Grounding Problems - Sources & Solutions

Low-level circuits are often interconnected using shielded cables, mainly for protection against externally induced noise. Aside from the effectiveness of the shield designs themselves, even more important is the integrity of the connection to ground. A poor ground may be worse than none at all.

The Signal Return Path

Used as a signal return path, typical in coaxial cables, the shield serves a secondary purpose of screening the center conductor from external fields. This dual role can exist in non-coaxial cables as well.

The resistance of a braided shield is typically much lower than that of other conductors. This may be desirable in the return circuit, but it is especially important in presenting a low impedance against external induction. For this reason, terminations must be carefully made or the shield will be useless as a noise barrier. In fact, since the shield is a straight "wire" and its area much larger than the conductor(s) inside, a massive imbalance of induced current can occur, causing noise. An unshielded twisted pair would likely be more immune to noise.

Simple Shielding

As a pure barrier to EMI, a grounded shield acts as a conductive channel for the conductor(s) within. "Anchored" at ground potential, which prevents it from floating wherever the magnetic or electrical environment may lead it, the shield serves not so much as a means of walling off noise as to simply divide an offending electric field and send part of it into the ground.

It is important to know that no shield can protect against magnetic fields as effectively as mere physical space between the noise source and the affected conductors. As little as 0.5 inches can reduce magnetic coupling by more than 30 dB, improving to about 70 dB with a 4-inch separation. This is probably the best remedy for noise originating in high-current wiring.

Ground Loops

Ground loops cause a lot more noise than warranted, considering how easy it is to eliminate them with thoughtful installation. Ground loop noise is easy to picture: every conductor, including the airframe itself, has some resistance, and any current passing through it produces a voltage drop between its source and its load. See Figure 1. The ground-loop problem develops where more than one circuit share the same return conductor, often a shield intended to be the ground, so the voltage drop from one current path simply shows up in another, adding "someone else's noise" to an otherwise-clean signal.

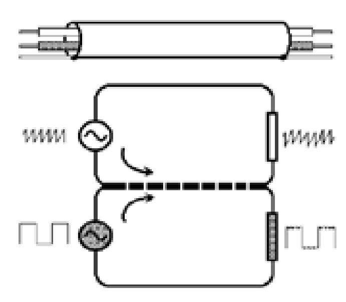

Fig. 1. Ground Loops. The influence of one signal on another as a result of using a common conductor (shown as dashed line). Similar signal corruption can result from any current induced in any circuit - even stray fields, which can be especially troublesome and audible in 400 Hz aircraft power systems.

Further, where several systems are "daisy-chained" to ground, any one of them can act as a weak link and reflect its current fluctuations as noise through them all. Common grounds are best run in a star configuration.

Frame Ground

The return path should never be a frame ground. While it may be metal and able to conduct, it not intended to be an active conductor. The ideal return for any circuit should be exclusive to that circuit, though it is not uncommon to share return paths where the current of every signal is very low. Nevertheless, good practice suggests no more than five signal conductors per ground. Using a frame for a signal return or current-carrying "lo" is poor economy and an open invitation to problems. Best to reserve the frame for its structural role; however, connecting it to battery ground at one point will achieve the effect of a universal electrostatic shield for the entire aircraft.

An improved all-around approach to using a ground is to use it only as a ground, confining signals and power lines to dedicated conductors. A balanced, shielded twisted-pair audio line would be an example.

Will the Real Ground Please Identify Itself?

Is there more than one "real" ground? Yes.

1 - For a signal path the "real" ground is the system ground, the true destination for the return signal. No other reference point is as good. Good practice for connecting a protection-only shield calls for terminating it at system ground. This keeps it from floating with "alien" signal sources and becoming a source of noise to the very circuit it is intended to protect. It might be likened to an extension of the system housing itself.

2 - What ground do you use between systems? Fact is, they may necessarily share the ground, as in the case of a signal between them via coaxial cable. If this is so, meticulous ground termination procedures are required at each end. Otherwise, a poor connection may cause serious noise almost anywhere, and continuity of the return path may be important. Ideally, signal returns should be isolated from ground and any shields terminated at one end only. See Figure 2. In some cases, the insulated oute shield of triax and quadrax offer the shielding and the isolation desired. This permits the establishment of inner shielding as signal ground and return path, if necessary.

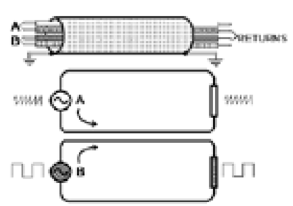

Fig. 2. Separate return paths prevent the direct influence of one signal on another. This does not rule out coupling between conductors but eliminates the "free ride" of extraneous signals by way of a ground loop.

3 - The "universal" ground, the airframe, is the shell housing all other systems. But it is only the shell and is best in its strictly passive role to all other systems, such as the avionics box which deserves its own recognition.This is true also of every other system on board. Each one, from engine starters to cabin entertainment systems to TCAS, will perform more effectively and with less interference using its own ground path.

The value of the "universal" shield is questionable in aircraft with composite-material construction, which leads to other concerns about the effects of HIRF - High Intensity Radiated Fields.

Twisted Pairs

Not the name of a rock group.

Shielding is at its best in blocking electrostatic noise fields, and is helpful in shunting some electromagnetic interference, but not near as effective in eliminating EMI as twisting pairs of signal conductors. This has been a popular noise-killer from the early days of telephones.

Every conductor residing in a changing magnetic field acts like the secondary of a transformer - producing some current replicating the waveform of the "primary," or source of the field. (Changes in the field may be due to AC or any varying current in the field source conductor(s) or even physical motion of a DC conductor, such as vibration.) In fact, transformers are designed to take advantage of this fact.

Allowing that every circuit is a circuit (a two-way path for the movement of electrons, or the signal), current will flow in both wires: the pair. External fields happily induce some current in these conductors, caring not at all whether this will pollute the signal in the circuit.

Untwisted pairs invariably position one conductor closer to the field source, and while they may receive the near the same induction (thus having a "balanced" noise in both), it is never actually quite the same. As a result, there will always be at least some undesirable differential current induced.

By twisting the signal pair, the conductors alternate in nearness to the noise field over each twist cycle, effectively canceling the effect of the polluting field. In effect, while the noise is present in both wires, the twist helps assure it will be equal in each wire, and the result is near-perfect balancing.

The best approach to minimizing unwanted signal "exchanges" is to simply add space between cables - but often this is difficult or impractical. In such cases, triax, twisting, and/or sensible grounding can help a lot.

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 chorinated 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.

Technical Article #7

Grounding

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.

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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.