



## Appendix Z

### Power Distribution Diagrams and Options

#### What's New . . .

Revision 12A incorporates all the interim revisions to the Z-figures published to date. It reinstates drawing Z-24 with enhancements and adds drawing Z-33. Figure Z-10/8 was added to suggest a combination of features in Z13/8 and Z-14 to support accessories that don't tolerate battery voltage sagging during the starter inrush interval. Unlike Z-14, this variation adds only the weight of a small support battery that's not used for engine cranking. Revision 12A also adds a patch to SD-8 alternators to make them "self-exciting". See Z-25 and Note 25.

#### How to use these drawings

**The drawings offered in this chapter are intended to convey suggestions for electrical system architecture and should not be used to select use of circuit breakers versus fuses, sizes of breakers or fuses, sizes of wire or even to decide what accessories will receive their power from which bus.**

The architecture drawings depict a variety of power distribution philosophies from which the builder may select a scheme that adequately addresses the way the airplane is to be used. The various architectures speak to design goals for meeting operating features and overall flight system reliability as discussed in Chapter 17. Further, many accessories such as progressive transfer switches, combined boost-pump and primer circuits, etc. can be intermixed between various architectures. When crafting a plan be cautious about making changes to the *architecture* or *operational* features of the Z-figure upon which your project is based. These drawings have evolved over the 20+ years that the 'Connection has been supporting the owner built and maintained (OBAM) aircraft industry. Features shown are thoughtfully crafted. Changes should not be implemented without thinking through the potential for unintended consequences to the reliability or serviceability of your finished system.

If you find that a drawing depicted herein falls short of your needs or expectations, join us on the AeroElectric-List which can be accessed at [matronics.com/subscribe](http://matronics.com/subscribe). This is an e-mail based forum where you can post your concerns and take advantage of the collective experience of hundreds of builders like yourself who have similar questions.

Study the diagrams and pick one that most closely matches your mission, budget and features. Then craft a document that lists each bus on a separate page, the items to be powered from that bus and the steady state current that each item draws based on the operational situation for the airplane.

**About the "missing" Appendices A, C and K.** In some places throughout this book you'll find references to a list of vendors from which you can order catalogs. I generated that list about 15 years ago when we began to develop the AeroElectric Connection . . . at that time, the shelves above my desk held a hundred pounds of catalogs and I thought it might be a good idea if all of you had access to the same parts data that I did. I published a list of the most useful catalogs above my desk in **Appendix A**. After a time, I began to receive calls from readers asking, "Okay, I got all the catalogs, I see about 10,000 switches in there . . . which ones do I order?"

Hmmm . . . it seems I didn't help much. I just made the list of choices longer and harder! A few revisions later, the out of date list was deleted. Today, it's even less appropriate - most of those catalogs have disappeared off my own shelves. The suppliers I work with have Internet sites and we interact with them almost totally by computer.

**Appendix C** was a brief catalog of products and services. This feature has expanded greatly and moved to our website at <http://aeroelectric.com> and/or the B&C Specialty Products website at <http://bandc.biz>

**Appendix K** used to have a couple of construction articles.

A survey of our readers showed that very, very few people found the information useful. Soooo . . . instead of printing the data in thousands of books, we converted them to articles for publication and/or downloading from our website at <http://www.aeroelectric.com>

The power distribution diagrams in this chapter are not intended to be recipes for wiring an airplane. There's very little cookbook data with respect to recommended parts. These drawings illustrate concepts for system architectures developed with and for our builders over the past 15 years. Features from these drawings may be mixed and matched to suit individual builder needs.

Early in the evolution of our mission, we attempted to offer custom wire book services for builders. The service was popular and it didn't take long before we had a backlog of 50-60 airplanes to wire . . . no way we could dig our way out from the mountain of work. When we discontinued the wire book services, the hard drive on my computer held many pages of drawings. We've decided to make a selection of those drawing available to individuals who have AutoCAD or any other CAD program that will import AutoCAD .dwg files. You may download several drawing packages from our website at <http://www.aeroelectric.com>.

