ElectroDynamics, Inc.

ELECTRONICS & More! FOR THE DISCERNING MODELER
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Considerations when installing RC equipment in larger aircraft

by Andy Low, ElectroDynamics, Inc.

RC equipment electrical configuration has not changed significantly since the 1960's. They were designed for up to .60 size airplanes. They have been "stretched" for use with ¼ scale and larger, but there is a limit, and we are approaching it.

We will discuss these limitations and available solutions under the following headings:
1. Control Load
2. Servo input load
3. RF pickup
   - RF into Receiver
   - RF into Servos
4. Redundancy and Reliability Issues

1. Control Load
   Larger airplanes have larger control surfaces, and often multiple servos on each surface.

   Larger control surfaces put a mechanical load on the servos controlling them, which require more servo Oomph to move them against the breeze...
   A "rough ballpark" formula helps us ***estimate*** the control torque required to deflect a conventional rectangular, front hinged control surface:

$$\textit{In-Oz} = \frac{L \times W^2 \times V^2 \times \theta}{430{,}000}$$

where L = surface length in inches
W = aileron chord in inches
V = max. speed in mph
θ = aileron travel in ° at V

e.g. Typical ¼ scale aileron, 26" x 3" , 20 ° and 100mph
In-Oz = 108.8 in-oz.

   In addition, on larger surfaces the "springiness" of the linkage system sometimes becomes significant. This springiness is one essential element in the 3-part "mass-spring-damper" components for a mechanical oscillation system... a.k.a. ***FLUTTER***!

Flutter in the controls of an airplane has been known to cause nasty self-destruction as the rapidly oscillating surface tears out the hinges or cause the entire wing or stab to flutter in sympathy... something that will surely raise the sympathy of your fellow modelers who help pick up the pieces after the entertainment! ***DEFINITELY NOT NICE!***

Multiple servos need to have their individual mechanical travels and geometry EXACTLY matched, or there will be a "tug-o-war", with the poor battery overworked a-huffin'-n-puffin' to keep up the required Oomph! This results in large voltage spikes in the power line in the Receiver, which can get confused and respond to these spikes (a.k.a. glitches) as spurious commands!

<u>Result?</u> A "nervous, twitchy" airplane with controls jittering for no apparent reason and a battery that gets exhausted very quickly. If left uncorrected? LARGE SPLATTER PATTERN at your favorite flying field, and guys yelling "I got hit, I got hit, I ain't got it"!

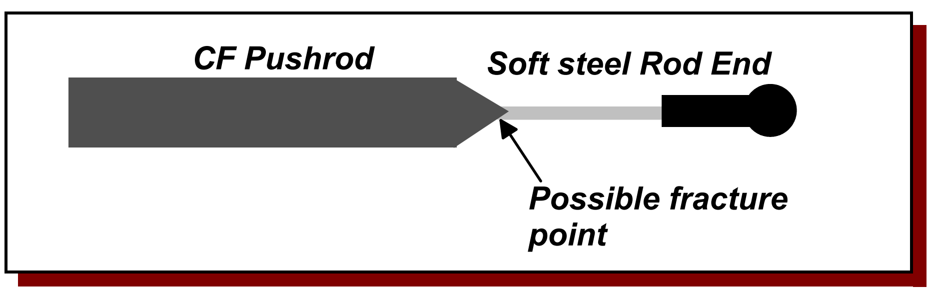
<u>What to do about it?</u>

Better, stronger servos, stiffer (no, bubba, not stiffer in motion, but more rigid and less springy) control runs, with less slop.

The new Digital Servos feature higher torque, especially Holding Torque, and stiffer (i.e. less springy) position holding. E.g. Multiplex mc/V2 servos.

