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## Avionics Master Switches: Really Necessary?

What's a mother to do? An on-line discussion about avionics master switches. . . .

I've never said that one should as a matter of common practice, leave all their radios on while cranking an engine.

*Ok, I suppose that this was the crux of the confusion. The point made on the mailing list was master switches weren't important because modern electronics could handle the spikes, and that the reputation that they couldn't was due to urban legends.*

In truth, modern avionics **can** handle anything that the aircraft bus can throw at it. For example, in a 14V system, qualification of modern aircraft electronics to RTCA DO-160 calls for withstanding 20 volts for 1 second and 40 volts for 100 milliseconds. Further, you need to stand off a 300-volt transient delivered through a 50 ohm source impedance for 100 MICRO-seconds . . . The current state of the art in electronics makes this a trivial design task. Not once in 25 years have I put any electronic device on the aircraft market (including devices with microprocessors in them) wherein I expected the pilot to carry out any duties with respect to my product's survival in an airplane.

The part about radio killing "spikes" in airplanes is indeed legend . . . that's what we **thought** they were back in the 60's when the avionics master switch was born . . . in retrospect, I suspect **low voltage** was killing the radios. The power supply transistors were 40V germanium with very poor second breakdown resistance. A radio left on while cranking with a soggy battery would produce 6-8 volt bus voltages which causing the power supply transistors to come out of saturation and self destruct. Nowadays, every radio is tested to show immunity to everything except extended, steady state over voltage. That's why we put over voltage protection on alternator systems.

*The implication was that you should just leave your radios on. Are you advocating that one **not** turn off the electronics before shutting down or starting up the engine?*

No . . . I wouldn't burden a battery with any unnecessary loads while it's being horse-whipped by a starter. Everything should be OFF, including radios. HOWEVER, there are no special concerns to be observed for protecting a radio from perfectly NORMAL conditions on the aircraft power bus either. . . .

*With modern panels containing 2 nav-coms, a dme, loran/gps, it takes a long time to turn all of these devices off individually,*

*. . . long time??? . . . one second per radio, 4 radios, 4 seconds . . . what's your hurry? I cannot imagine that in the grand scheme of running down every item on a checklist that turning two or more radios on or off is significant.*

*. . . and puts wear and tear on each switch.*

Actually, a switch is more likely to fail from disuse than from regular use. Contacts corrode and NEED a little electrical teasing from time to time to keep 'em clean. Further, my experience with "modern" panels is that the number of radios is rapidly going down. ADF is dead, DME is going fast, dual nav/coms are still popular but most folk would rather have the #2 radio be hand held and not require ship's power. Given all the OTHER things that need twisting, pushing and pulling on the panel during preflight . . . a couple of radios more or less is trivial.

*Thus a master switch is simpler.*

. . . and a single point of failure for all radios. We don't seem to worry about strobes, turn-coordinators, D.C. gyros with built in inverters, audio amplifiers that are hot anytime the bus is up, what about the hand-held plugged into the cigar lighter? etc. What makes these devices "immune" while we still worry about the stack of avionics?

*All transistors are not made alike. The transistors you find on power supplies are huge and are designed to take heavy load. Normal spikes aren't going to hurt them.*

Here's where legend kicks in . . . "spikes" simply don't exist . . . normal or otherwise. Small perturbations in system voltage are accounted for by design. How about your car? There's as many transistors, power -AND- microprocessor as most airplanes . . . how come no "master electronics power switch" for the electronics in your car?

*Transistors in a microprocessor are about 10 microns on a side. A few nanoseconds of spike is going to burn them out of existence. Generally the smarter the device, the more likely it is to have integrated circuits in it and the more vulnerable it is to a spike. Just the static electricity you get from walking across a carpet will destroy any modern microprocessor or memory card.*

Not relevant here. If your radio is out in your hands with its covers open while you slide across the Velour seats in your airplane, there could be some exposure . . . there are many firewalls between the devices you mention and the outside world. I've been building black boxes for everything from Kitfoxes to Gulfstreams for over 30 years. I should be strung up by my thumbs and flogged with my own soldering iron if I were to let any product leave my bench that required pilot intervention or special handling by a mechanic for survival in an airplane. King, Narco and contemporaries would be equally embarrassed.

