terminal strip screw; welding ... all can be successful in forming a good, gas-tight connection. While each has its place, they all require low resistance consistent with circuit demands. This means the conductors must be clean at the point of contact - clean enough to put pure metal in intimate, permanent contact with pure metal.

To begin with, every conductor deserves a measure of basic cleanliness. Oils, wax, water, rust, corrosion, scale, dirt - in short, everything that can be reasonably removed should be - by wiping with a solvent or, in some cases, scrubbing or abrading the surface. After drying, the connection should be made as soon as possible, before surface corrosion can take hold.

Some conductors are chemically more active than others, that is, they will form poorly-conducting surface oxides which act as a barrier, not always obvious because they may be, in effect, transparent. In some cases, however, these oxides are readily broken in the process of connections made by pressure, or they will flow into a hot medium such as solder, or evaporate when welding.

Fluxes

It is common to use oxide-destroying chemicals - fluxes - before soldering or welding. Because welding is rare in avionics installation, we will focus on soldering as the most popular heat-involved connection process. But keep in mind that safety restrictions on fueled aircraft forbid soldering without special precautions.

Acid fluxes. Among the great fluxes for metal cleaning before soldering is the dreaded acid flux (several types), which not only dissolves oxides but etches the metal. However, acid fluxes are suited only for mechanical (such as jewelry, sealed containers, copper plumbing, etc.) joinery, never electrical soldering. Eliminating every trace of flux residue is impractical, if not impossible, and even a few stray acid flux molecules can cause corrosion.

Rosin fluxes become chemically active with heat and dissolve the oxides on tin, silver, and clean copper reasonably well. They are non-conductive at room temperature, but it is important to clean residual flux from the connection because moisture can combine with it to form a corrosive substance which could affect the connection over time.

There are many types of rosin fluxes available, and the solder manufacturers are helpful in directing you to the best choice for your particular applications. Suffice to say, however, that high-quality flux-cored solders incorporate a flux which will perform well in the great majority of field- or bench-soldering operations.

Cleanup is another problem - especially where a solvent can wick into the crevices of the wire, even up under the insulation, carrying flux residue with it. Electronic chemical manufacturers are helpful in selecting appropriate solutions and can offer advice on maximizing their effectiveness.

Flux-less Soldering

It should be added that no flux may be needed if the metals to be soldered are clean, perhaps freshly stripped, and tinned to begin with. Obviously, this eliminates flux-removal concerns but such a process calls for careful evaluation and preparation, not to mention inspection after soldering. A classic no-flux soldering process is re-flow soldering, where sufficient clean solder is already applied to the surfaces to be joined, which are then placed together. Heating causes the solder to flow and complete the joint. This process is mandated in some military and aerospace applications, and is common in circuit card manufacturing.

Crimping

Crimping comprises the majority of wire terminations in aircraft where quick, easy, and reliable contact is called for. Crimping may be the method of choice if other methods compromise safety in fueled aircraft.

It is generally understood, however, that a soldered connection is superior where signal frequencies above 1,000 MHz are involved. This may be reason enough to consider special accommodations, even to the point of removing cables to make the connection or making terminations before installing cables. One good reason for using pre-made RF cable assemblies.

The barrel of a crimp-type terminal fits snugly over the wire and is then deformed, or crushed, using a tool chosen or adjusted to "dent" or deform the barrel to the proper depth and length. Depth of this dent is important to assure that the wire surface(s) and the inside surface of the barrel are in maximum, intimate (gas-tight) contact. The length and location of the crimp must be carefully placed so that only the area surrounding the wire is deformed, not other parts of a pin or terminal. Both depth and length contribute to mechanical strength.

One of the benefits of the crimping process is the breaking-up of surface oxides by the sheer force of deformation.

To make a gas-tight crimped connection, it is important to begin with clean wire and properly-sized terminal or pin. Obviously, a terminal with too large an internal diameter will not form correctly around the wire, leaving excessive space to harbor contaminants, and could even fall off (insufficient deforming) or crack (excessive deforming).