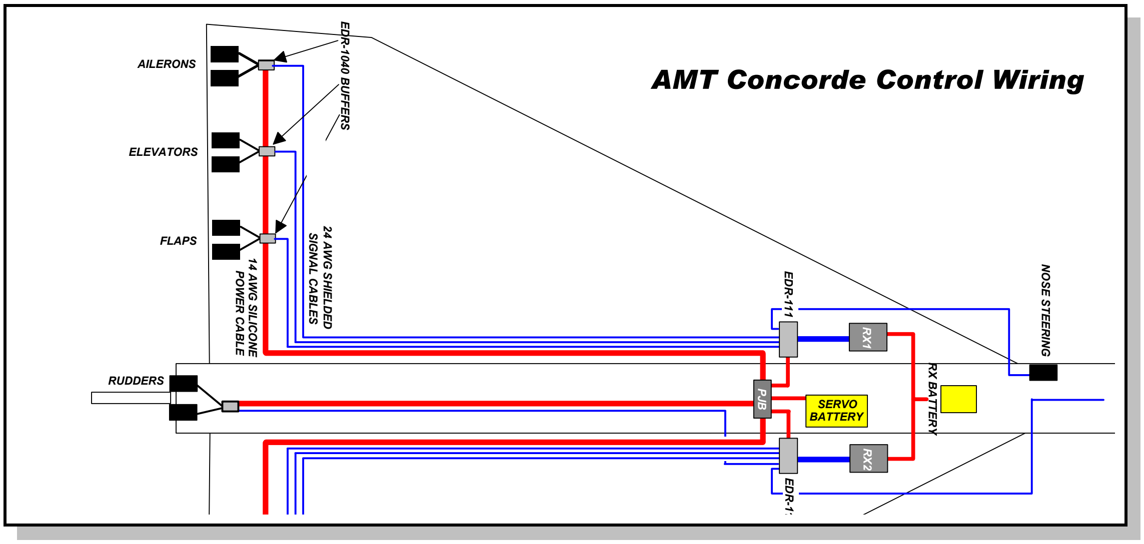
The trend towards 4-40 steel and Carbon Fiber pushrods for Giant Size airplanes also helps in resisting flutter. Be careful though when combining CF with traditional soft steel rod ends - these can fracture at the transition between the CF and the steel due to the sudden change in tensile strength at the joint.

Solution? Use titanium or hardened steel rod ends.



Larger control loads = Higher current draw = voltage losses in cables.

Solution? Use Heavy duty cables; like our HD 22 AWG cables and extensions. In very large models, use separate power and signal cables. This generally requires specialized, custom work. We have done this type of work for the AMT Concorde and a number of 40% and 50% airplanes. Contact us for help on your special project.



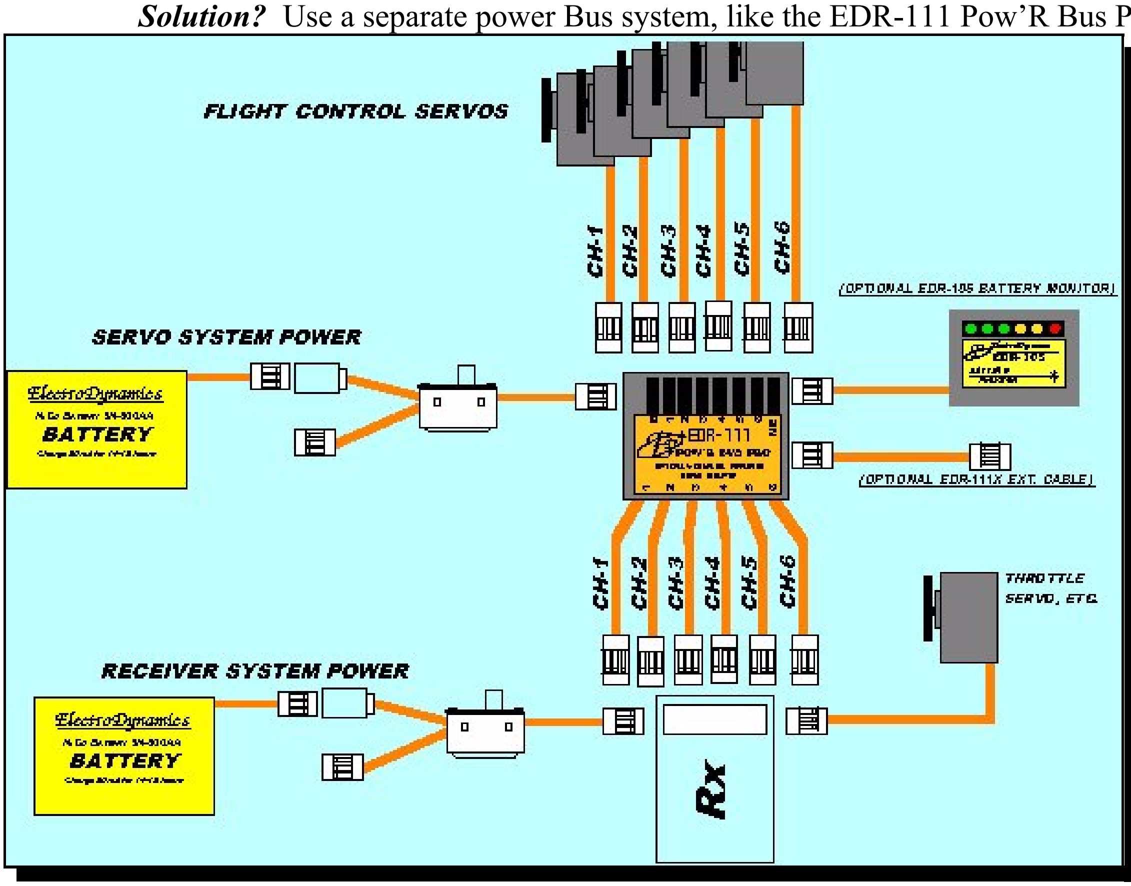
Larger control loads = Faster drain on batteries