Keep an eye on the Page per Systems drawing section at:

<http://aeroelectric.com/PPS>

In sub-directories under this heading you'll find a growing collection of single-page drawings in both .pdf and .dwg format. If you have access to AutoCAD or a computer aided drafting program that will open, edit, print and save AutoCAD files, feel free to download the drawings for use as you see fit. The Adobe .pdf files are readily downloadable printable. I've left the page number box on these drawings empty so that you can assemble any of these pages into your own project's wirebook. The drawing package on the website INCLUDES the architecture drawings in this appendix.

### A Short Discussion on the “Endurance” Bus

For a number of years the ENDURANCE bus was called the ESSENTIAL bus . . . bad choice. Words like “emergency”, “critical”, and “essential” conjure up tense images of things going badly in the airplane. I've had a lot of queries from builders asking about running flaps, fuel pumps, and lighting systems from the e-bus. The purpose of an e-bus with two feeds was to provide reliable power for the minimum equipment necessary for comfortable continuation for the en route phase of flight using only the battery for power.

Unless you're planning TWO alternators (Z-12, Z-13 or Z-14) then the purpose of the e-bus is to provide a minimum power consumption mode of operation in a battery-only

condition such that comfortable arrival is assured after you have a clearance to land. Then, you can re-close the battery master and run any accessories you like on whatever remains of the battery's energy. If the battery goes flat then, it doesn't matter.

What endurance do you want from the battery? If your design goal is to permit only fuel aboard to dictate endurance, then your battery capacity needs to be matched to your e-bus loads such that a fully charged battery will carry the e-bus for time equal to or exceeding fuel duration.

If your personal endurance value is less, then you can increase the e-bus loads accordingly. Know further that a battery's useful capacity goes DOWN as load increases. An 18 AH battery may well have received that rating based on a 20 hour discharge rate . . . or about 0.9 amps! If your proposed e-bus loads are, say 3 amps, it is not reasonable to expect 6 hours of performance from the 18 AH battery . . . it WILL be less, probably more like 12-15 AH

Consider further that you'll want to periodically test the battery so as to KNOW its capacity or simply replace it every year. The choice is yours. The goal is to KNOW how long your battery will carry an e-bus load so that you can depend upon it. Most single engine airplanes flying right now have “failed” batteries aboard . . . they cranked the engine but do not carry enough energy for really useful battery-only endurance. Worse yet, the pilots of those airplanes don't have a clue as to what the battery's capabilities are.

As you craft your dream project, keep in mind that the e-bus and your battery maintenance philosophy can provide system reliability that few single engine airplane drivers enjoy. But you MUST understand how it works, what it's for and how to maintain it.

### Individual Drawing Descriptions

The pages of wiring diagrams contain some pretty small print and graphics. Consider up-sizing pages of interest to you on a copy machine. Kinko's and office supply stores will often be able to enlarge these pages by approximately 130% to place them on 11x17" sheets of paper to enhance readability. Figure Z-14 is printed in two pages with overlapping features so that you can make copies of both pages and then splice them together with clear tape to make a larger, more readable drawing.

### Figures Z-1 thru Z-9 Not Used.

**Figure Z-10/8. All Electric Airplane on a Budget with a Brownout Battery.**

The hardware in Figure Z13/8 is fitted with a second but small battery that is not used during engine cranking. The small battery is intended to support devices that do not tolerate sagging bus voltage during engine cranking. Wobbly accessories are powered from the e-bus. Before cranking the engine, the E-Bus Alternate Feed switch is CLOSED. A Brownout battery disconnect relay is energized to isolate a small battery in support of the E-Bus while the starter is energized.

**Figure Z-11 Generic Light Aircraft Electrical System** depicts a single-battery, single-alternator architecture useful on about 90% of the airplanes being built. This figure features the B&C alternator control system (regulator, OV protection and LV warning in a single product). The classic acres-of-breakers has been replaced with two fuse blocks that offer exemplary circuit protection and save many hours and dollars of fabrication effort on a breaker panel. Toggle switches for magneto and starter control are illustrated as well. This architecture plays well with any number of battery, starter and alternator brands.