About Fluxes

MIL-F-14256 is the standard for definition of fluxes used in electronic soldering. Considerations as to corrosive and/or conductive residues are most pertinent, and a variety of chemical compositions address the relative solderability of various metals.

Most prevalent among flux-core solders is activated rosin (Type RA) - a formulation which MIL-F-14256 states may cause corrosion under some circumstances. MIL-F-14256 recommends complete removal of RA flux residue, and states a preference for less activated formulas Types R (rosin) or RMA (mildly activated rosin).

Solder manufacturers, however, claim core formulations, meeting military solder specification QQ-S-571 Type RA, are non-corrosive and non-conducting. There is long history of satisfactory performance which lends itself to confidence in this type of flux.

Is there a message here that all is well with the activated rosin fluxes?

The recommendation is to use solder and flux according to system manufacturers' recommendations, or appropriate military designs if called for.

Cleaning residues is always a good idea - even for Type R fluxes whose residue, while considered no problem as to corrosiveness or conductivity, can affect subsequent bonding with conformal coatings, if used.

And then, while some fluxes are water-soluble, Types R, RMA and RA require alcohols or chlorinated solvents - the ozone-depleting chemicals which are said to affect the atmosphere. But that's a whole 'nother topic.

Too small a terminal invites strand-cutting or some other form of butchery.

Every terminal is designed for a specific-size wire (or range of sizes) and has a recommended tool, die or tool setting for correct application. See Table 1. Truly consistent crimps are performed using only cycling-type tools - those that will not release the terminal until the crimping operation is complete.

| TERMINAL SIZE | COLOR BAND | WIRE AWG | CRIMP TOOL | POSITIONER |
|---------------|------------|----------|-------------|-------------|
| 22 | Green | 22-26 | M22520/2-01 | M22520/2-23 |
| 20 | Red | 20-24 | M22520/2-01 | M22520/2-03 |
| 16 | Blue | 16-20 | M22520/1-01 | M22520/1-02 |
| 12 | Yellow | 12-14 | M22520/1-01 | M22520/1-11 |

Table 1 - Common ARINC pin/crimp specifications. Terminals are per MIL-C-39029 and are all gold plated.

Even the lowly screw terminal (on a household light switch, for example) is capable of an excellent gas-tight connection. Assuming things are clean, the pressure and scuffing of the screw-head on bare wire penetrate surface oxides of both and make a good, low-resistance connection. This, of course, also applies to barrier-strip connections found in many electronic and power systems.

Low-Loss RF Terminations

Making a good coaxial cable termination may be "second nature" to those who do it every day, but some avionic technicians don't have this luxury. So here are some tips you may find useful.

Almost all PIC coaxial connectors have the same "cut spec." Basically, this means that regardless of the cable size or the connector type, there is uniformity as to where cuts are to be made. Keeps things simple.

Not so simple is dealing with tape-wrap low-loss dielectric (the insulation between the conductor and the shields). This stuff is soft, delicate, sometimes "stringy" and hard to remove. But this is the magic ingredient that yields superior electrical performance.

Tape-wrap Teflon® has a way of conforming to the conductor - even to the point of getting buried in the tiny spaces ("interstices") between adjacent strands of a stranded conductor. It may be hard to completely sever when you make the cut, and surely you don't want to bear

down on the blade just to get it all, only to create nicks in the conductor.

So you'll pull off the slug - most of it - and then very carefully pick at the stringy leftovers. This may not be fun & games, but an important part of making the conductor ready for the pin.

The advantages of PIC's weatherproofing on every connector will be realized only if potential leaks are eliminated. This is accomplished by trimming shield braid with care, one connector at a time.

If all this seems laborious, it is not. And we have thorough instructions provided with every connector. We also have a video - a "how to" run-through that shows every detail. Contact us to order a copy of this video.

So the process, while vital to signal or power continuity, is not at all formidable as long as the proper methods and tools are used. Skill and experience head the list and can assure long-term excellent connections.