Solution? Use larger capacity battery packs

But, when using these larger packs, it is necessary to use the properly-sized charger - *a NiCd needs to be charged at least the C/10 rate* - “charging with my standard charger but for a longer time” just won’t cut it!

Larger control loads = glitching on the Receiver power line, as described above.

Solution? Use a separate power Bus system, like the EDR-111 Pow’R Bus Pro.



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Larger control loads = heating effect on Receiver power bus.

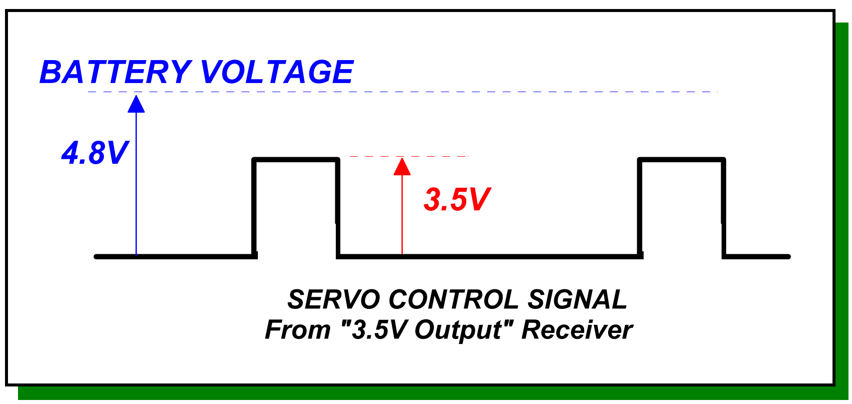
The extra power required by the larger servos driving the larger control surfaces must be supplied by the battery. But in a traditional RC system, this power is routed thru the power bus line on the circuit board in the Receiver. Excessive current can cause heating of this line, with possible delamination of the circuit board.

Solution? Use a separate Power Bus System , like the EDR-111 Pow'R Bus Pro.