**Figure Z-12. Single Battery, Dual Alternator** shows the architecture for a two alternator/single battery configuration not unlike that which B&C has certified onto many type certificated aircraft. If your builder's budget can stand a little taller while considering the all electric panel option, this diagram is a nice step up from the budget system shown in Figure Z-11. This system is a popular option on production Bonanzas. The major difference in the Figure 12 drawing and systems being installed on the certificated aircraft is addition of the Endurance Bus with normal and alternate feed paths.

The SD-20 alternator from B&C is capable of running a full up electrical system . . . including pitot heat if you're not running lights (and you don't want to run lights when IFR in clouds anyhow). The two alternator one battery setup with an endurance Bus is a very attractive configuration for field approval onto certified ships. Further, it's not a bad option for OBAM aircraft.

**Figure Z-13 The all Electric Airplane on a Budget** was conceived during a conversation with a builder who really wanted to put the SD-20 alternator in his all electric airplane project but just didn't have the dollars. I was trying to figure out an architecture that would allow the SD-8 alternator to supply engine driven power without having to keep the battery contactor closed.

Z-13/8 is a two layer electrical system. When the battery contactor is open and the main alternator off line (DC POWER MASTER - OFF), one can close the AUX ALT switch and use the SD-8 to support the battery and whatever loads are presented by closing the Endurance BUS ALT FEED switch. In this condition, you have a system not unlike that which supplies electrical needs for a whole lot of

little airplanes. LongEz and VariEz projects were B&C's customers about 25 years ago and the SD-8 was B&C's only product!

If the battery contactor is functional -AND- the main alternator is okay too, then closing the DC POWER MASTER switch gets the second layer of electrical system up and running to support everything on the main as well as the endurance bus in the classical DC power distribution scheme. I published this diagram in the summer of 1999 on our website with a short article entitled, "*All Electric Panel on a Budget*" The response from the field was amazing. Orders for the B&C SD-8 alternator increased dramatically and a whole lot of builders were looking forward to NOT fighting a vacuum pump, filters, regulators and spaghetti bowl of hoses behind their instrument panels.

**If I were building an airplane today**, my ship would be fitted with Figure Z-13/8 electrical system with an 18 AH battery and dual Emagair ignition systems. I can deduce no other configuration that delivers more value.

**Figure Z-14 Dual Battery, Dual Alternator, Split Bus** is the Mother of all Electrical Systems. *Note that this drawing was too complex to put on a single page and still have readable details. Make copies of the two pages (blow them up if the machine has that capability) and tape them together to make a nice big drawing. You'll have to trim one page at the overlap to get the wires to line up across the sheets.*

Here I show how to configure two independent electrical systems so they share system loads according to their generating capacity. However, they'll support some loads on the other system should one alternator fail.

A crossfeed contactor is wired to connect both batteries together for cranking. *In normal operations, the crossfeed contactor is left open and the two systems operate independently of each other.* Should one alternator fail, the crossfeed contactor may be used for the failed system to borrow power from the working system. The two systems need not have the same capacity . . . I've illustrated a 60 and a 20 amp system common to Lancairs and Glasairs with total-electric panels. This same configuration would work nicely with a twin engine aircraft like the Defiant. In this case, you might have a pair of 40 or 60 amp alternators.

Keep in mind that having two electrical systems with crossfeed capability doesn't mean that all electrical equipment can be operated at all times. If your alternators are 60 and 20 amps as shown, then failure of the 60 amp machine means that you need to reduce total system loads below 20 amps for endurance. This system has greater potential for pilot workload in times when it's least welcomed; such as inside the final approach fix. The risk of this happening is small and if it does happen, there's no

advantage or need to respond to the failure until after landing. Simply close the crossfeed switch and allow the batteries to make up the difference between alternator capacity and system loads.

The vast majority of general aviation aircraft including twins and light jets do not have the reliability offered by this configuration. If you're building a high performance but electrically dependent aircraft, consider the extra effort and expense of installing this kind of electrical system.