I looked through all the installation manuals I could find from Narco/King/Terra a few years ago. One Terra manual alluded to an avionics master switch. I called and asked if they'd qualified to DO-160 and the answer was an emphatic "yes". "They why the avionics master switch?" says I. "Because everyone seems to want one," says he, "but we really don't require it."

*There's a famous principle in physics that basically says that we can't really know anything for certain about our environment because the mere process of measuring it perturbs it. How do I know if the 20 year old wiring in my plane is ok?*

If you don't know, you'd better find out. Besides, how does a wire failure cause a "spike?"

*The only way to is to take it all out and analyze each wire. But the information is worthless at this point since the wires are no longer in the plane and putting them back will create a new situation (which means taking the wires out... etc). So every day we must deal with uncertainty.*

Analyze each wire? Aside from a wires need to be well insulated, what's to analyze? Perturbations in bus voltage come from operation of other appliances in the system. Is it reasonable to expect the bus voltage to hold at 14.0 +/- 0.2 volts for all operations? Of course not. It IS reasonable to expect the bus to be between 0 and 16 volts for all conditions except for overvoltage during alternator runaway (and very tiny stresses from the opening of inductive, D.C. power contactors). The 20/40/300 volt numbers I cited above were developed to put manufacturers on notice that compliance with the requirements would make their products immune from the vagaries of vehicular D.C. power systems. I'll suggest that there are NO uncertainties. This isn't rocket science. Every vehicular DC power systems designer on the planet deals with this very effectively every day. It's the "certified designs" and "certified paranoia" that linger to plague us.

This is why DO-160 criteria were developed for manufacturers back in the early 60's; it has seen major revisions (up to rev D now, I think) ever since. RTCA's committees are staffed with all the kinds of folk I worked with at Cessna, Lear, Beech, Piper, King, etc. etc. They've poured over failure mode effects analysis and past failure reports to develop REASONABLE performance specifications for equipment to survive in airplanes.

*Most people don't like uncertainty so insurance allows one to reassign the uncertainty from the insuree to the insurer. The insurer is an expert at the probability in a certain field. If I have a plane without an (avionics) master switch, I can either turn off each radio at startup/shutdown, or put in a master switch, or find someone willing to give me insurance against failure of the radios during startup/shutdown. The quote from the insurer is interesting because it lets me know what the probability is of such a failure occurring (with a little safety factor added in to give the insurer some profit).*

Fair enough. Insurance companies base their rates on actuarial data. I have a cousin-in-law who makes his living figuring out what his company needs to charge for various kinds of insurance in order to make money for the service.

Hard data are needed to balance income against potential payout. I'll suggest that there is no actuarial data on the need for avionics master switches. The biggest single variable is the pilot: if one chooses to ignore procedures, then 10 avionics master switches insure nothing. Much better we should build systems that don't require one.

*I agree with this. For that matter what good are flaps or ailerons if people don't know to use them correctly? Let's not remove things just because there exist people who don't know how to use them.*

Agreed . . . but I do **remove** any item when it no longer serves a useful purpose . . . especially if the device(s) are more of a hazard than a help. The classic avionics master switch is a single point of failure for ALL radios that receive power through the switch. It's existence in the system increases complexity and therefore increases probability of failure in that path. Failure in an avionics master switch can be mitigated by the alternate feed path philosophy illustrated elsewhere in this document.

*This is true. In fact the discussion on the mailing list started when someone asked if anyone had more than one master switch. My plane, in fact, has two. The reason I have two is that the avionics shop insisted that there be a backup for the master switch in case it failed. I hope that this is common practice.*

Actually, very few airplanes with a single avionics master switch have a "backup" . . . the practice is not at all common in certified ships. New designs I'm doing for homebuilts feature two power paths for essential goodies in spite of the fact that there's **no** avionics master switch.