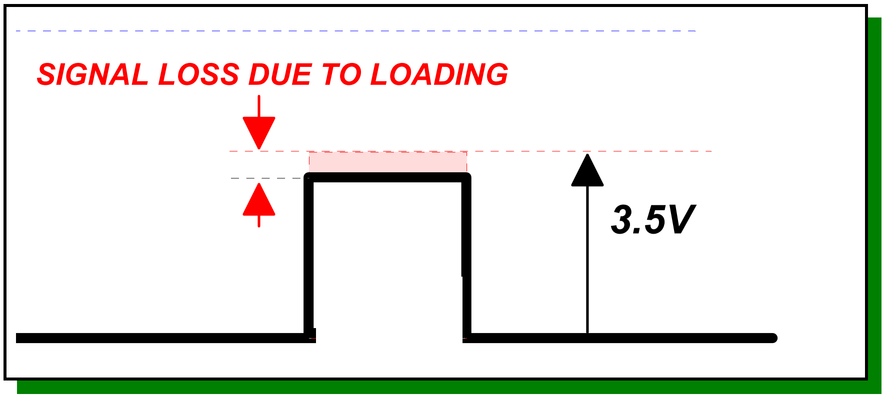
2. Servo input load
   Each servo absorbs a little of the servo control signal coming out of the Receiver.. The effect of multiple servos (as in two or more servos on y-harnesses) add up. This is a problem especially with "3.5V output" Receivers.

What in the world are "3.5V output" Receivers??

Most RC systems utilize a 4.8V or 6V NiCd battery. In order to reduce the effect of varying battery voltages on the operation of the Receiver, most RC Receivers operate their internal electronics on a regulated, lower internal voltage, most often 3.5V. Receivers have an output stage, called a decoder. Some receivers raise the output control voltage of the decoder back to the full battery voltage, some leave it at the internal regulated 3.5V

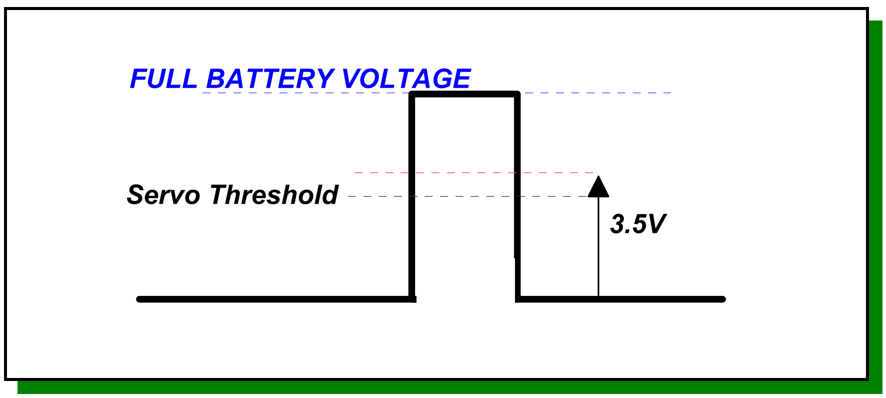


Most RC servos will operate fine with a 3.5V control signal, but some will become intermittent if the signal falls much below this.



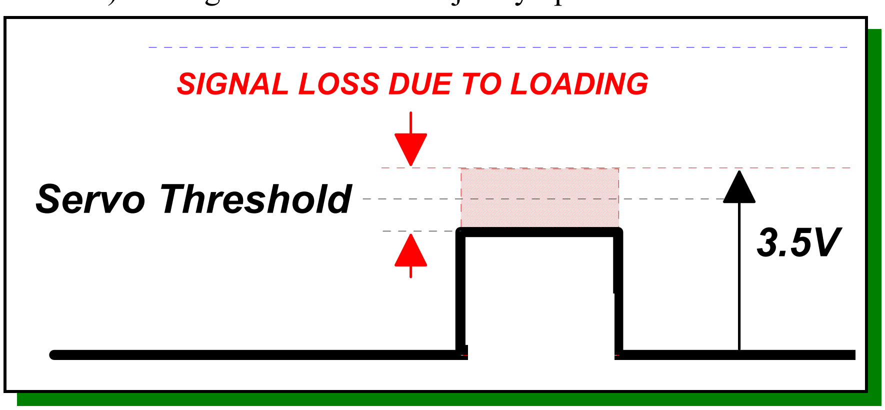
Some servos utilize circuits that set an input threshold level at a certain fraction of the power line voltage, so that any signal below the threshold will be rejected as random noise.

