8th Intercollegiate Rocket Engineering Competition
Safety-critical Wiring Rules
Rev 1.0, October 7 2012

Introduction

Experience with ESRA competitions in previous years has shown that parachute deployment failures are a common problem. This is a serious safety concern as it can result in rockets striking the ground at high speed. Post-crash analysis is difficult, but in a number of cases it has been shown that the drogue deployment circuits were damaged by launch acceleration. The main parachute deployment circuits may also be damaged by the drogue deployment shock. In the 2012 competition not one single rocket successfully deployed both drogue and main parachutes correctly!

With the aim of improving recovery and safety for the 2013 competition, this document sets out specific rules for all safety critical wiring. This is defined as wiring associated with drogue (or other drag device) deployment, main parachute deployment, and any air-start rocket motors. It is understood that there are many perfectly reliable wiring techniques that are not permitted by these rules.

The safety critical wiring in all rockets will be inspected by the judges before launch, and all serious non-conformances must be fixed before permission to launch will be given. The wiring techniques mandated here are optimized for inspectability and ease of field repair.

This document places no restrictions on non-critical wiring. Wiring associated with the payload system, and with the engines of complex rockets, may be built however you wish. The only requirement is that the critical wire harness be routed separately from other harnesses.

Wiring Rules

1. All wire shall be stranded, insulated, 22 AWG. Strands shall be copper, plated with either silver or tin.
   - 1.1. When an off-the-shelf component includes flying leads, those leads may be used unmodified. For example, an E-match may contain solid wire. A battery connector may integrate 26 AWG wire. Etc.
   - 1.2. Stranded wire of sizes other than 22 AWG may be used only when required by an off-the-shelf component. For example, if the terminal block on an altimeter is sized to accept 24 AWG wires then that is the size of wire that should be used for that portion of the circuit.
   - 1.3. Wire strands shall never be removed in order to allow a wire to fit into a smaller hole or terminal. Use smaller wire for this purpose.

2. Wire shall be stripped only with a wire stripping tool of the correct gauge. Any severed strands shall be cause for rejection.
   - 2.1. The best wire stripping is achieved with thermal strippers and Teflon/Tefzel wire.
   - 2.2. When testing a new wire stripper, strip a short length and then strip more insulation from the same wire. If you can now see scratches or nicks in the wire strands from the first strip, something is wrong with either tool or technique.
   - 2.3. Pocket knives and teeth are right out!

3. Each end of a wire shall be terminated in one of the following approved methods:

3.1. Crimped into a crimp terminal (preferred)
3.2. Screwed into a binding screw terminal (acceptable)

4. Wires shall be terminated into a terminal block, only if a piece of off-the-shelf equipment (i.e. an altimeter) has built-in terminal blocks and so there is no other choice. Two-piece terminal blocks must be positively secured together – friction fit is insufficient.

5. Wires shall be terminated by soldering, only if a piece of off-the-shelf equipment (i.e. an arming key switch) has built-in solder terminals and so there is no other choice.
   5.1. There's nothing wrong with solder, of course. The issue is that the reliability of a solder joint cannot be established by the judges by visual inspection alone. There are a number of process parameters (temperature profile, solder alloy, flux, gold removal, etc.) that must be well controlled to give reliable results and these cannot be inspected post-fact.

6. All crimp operations shall be performed with the correct tooling, using crimp terminals sized for the appropriate wire gauge. Where multiple wires are crimped into a single terminal, calculate the effective gauge (for example, two 22 AWG are effectively 19 AWG).
   6.1. Crimp tooling shall not be improvised from pliers, vices, or other incorrect tools. Crimp features of multitools (Leatherman, Gerber, etc) shall not be used.
   6.2. Crimp tooling can be expensive. You may want to borrow it from a sponsor.

7. Terminals with insulated plastic sleeves (usually colour-coded to indicate barrel size) shall not be crimped.
   7.1. If a terminal is supplied with an insulated plastic sleeve, it shall be removed prior to use. It may be necessary to adjust the crimp tooling to get a tighter squeeze.
   7.2. The crimp quality of insulated terminals is difficult to inspect. There is normally no need for insulation when terminals are mounted properly in barrier blocks. If insulation is required, add clear heat-shrink tubing.

8. When a bare wire is held down by a binding screw terminal the wire shall make a 180 degree hook, and strands must be visible exiting the screw head. Only one wire shall be permitted per screw. The wire bend shall be clockwise, so that it will tighten as the screw is torqued.

9. When ring or spade terminals are held down by binding screw terminals, a maximum of two terminals are allowed per screw.

10. A maximum of three wires shall be crimped into a single terminal barrel. Butt-splice terminals are considered to have separate barrels in each end.

11. If two or more wires must be joined, one of the following approved methods shall be used:
   11.1. Crimp a ring terminal onto each wire, and then screw them into a barrier block. Add approved barrier block jumper pieces if many wires must be joined.
   11.2. Screw bare wires under binding head screws in a barrier block. Add approved barrier block jumper pieces if many wires must be joined.
   11.3. Crimp the wires into an un-insulated butt-splice terminal, and then insulate with clear heat-shrink tubing.
   11.4. Any wire-twisting splice method is explicitly forbidden. Forget everything you know about household wiring. Houses don't see launch vibration!

12. All insulating tubing (usually heat-shrink) shall be transparent.
    12.1. This allows inspection of the underlying hardware. It's a good habit to get into.

13. No tape, glue or RTV shall be used to insulate or bundle any element of the wire harness.
    13.1. If you have followed these guidelines properly there should be no exposed metal in need of insulation.
    13.2. Tape (especially PVC electrical tape) is messy and uninspectable.