*A master switch isn't exactly a complex instrument. I'd be much more worried if there was a computer controlling the electrical bus.*

It's not complex but it is an electro-mechanical device with springs, crimped case, some arcing at the contacts and some moving parts . . . the only way you can say that it will never fail is to eliminate it.

*I've never had the experience of a master switch failing in any plane I've flown (and nearly all had master switches).*

Nor have I . . . but I have replaced several switches for others who have had the pleasure. . .

*I agree with the kiss (Keep It Simple Stupid) philosophy. In fact if I'm designing something and it ends up getting complex I keep working on it until I find the simple solution*

*and this will make it easier to build and more importantly maintain over the years. I see the master switch as a workload reducing device. It's much easier to remember . . .*

Remember . . . REMEMBER? Where's your checklist?

*. . . . . to toggle that than to turn off or on each radio. But I would definitely not want the power bus to rely on just one master switch.*

Your current battery master and battery contactor supplying the main bus does EXACTLY that! A failed battery master, wiring or battery contactor can bring down the whole system . . . what's your "plan B" for dealing with it? You're focused on reliability and justification for a single entity on the panel without regard to SYSTEM reliability.

My basic philosophy has been to design for failure tolerance. ASSUME from square-one that EVERY component you install is going to fail in flight at some point in time. Decide whether or not it's needed for comfortable completion of flight. If so, plan a backup; if not don't worry about it. In neither case, do we plan to push and pull breakers or dig out the POH and see if there's an emergency procedure for the predicament.

My amateur builders have at most two switches to deal with, a DC POWER MASTER and an ALTERNATE FEED to an essential bus. They mount their circuit protection in fuse blocks up behind the panel . . . out of reach and out of mind. We concentrate on being a pilot in the air and saving mechanic's tasks until on the ground. Failure tolerant system design allows us to take advantage of clean, quiet, simple systems built from ordinary, low-cost components where no single failure is more than an nuisance. Airplanes are not unique with respect to electrical systems. Cars, trucks, even snow-mobiles are being fitted with accessories with the same potential for vulnerability as anything bolted to an airplane.

Airplanes are unique in that the people who own and work with them were trained to believe that there's something magic about aviation that's beyond the capacity of the mortal pilot or mechanic to understand. We've bought into that idea for years. Our brothers in the consumer marketplace have enjoyed a rapidly expanding world of technology, tools and personal skills. Many who choose to work on airplanes and fly for pleasure are stuck in regulatory mud and fog that completely obscures technological advances made over the past 30 years.

Avionics master switches are but one idea who's time has gone in favor of better products and more knowledge on how we can take advantage of their capabilities.

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End of thread as of 7-11-97  
Here's another short  
exchange with a cyberflyer . . .

*I guess I have once again "lost the bubble" on one of your threads. Let me recap my understanding of what has passed here and you can tell me where I reached the wrong conclusion.*

*1) There was a copy of a message to Avweb posted by someone with acknowledged expertise advocating the use of an avionics master to protect any/all installed avionics in an aircraft during engine start.*