This threshold is normally about 50% of the power supply voltage

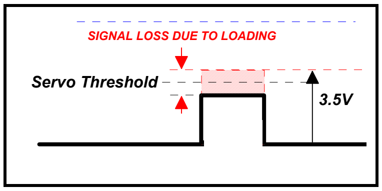


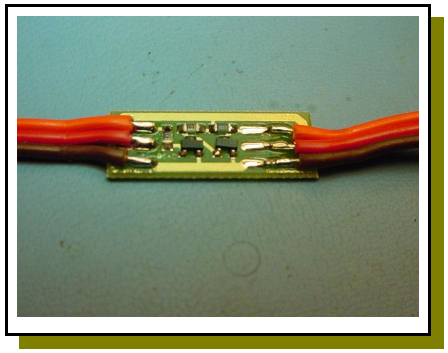
...

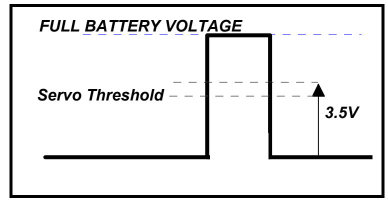
which works fine for 4.8V batteries (threshold is 2.4V) or partially discharged 6V batteries (threshold is 3V), but...
A fully charged 6V battery tops out at 7.2V (threshold 3.6V) and...
Multiple servos on a 6V system (the multiple servos loads the receiver output to below the 50%, 3V threshold) leading to intermittent or jittery operation.



Solution? Inline Buffer Amplifiers (our EDR-1040) or buffered extension leads amplify the receiver signal from below 2V to the full power supply voltage.







3. RF Pickup and Bleedthru
   Long conductors placed in an electromagnetic field develop an electromagnetic "standing wave" in them, much like a tuning fork develops a mechanical "standing wave" or resonant vibrations when placed in an acoustic (musical sound) field. Radio signals are electromagnetic fields, with a characteristic propagation wavelength depending on frequency of the Transmitting carrier.

   The following formula is used to calculate the radio signal's wavelength:

$$f = \frac{c}{\lambda}$$

where f = radio frequency
c = the speed of light
λ = the radio signal wavelength

For f = 72MHz; $c = 3 \times 10^8$m/s
λ = 4.17m
$\lambda/4$ = 1.04m = 41 inches

   The optimum RF pickup at the end of a long conductor occurs when its length is $\lambda/4$ or a quarter wavelength. For 72MHz this critical length is approx. 41 inches, which, by the way, for obvious reasons, also happens to the length of the ideal receiving antenna!

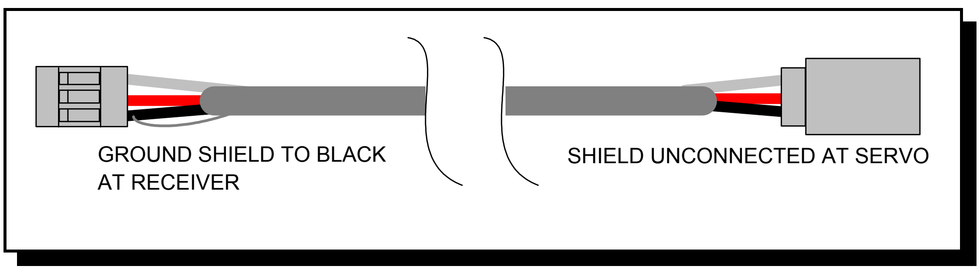
   On smaller airplanes, "things" are generally shorter than the ¼ wavelength, so there are no obvious problems. But, with larger airplanes, distances between servos and receiver can approach and exceed the ¼ wavelength.

   RF pickup occurs in two areas on a larger airplane.

- RF reflections into Receiver
  ¼ wave-long extensions act as secondary antennas, reflecting stray RF into the Receiver, giving rise to "ghosts" not unlike what we see on some TV screens. The trouble is, your Receiver interprets these ghosts and commands, causing the servos to jitter and glitch!
- RF Bleedthru directly into Servos
  ¼ wave-long extensions act as RF pickup antennas, sending Transmitter signals directly into servos, which don't understand the format (with no Receiver in-line to decode them), driving the servos bananas!