### Caution

**Z-14 is appropriate to perhaps 1% of all OBAM aircraft being built. Before you launch off to install this system in your airplane, join us on the AeroElectric-List and let's talk about it. Recall that less than 1% of all incidents that bend airplanes and break people have electrical system failures as causation. It's exceedingly easy to achieve system reliability on the order of 10x all single engine airplanes flying . . . and many of those aircraft spend time in IMC conditions without having a bad day in the cockpit. Figure Z-13 is an excellent example of simple, light weight, low cost reliability.**

**Figure Z-15 Grounding Systems** illustrates three strategies for dealing with the special nature of ground systems in tractor, canard pusher and seaplane type aircraft.

Most tractor engine aircraft can mount a battery in relatively close proximity to the engine. Perhaps on the forward side of the firewall or (as in many RV's) on the aft side of the firewall between the pilot and copilot's rudder pedals. In some cases, the battery might be aft of occupant seating for the purpose of moving the center of gravity aft. View -A- is typical of all tractor engine situations.

If the airplane is composite, then both (+) and (-) leads to the battery need to be wired. In an all metal or tubular fuselage aircraft, the builder might consider grounding the battery locally to the airframe.

Remote appliances that are not potential victims nor strong antagonists for noise such as pitot heat, nav lights, landing and taxi lights and strobe power supplies can be grounded locally to airframe also.

For all other systems and accessories, use the single point ground at the firewall to terminate grounds for either engine or cabin mounted equipment.

Canard pusher aircraft often place the battery and engine on opposite ends of the aircraft. Further, canard pushers are always composite. Run a pair of 2AWG wires side-by-side for the length of the aircraft to complete the heavy current connections to the battery.

Seaplanes often locate the battery forward in close proximity to the instrument panel ground block. They often require a mid-ship ground for hydraulic motors (landing gear), bilge pumps or perhaps a second battery. In View -C- I've suggested a segmented ground system. Long runs in seaplanes always call for at least 2AWG wire in the ground and cranking circuit paths. Large seaplanes like the TA-18 Trojan use **paralleled** runs of 2AWG to maintain cranking performance of the large, 250 HP engine.

**Figure Z-16. Rotax 912/914 System** is a "stone simple" electrical system typical of many aircraft fitted with permanent magnet alternators. A noteworthy feature in this figure is the means by which I've added OV protection to the alternator system. Many airplanes flying with a Rotax 912 have relatively small batteries. Even the limited 18 amps of alternator output can push the bus voltage up rather quickly on a small battery. Adding the relay and OV module as shown provides automatic protection from unobserved regulator failure.

**Figure Z-17. Small Rotax System (or Aircraft with SD-8 Alternator as Primary Engine Driven Power Source** was requested by builders with the smaller Rotax engines having 10-12 amp alternators. This diagram shows how to wire a small system without a battery master contactor. This same architecture applies to small aircraft using the B&C SD-8 alternator as the primary engine driven power source. This system is flying in dozens of Vari-Ez and Long-Ez airplanes.

**Figure Z18. Single Battery and LOM engine** shows how to wire one of the very few generators still in production for installation on new aircraft. The LOM engines come fitted with 28 volt GENERATORS which require a unique OV protection scheme. This figure also illustrates interconnection of the LOM starting vibrator (similar to Shower-of-Sparks) and the various filters that LOM recommends for use with their engine.

**Figure Z-19** was crafted to suggest a dual power path and redundant batteries for an electrically dependent engine. *Note that this drawing was too complex to put on a single page and still have readable details. Make copies of the two pages (blow them up if the machine has that capability) and tape them together to make a nice big drawing. You'll have to trim one page at the overlap to get the wires to line up across the sheets.*

**Figure Z-20** shows a power distribution diagram unique to

the smaller Jabiru engines.

### Figure Z-21 Not Used.

**Figure Z-22. Fix for “Run-On” in Starters with Permanent Magnet Motors** shows how to delete the recommended starter contactor and add a heavy-duty (Our S704-1 or similar) relay to control the built in contactor and pinion engagement solenoid found on some permanent magnet starters.