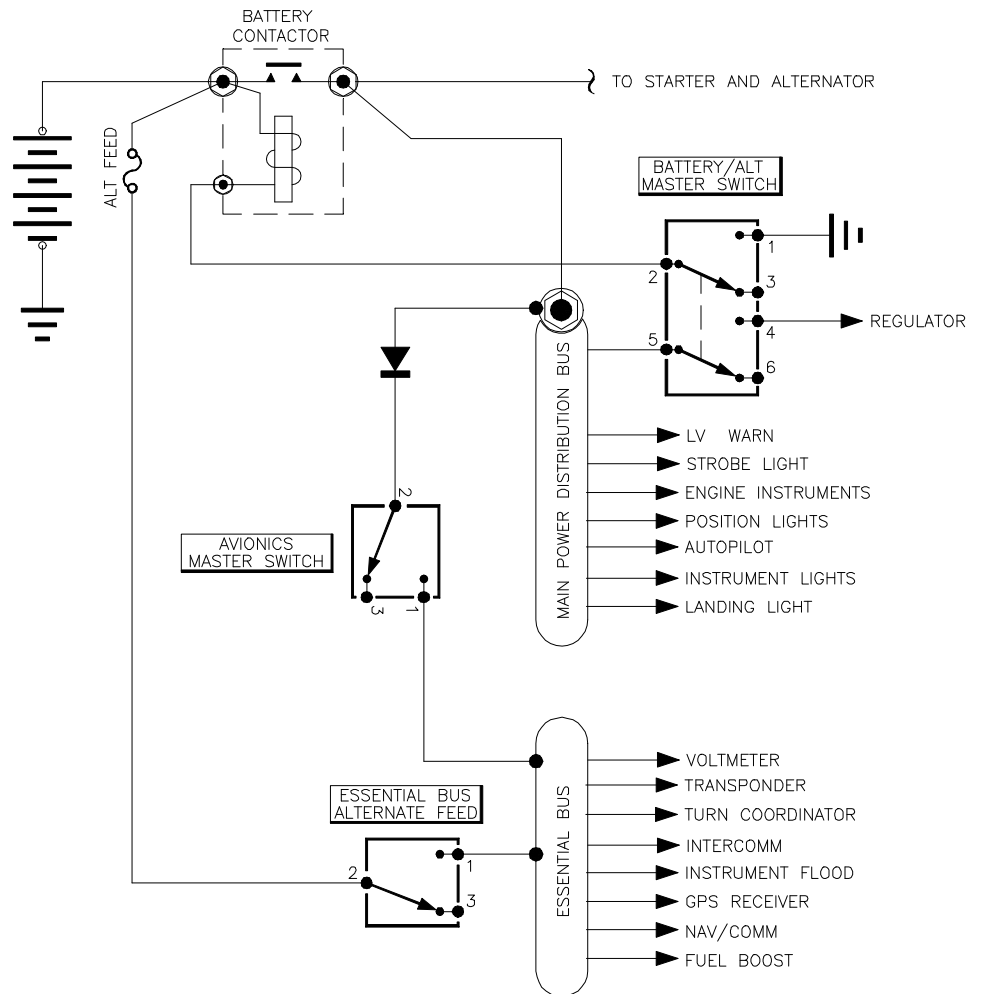
The keyword here is "protect" . . . protect from what? The AMS was conceived 30 years ago. Avionics have evolved through 4-5 generations of technology advancements but our way of thinking about them has not.

*2) There was a reply from you stating that the avionics master is an anachronism that has no place in a homebuilt using modern avionics and electrical system layout/design techniques.*

*(3) Flurry of responses from listers saying, "yeah but if the switch cost so little and could potentially save me thousands of dollars in repairs on my avionics, why not use it?"*

Because, if it's the ONLY power path to all the radios, then it's far more likely to be the source of failure for all radios than to be the guardian angel for any radio.

If one wants an AMS, by all means have one but do good systems design and ASSUME that all wiring and components are subject to failure. Any such failure kills all radios. Radios, (and a few other "essential" items should be supplied via independent power paths. See adjacent figure. Here, the AMS is but one of **two** power paths to the essential bus.



If you really want an avionics master switch, how about doing it this way?

*4) Ongoing debate amongst you and various listers stating that manufacturers should be forced by the laws of supply and demand economics to provide avionics that are impervious to any power supply anomalies.*

I guess my argument is that there is no such thing as a "power supply" anomalies. An anomaly is an unexpected event outside the parameters of known operation. Why should there be anything about the power supply in our airplane that is "unknown?" The thrust of my words was to ask 'em. If any manufacturer admits to some form of fragility in their design beyond gross overvoltage, ask them why they don't conform to the industry standard testing regime RTCA DO-160. I'm working on an article about DO-160 which I will publish on our website and elsewhere.

*I guess its #4 above that prompted my post. I was under the impression from your postings that there is still avionics gear on the market that is subject to problems during engine*

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start.