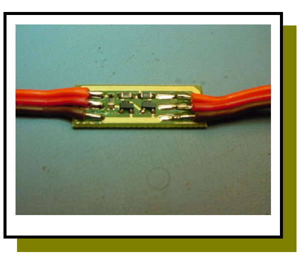
Solution? Shielded cable, where a grounded copper or aluminum foil sheath is wrapped around the extensions; and Inline buffer amplifiers, which electrically isolate sections of extension so that each section is much shorter than the ¼ wavelength.

Shielded cables work quite well if done properly. But for most aircraft they need to be custom-made, and cannot be easily made into Y-harnesses. And, usually the wire gauge used is too small to help with the other problem we discussed earlier with regard to long lines - the voltage loss due to thin wires.

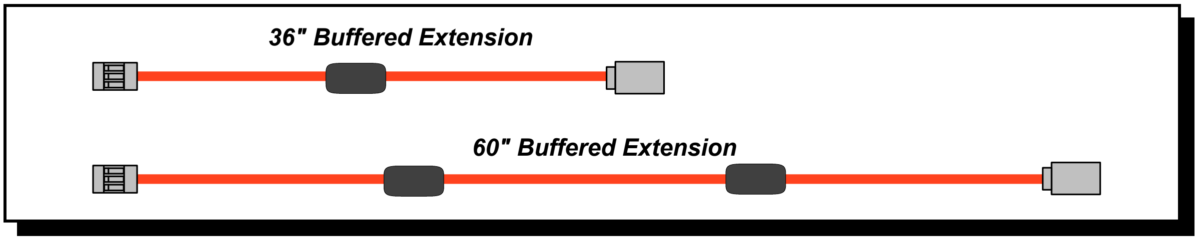


And, an improperly terminated/grounded shielded cable can make matters worse, actually acting as an antenna amplifier, feeding RF into the extension!

Buffered Extensions on the other hand can be made with heavy duty cables (e.g. ElectroDynamics' standard 24", 36" and 48" Buffered Extensions), can be made in various lengths, and can be extended end-to-end when needed, and can be made into Y-harnesses.



The rule of thumb with Buffer Amplifiers is: "avoid cable runs with more than 24" of unbuffered cable". I.e., for a 36" run, use one buffer in the middle at 18"; for a 60" run, use two buffers, at the 20" point and the 40" point.



<u>Note carefully that not all buffers or "chokes" are made the same!</u> Some use IC amplifier chips, and can be subject to the "3.5V Output Receiver" syndrome discussed earlier, and indeed cause MORE trouble than they cure!

ElectroDynamics' buffers are specially designed to address the voltage incompatibilities of various manufacturers' Receivers and servos, you can mix-n-match freely with full abandon!

4. Redundancy and Reliability
Larger aircraft are more expensive and have more "destructive potential". Measures to improve reliability and robustness from interference should be sought. There are two approaches to this:
- Redundant batteries/switches
- Redundant Receivers

Redundant battery/switch systems are more than just simply plugging two batteries and switches into a Y-harness or two servo ports on the receiver.

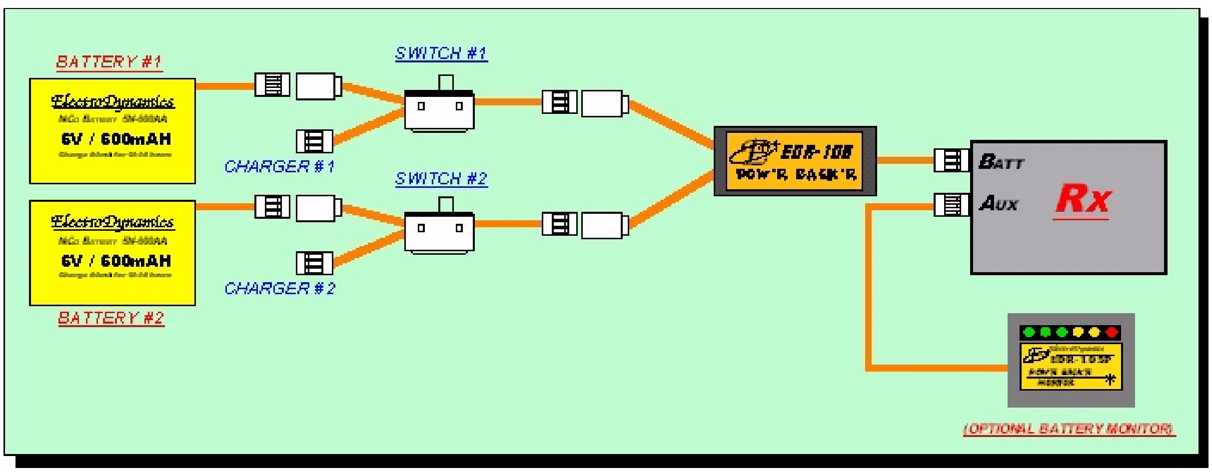
Simply plugging in two batteries into one receiver may look attractive at first, but it really only protects against the rare case when one of the batteries or switches fails open-circuit. But, NiCd's predominantly fail in short-circuit, and in most cases it is one or more cells that short out in a pack.