A permanent magnet motor will act as a generator during its spin-down cycle and create enough current flow to keep the pinion engaged for several seconds after the START button is released. The relay isolates the panel mounted start button or switch from high inrush currents typical of modern starters. The relay can be mounted under the cowl and wired as shown.

### Figure Z-23. Generic Regulator and OV Protection for Externally Regulated Alternator (with diagnostics)..

There are hundreds of generic automotive regulators that will adequately control about any alternator configured to use external regulation. Here we illustrate the connections for a generic “Ford” regulator sold by many automotive stores as a p/n VR-166 by Standard. There are dozens of other manufacturers of equivalent devices.

When you elect to go generic, be sure to include over-voltage protection as shown. Make some provisions for acquiring active notification of alternator failure in the form of light or tone that activates below 13.0 volts.

No matter what alternator/regulator combination you choose, consider adding the diagnostic measurement accessory circuit described here. The cockpit mounted connection to monitor field voltage from the cockpit is an important tool for accurate diagnosis of charging system problems. See Note 8.

### Figure Z-24. Adding OV Protection to an Internally Regulated Alternator.

Z-24 has been the subject of much debate concerning a tendency for some alternators to be damaged when turned OFF under load using Figure Z-24 OV and control architecture. After considerable study, we find that some aftermarket alternators (virtually all of them rebuilds of some genre') are not routinely tested for an ability to withstand their own load dump events.

Consequently, there have been some unhappy events where the operator turned their alternator OFF while the engine rpms were greater than idle . . . resulting in damage to the alternator's built in regulator.

Know two things about this drawing:

(1) It is not a good idea to go flying with an alternator that is NOT fitted with positive control of a voltage runaway failure. ALL internally regulated alternators have some risk of regulator failure. This begs adding Z-24 (or equivalent) for the purpose of corralling an alternator bent upon smoking stuff on your panel.

(2) There is a replacement system in the works that will upgrade a Z-24 installation to allow ON-OFF control of any internally regulated alternator at any time under any conditions. If you'd like to take advantage of modern, exceedingly attractive automotive alternators, Z-24 is recommended in the interim with an upgrade at a later date.

The only caution is that you don't sit and fiddle with the alternator switch in any manner not consistent with normal operations of the airplane. Turn alternator ON at engine idle after starting. Turn alternator OFF at engine idle before shutting the engine down.

Understand too that most aftermarket alternators are not subject to this caution . . . but I have no way to guide you as to the appropriate purchase. So treat all aftermarket alternators gently as described above until the permanent fix is available.

**Figure Z-25. SD-8 Auxiliary Alternator Installation.** Got an unoccupied vacuum pump pad? How about populating it with an SD-8 alternator from B&C Specialty Products? Wire it right to the main battery as shown so that in case of main alternator failure, you can shut down the main alternator, shed the main bus loads by killing the DC Power Master switch, close the Endurance Bus Alternate Feed, turn on the Aux Alternator and enjoy indefinite electrical system endurance for the E-Bus irrespective of battery size or present condition with respect to capacity.

With two alternators, one may comfortably and logically be less stringent about battery testing and replacement - a replacement cycle of 2-3 years seems practical.

Revision 12 to the ‘Connection adds a diode bridge rectifier and two resistors to the SD-8 installation to make it “self exciting”. See Note 25.

**Figure Z-26 Ignition Switch Options - Two Magneto with Key-Lock Switch** If you really gotta have a key-locked ignition switch a-la spamcan, here's how it works and how you wire it up. Note the jumper between GRD and R terminals. A study of the switch's position-connection chart shows how this junction becomes grounded during engine cranking. This feature is used to disable a non-impulse coupled magneto (usually the right magneto).

If both magnetos are fitted with impulse couplers, delete the

jumper.

**Figure Z-27. Magneto and One Electronic Ignition** (with toggle switches) Here's my favorite way to wire the magneto and starter circuits. Two-pole switches accommodate the need to short out a magneto's p-leads to shut down the engine. A second pole provides a means for interconnecting the switches such that the starter is disabled while the right (non impulse coupled) magneto is ON.

Toggle switches for ignition control offer the ultimate flexibility for later upgrading to electronic ignition using switches that are inexpensive and look like they belong on the panel with the rest of the system's electrical controls.