14. The following rules apply to connectors:
    14.1. They shall use crimp contacts, as soldering has been forbidden.
    14.2. They shall use a positive locking mechanism to keep the two halves mated under vibration and tension. Friction fit alone is not acceptable.
    14.3. Plastic connector latches shall not be used, but circular connectors with plastic coupling nuts are acceptable.

15. Individual wires shall be bundled together to make a harness. The safety critical harness shall be kept separate from the payload harness (if any). Bundling shall be accomplished by:
    15.1. A light twist (for mechanical reasons only, no EMC mitigation is intended)
    15.2. Clear heat-shrink tubing, or zip-ties every 5 cm.

16. The harness shall be supported by plastic P-clamps. It shall not be permitted to touch any sharp edge or screw thread.

17. All items that are connected by the harness (barrier blocks, sensors, batteries, actuators, switches, etc) shall be rigidly fixed to the rocket structure so that they cannot move. Rigid fixing implies attachment with threaded fasteners or a solid glue bond. Cable ties and/or tape are not acceptable examples of rigid fixing.

18. No wire shall be tight. All wire must have some slack, demonstrated by a curve at its termination.

19. Batteries shall be connected appropriately:
    19.1. 9V transistor batteries shall be secured in clips, and connected using proper snap terminals
    19.2. Gel-cell batteries shall be secured with clamps, and connected using “faston” crimp terminals
    19.3. Cylindrical batteries (AAA, AA, C, D, etc) shall be mounted into commercial holders. The holders shall be rigidly secured to the structure, and the batteries shall then be strapped into the holders.

<u>Circuit Board Rules</u>

It is expected that most rockets will use only commercial rocketry circuit boards (altimeters, attitude sensors, etc) in their safety critical circuits. Any commercial board for the rocket market shall be considered to meet the quality requirements, provided it is in an undamaged factory state. The wiring to and from the circuit board is subject to the wiring requirements of this document.

The judges will pay careful attention to those teams that choose to build their own safety critical circuit

boards, or repurpose commercial circuit boards that were not intended for rocket applications (i.e. smartphones). Boards will be inspected the prior to launch to the IPC-A-610E class 3 requirements. All heavy components shall be staked. All IC sockets and press-fit contacts shall be positively restrained so that they cannot demate under vibration. Provided they are done right, wire-wrap, through-hole solder, and surface-mount solder are all acceptable fabrication methods. Solderless breadboard (aka plug-in breadboard) shall not be used.

Launch permission may be denied to rockets with safety critical circuit boards that do not meet these requirements. These rules place no requirements on payload circuit boards.

Suggested Parts

Here are some suggested components that can be bought from Digikey that will help to satisfy the wiring requirements. These are guidelines only, and you are free to choose other parts and buy from other suppliers. Look up the catalog pages associated with each number to find similar parts of different sizes.

Part	Digikey Number	Notes
Wire	A5855W-100-ND	This is good Teflon insulated wire. Cold-flow is a long-term consideration, but shouldn't be a problem for a short lifetime rocket.
Ring terminals, uninsulated	A27021-ND (#6 hole)	The Solistrand series is a high quality terminal. Various crimp tools are available. You get what you pay for – the expensive ones are very nice, but the basic ones will do in a pinch.
Butt-splice terminal	A09012-ND	Another Solistrand series terminal
“Faston” terminal	298-10011-ND (check size)	These terminals are useful for connecting switches, gel cell batteries, and many automotive devices
9V battery snap-on terminal with 12” leads	BS12I-ND	These are uniformly cheap and low quality. I'm not a fan.
9V battery holder, with solder terminals	708-1409-ND	Screw this holder to your chassis, and then cable tie the battery in.
4 AA battery holder	708-1399-ND	This is a nice enclosed battery box for 4 AA cells
P-clamp	7624K-ND (check size)	This particular unit is for a 0.25” dia harness. Select the correct size.

Heat-shrink tubing	A014C-4-ND (check size)	Material is clear polyolefin with low shrink temperature. Shrink with hot-air gun or oven.
Barrier block (double row)	CBB206-ND	Available in a range of lengths. Can accept ring or spade terminals (preferred), or bare wire (acceptable).
Barrier block jumper	CBB314-ND	Connect adjacent strips, when many wires need to be connected together.
D-sub connectors (9 contact)	A31886-ND (male shell) A34104-ND (female shell) A1679-ND (male pins) A1680-ND (female pins)	The connectors and contacts are cheap, but the crimp tools are expensive.
D-sub fixing hardware	MDVS22-ND (screw) MDVS44-ND (socket)	These kits convert the D-sub friction fit into a proper positive lock.
MIL-C-38999 connectors	956-1017-ND (13 pin panel mount receptacle with pins) 956-1020-ND (13 pin plug with sockets)	These connectors approach the style and quality used on orbital launch vehicles. Extremely robust, but very expensive!

Contact

Please feel free to email me during the lead-up to the 2013 competition. I will be happy to give advise on techniques and suppliers, and to inspect block diagrams and photographs of your work so that there are no surprises at the launch site. If you feel that there is an omission or error in this document, please let me know.

Barring unforeseen circumstances I will be in Green River, IPC-A-610E manual and magnifier in hand, to inspect the rockets.

Good luck!

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About the Author

Doug Sinclair is a certified IPC trainer for J-STD-001ES. At the time of writing he has hardware on 14 orbiting satellites, with one more on the pad due to launch in 7 hours and another set to go in a few weeks. Check http://www.sinclairinterplanetary.com/spaceheritage for the latest list.