This results in a pack with a large drop in terminal voltage. If a second pack is plugged in essentially in parallel with no protection, the "good" pack will try to share its charge with the "bad pack", i.e., attempt to charge the bad pack. Whilst this may or may not damage wiring and receiver power bus lines with over-current, at the very least the terminal voltage supplied to the receiver and the servos will be the average of the good pack and the bad one.

You may get away with this if the good pack is a strong 5-cell pack and the bad pack only lost one cell, since the average voltage will initially be approximately 5.4V, but in many cases a bad pack will have be at less than 4.8V (the nominal 5-cell pack with one cell shorted), and the good pack will have the additional burden of trying to "charge the bad pack, often with currents in excess of 2 Amps, which will rapidly lower its terminal voltage. The result is, a low terminal voltage, rapidly deteriorating battery charge and premature death of the airplane so "protected"!

Another problem with paralleling dual batteries is there is a common DC ground between the two batteries, since most RC switches only interrupt the "hot" lead. This common ground can confuse many multi-output chargers, so that one or both sides may be improperly charged when simultaneously connected to the charger.

The proper way to do a dual-redundant battery system is to use an electronic circuit like ElectroDynamics' EDR-108 Pow'R Back'R. The Pow'R Back'R totally isolates the battery packs from each other, taking power from the pack with the highest voltage at all time. In addition, it is built with true dual-redundancy, with every circuit component duplicated for each circuit path, so a total failure of one side, in open or short circuit does not affect radio operation. This isolation extends to the charging circuit as well, so any multi-output charger may be used to charge the two batteries.



Redundant Receivers is another way to improve reliability. The usual scheme is to use two receivers tuned to the same transmitter, but with airplane's control surfaces divided symmetrically between the two receivers. Of course, one must use PCM or IPD (see Multiplex's website, www.MultiplexRC.bom) receivers, which have a programmable failsafe and set the failsafe to neutralize its side in case of radio problems. For example,

Rx1: Left Aileron
Left Elevator
Rudder
Throttle

Rx2: Right Aileron
Right Elevator
Throttle Kill (Gas engine)

In theory, at least, this will allow the airplane to be controlled if one side were to fail for whatever reason, at worst, the ability to shut the engine down from either the throttle or the kill switch from one or the other side, In practice, this may be more difficult than first appears. Many high performance aircraft cannot be safely flown with one side disabled - for instance, imagine pulling elevator with one side failed - it would result in an instant snap roll!

But, many who use this scheme feel that some measure of control is better than no control at all, and some pilots have the uncanny ability and catlike reflexes to struggle with a "tiger by the tail" and get it down in one piece.

Why PCM or IPD receivers? Imagine coping with an airplane with one side doing wild things while you are trying to fight it with the "controlled side"!

AMA Giant Aircraft Rules

The Academy of Mode Aeronautics recognizes that there are special issues associated with very large aircraft, and publishes a set of rules by which such aircraft may be flown, including a mandatory professional inspection during the building process. The AMA's Giant Aircraft Rules can be found on their web site, www.modelaircraft.org..