**Figure Z-28. Dual Electronic Ignition with One Alternator.** If you plan dual electronic ignition, you should consider adding an auxiliary battery (Figure Z-30) to support the second ignition in the rare event that the main alternator is lost. Figure Z-28 shows how the two ignition systems and starter get their power.

**Figure Z-29. Always-Hot Battery Bus.** It occurs to me that any time the magneto switches are ON in an airplane so equipped, the engine is HOT and ready to run. A desirable feature of magnetos over electronic ignition is the fact that the engine runs irrespective of the condition of the airplane's electrical system. So why not retain this advantage when you go to electronic ignition?

I'll suggest that electronic ignition systems should enjoy a direct connection to the ship's always-hot battery bus. Wired as suggested, the pilot may shut down the entire electrical system without affecting engine operations. If you have strange smells in the cockpit, you don't have to think twice about killing the DC POWER MASTER and alternator switches. The engine will continue to run while you sort out the problem and select your plan for continued flight . . . hopefully to intended destination.

**Figure Z-30. Auxiliary Battery and Bus.** If you have an electrically dependent engine . . . either by virtue of dual electronic ignition, electronic controlled fuel injection or an engine that depends on electrically delivered fuel, then a second battery should be considered to distribute power sources among the primary and secondary systems.

If both batteries are hefty (12 AH or more and capable of delivering energy into the starter system) then you would run BOTH batteries for all normal operations including engine cranking.

If you wish to run an auxiliary battery smaller than the main battery, then the S701-1 contactor (big guy capable of helping crank the engine) may be replaced with an S704-1 relay. In this case, the AUX BATTERY MASTER would be

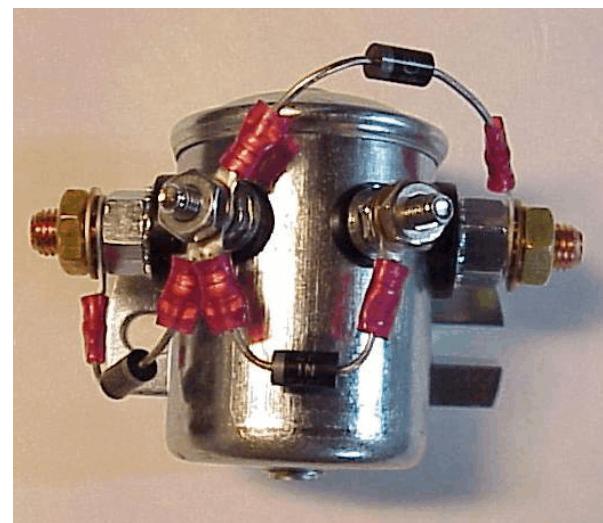
OFF during engine cranking and ON for all but failed alternator operations.

There is a distinct service and reliability advantage to equal-sized main and auxiliary batteries. You can replace the main battery every annual with a fresh battery (a very low cost activity when compared with the total cost of owning and operating an airplane). Move last year's main battery into the auxiliary battery slot. This means that you never have a battery more than two years old and one battery is always less than one year old . . . *a very robust, reliable combination for dealing with potential alternator-out operations.*

**Figure Z-31 Ground Power Jacks.** This figure illustrates two popular versions of a ground power jack installation that can be added to any airplane. One uses the military style, 3-pin connector popular with Cessna and the larger Beech products. The other illustrates a single pin connector adapted from the trucking industry and popular with Piper and the smaller Beech products. Most airports will be able to connect to either style ground power jack.

**Figure Z-32. Heavy Duty E-Bus Feeder.** As a rule of thumb we try to avoid long runs of always hot wire fused at more than 7A. This is a crash-safety issue. If your E-Bus really needs a feeder protected at more than 7A, consider adding a power relay contactor or AEC9030-14 Solid State Relay as a "mini" battery contactor right at the battery bus to control the e-bus alternate feed line.