. . . if there are, I'm unaware of them. I've asked everyone to show me documentation from any manufacturer that requires pilot intervention to "protect" their product from ordinary airplane systems operations. Starting the engine seems pretty ordinary. Further, I'd like to know about it. I'll write or call them and get the scoop. I did write to Terra some years ago about a statement in their installation manuals alluding to an AMS . . . the engineer said, "Oh, we just stuck that in there because everyone seems to expect it. Sure, we've done our homework and fully comply with DO-160 requirements for input power conditioning."

. . . . . *Your response to my post implies that this is not the case. If that is so, then how do you explain the Avweb post that started this whole thing? Was that guy just plain wrong?*

Not for what we knew in 1967, but thirty years later, there's no resemblance in radios. So I guess I'll have to say, "yes," he is wrong.

. . . . *And what was the point of your repeated posts calling for change to be forced on avionics manufacturers by the marketplace? I guess I am no less confused about what you are trying to say than I have been all along.*

The "call to arms" was intended as an inducement to consumers of expensive, complex equipment to find out for themselves if the ol' mechanics and pilot's tales are worthy of consideration. If you've got a concern about it, call the manufacturer. If you don't like what they tell you, I'd like to hear about it. The Avweb article was simply a repeat of a 30-year old mantra.

Frankly, people who build high dollar airplane radios don't care much one way or another. It doesn't HURT their product for you to "mother" it. However, based on points above, the mothering circuitry has a potential for bringing the whole system down. Further, an electrical system failure modes effects analysis shows there are times when you may want to shut down both normal battery and alternator circuits for best utilization of a finite quantity of energy in the battery. This **also** calls for the second power path to essential goodies.

All technology based products experience quantum jumps in performance and value happen every few years. Gizmos that run from automotive DC power systems are included. There's not 2 cents worth of difference between the DC power system in your airplane and the one on your garden tractor or car. **Everyone** in these markets has enjoyed access to transient suppressors, high voltage silicon transistors and high quality

capacitors for over 15 years. For a very nominal cost, today's products can thumb their nose at **anything** the DC power system throws at it . . . including overvoltage to the tune of 20 volts for 1 second . . . plenty of time for an ov system to react and tame the runaway alternator.

*Please understand that I don't intend this as any type of flame. I have no knowledge of avionics whatsoever. The various standards that you have referred to in this thread mean nothing to me. I, as do many other listers, rely on the expertise of others such as yourself to attempt to make an intelligent decision. When expert advice from 2 different sources conflicts, what are we supposed to do? I'm simply trying to avoid making a very expensive mistake.*

No offense taken. I also understand your problem. As spam-can owners, we have had to take comfort in the reams of regulation and decades of tradition (I prefer to call it "regulation-induced antiquity"). Now you're a one-man airplane factory and you're getting some exposure to a few of the issues that were once left to unseen gurus. If you're more comfortable having an AMS, by all means, put one in. The figure above shows where it would go in the dual power path to an essential bus.

#### Caution

The diode is necessary to prevent inadvertent back-feeding the main bus from the essential bus by inadvertent mis-positioning of switches. If you do install an AMS as shown, don't leave out the diode.

But the real issue here is **system reliability** which goes far beyond concerns for "spikes" . . . real or imagined. If I have a mission here, it's to ask people to focus less on the minutia . . . it's admittedly easier to do and we all used to take great comfort in spec'ing the bejabbers out of everything bolted to an airplane. But what good is it to put a \$100 mil-spec switch on a landing light system when you **know** the bulb is going to burn out? If you're not comfortable with night ops with no landing light, wouldn't you be better off with a \$5 switch and spending the extra \$95 on a SECOND landing light installation? What we're really interested in is comfortable completion of every flight. I work toward that by assuming that **everything** is subject to failure and I'll either have (1) a backup or (2) don't need it. My real heartburn with the classic AMS has nothing to do with "spikes" . . . it has to do with system reliability in that it goes against well considered design.

Alternative views and comments welcome. . . .