**Figure Z-33. Dual Power Feeds for Battery Contactors.** Note that the cross-feed contactor of Z-14 can be energized if either the main or auxiliary bus is hot. This is accomplished by wiring diodes from both fat terminals of the contactor to the hot side of the coil. In some cases,



especially if any of your alternator(s) is/are self exciting, then modifying your battery contactor with a trio of diodes as shown is a useful thing to do. For example: After hand-

propping the engine with a dead battery . . . or after starting the engine with only one of two batteries (as in Z-14 or a dual-battery installation) you can get the dead battery's contactor closed with power from the ship's system.

Obviously, this mod precludes the use of a 3-terminal contactor. You'll need a 4-terminal device with diodes installed as shown here. Note the banded ends of all diodes tie to one coil terminal. Either fat terminal can go to the battery. The other small terminal is the coil connection to the battery master switch. The diodes are uncovered in the photo for clarity. Your installation should include heat-shrink over the diodes.

**Figure Z-34.** Not used.

**Figure Z-35. Non-Cranking (small) Aux Battery and Bus** It's perfectly valid to consider adding a second battery to any system shown for the purpose of supporting certain equipment items in the aircraft. Small batteries not designed for delivering high current (generally 15 AH or less and don't feature bolt-tabs for connecting fat wires) may be paralleled through a relay that's much smaller than the classic battery contactor. In this case, I've illustrated a 30A, "plastic cube" as the aux battery master relay. Obviously, the small aux battery master should be left OFF until after the engine is started and the alternator is on line.

#### Numbered Notes from the Drawings

References to numbered notes are sprinkled about the face of each drawing. The following notes will offer additional information about the tagged feature.

**Note 1.** The minimum recommended wire size for all wiring is 22AWG except as noted. Try to keep wires marked with an asterisk (\*) limited to 6" or less in length.

**Note 2.** Contemporary magneto switches are fat, ugly, expensive and heavy. They provide only a modicum of protection against airplane theft. They also contribute to occasional engine kick-back with possible damage to engine and/or starter. Consider using two double-pole, double-throw switches with one position spring loaded to center. The AeroElectric Connection S700-2-5 switch is suitable.

Note that p-leads are grounded out with the switches in the lower, OFF position. The center position of each switch un-grounds a mag, allowing the engine to run. The spring loaded upper position of the left mag switch controls both magneto and starter contactor. The starting circuit is completed through lower, MAG OFF contacts on the right mag switch. This interlocking prevents inadvertent engine cranking with the right mag energized. If both magnetos have impulse couplers, the right mag, starter lockout feature should be eliminated. Of course, electronic ignition systems used to replace the non-impulse coupled magneto do not

have to be OFF while cranking an engine . . . indeed they're better left ON.

Using toggle switches for magnetos has an important future benefit: you have the option to replace a magneto with an electronic ignition. An OFF-L-R-BOTH-START key-switch cannot be used to control some electronic ignitions. On the other hand, a toggle switch has circuits which close in both the up and down positions. You simply use the opposite set of contacts on the same switch for control of an electronic ignition.

**Note 3.** Use shielded 20 or 22AWG wire to control the mags. Attach the shield to engine ground at the magneto end. Attach the shield to one and only one switch terminal at the cockpit end as shown. In the switch OFF position, the shields are used as a ground return for the magnetos. In the MAG ON position, the shields are protection from electrostatic coupling of magneto noise. The shields should not be attached to any form of ground at the panel, just the magneto switch.

**Note 4.** Automobiles have been using fusible links for many years. From the outside, they appear rather "special" . . . many have a tag molded onto what looks like a piece of wire with a terminal on one end . . . the tag says, "FUSIBLE LINK." Hmm . . . well guess what, what looks like a piece of wire is indeed a piece of wire . . . and rather ordinary at that. I've deduced the rationale behind design and incorporation of fusible links after lots of e-mail, phone calls and literature searching.

All fusible protection of a wire functions the same way. A thermally weaker segment is placed in series with the wire segment to be protected. Sometimes the link is a piece of special wire inside a glass tube or block of plastic and we call it a "fuse". The purpose of the weak link is to provide an orderly failure of a faulted circuit's ability to carry current. Suppose the weak link was simply a piece of ordinary wire? It turns out that the link used on cars is 4AWG wire steps smaller than the wire being protected. 10AWG wires are protected by 14AWG links, 14AWG wires are protected by 18AWG links, etc. Obviously, should a hard fault occur, you WILL get some smoke and the smaller wire will melt and separate. Successful incorporation of fusible links takes some consideration . . . they're not for every situation which might otherwise require some form of in-line fuse.

First, 24AWG is the smallest practical wire that can be worked with terminals and tools used. A 24AWG wire will carry a 3A continuous load with a reasonable temperature rise. The downstream segment from a 24AWG fusible link has to be 20AWG. Hmm . . . a tad heavy for a 3A circuit but not outrageous. Take a look at the alternator loadmeter shunts on Figure Z-14. Short pieces (4-6 inches) of 24AWG wire are butt-spliced onto 20AWG extensions to take shunt

signals into their respective loadmeters.

Now, how likely is it that these "fusible links" will ever be called upon to do their job? . . . VERY small. What's the damage if it does happen? Not much: a short piece of 24AWG wire burns up. If we slip a piece of fiberglass sleeving over the wire, you wouldn't even toast an adjacent wire in a bundle. Why would we want to do this? Lower parts count for one, increased reliability for another. All components of this protection scheme are ordinary pieces of wire connected together with solderless splices and terminals having reliability approaching that of the wire itself . . . *much easier to install and more reliable than any form of holder for discrete fuses.*

Hmmm . . . how about the Aux Alternator B-lead feed in Figure Z-14? Here's a special challenge that is nicely met with a fusible link. Here the B&C SD-20 alternator is capable of 20 amps of continuous output. Inline fuse holders at this current level are marginal at best; fuse holder components corrode, accelerated by moisture and temperature cycles. The fusible link is a very reliable alternative for circuit protection in this location.

I show fusible links on other single line feed paths as well. Our website catalog will soon offer small quantities of 24AWG tefzel wire (not commonly offered in other folks catalogs) and small quantities of silicone rubber impregnated fiberglass sleeving to place over fusible link installations. This sleeving is not necessary but it does offer some protection to adjacent wires and equipment from effects of heat and smoke.

**Note 5.** When the battery and engine are on opposite ends of the airplane, heavy wires between the battery and engine compartment should be routed as close together as possible along the length of the airplane. Try to run ALL wiring in a single path down one side of the airplane. Attempts to use both sides of the airplane for electrical pathways have resulted in some bizarre noise and magnetic interference situations. Use one side for wires, the other for engine controls. Even then, make sure that jackets for engine controls do not ELECTRICALLY ground both a metal panel and the engine . . . they can easily become a SECOND ground path on the wrong side of the airplane and create the same problems we're striving to eliminate.

**Note 6.** The ground busses shown are fabricated from brass sheet, strips of .25-inch Fast-On tabs and a brass bolt. These are available from B&C Specialty Products.

**Note 7.** In composite aircraft, the B & C linear regulator requires two separate grounds to insure OV protection integrity. If you choose to use this device be sure to wire it as shown.

**Note 8.** When an alternator quits alternating, good data is

useful in making an accurate diagnosis of the problem. If you don't know what the alternator field voltage is doing when the system is failed or misbehaving, you're not ready to put a wrench to the airplane. There are few mechanics out there that even know what you're about to learn here . . . and even fewer that will stand behind a running propeller to gather the needed information. So consider this:

Referring to Figure Z-23, you can see where a 1K, 1/2 watt resistor can be spliced into the alternator field lead at any point along the route between the regulator and the alternator's field terminal. Splice a 22AWG wire to the other end of the resistor and then cover the whole business with heat shrink before you tie it back into the wire bundle. The resistor serves as a current limiting device to isolate the test wire from the field wire and eliminate the need for a fuse to protect the test wire. The resistor also prevents a shorted test wire from upsetting normal alternator operations.

Now, extend the wire into the cockpit where you'll attach it to a Radio Shack 274-1576 receptacle. The receptacle is small and would not take up much room on a panel but if you want it out of sight, at least make it easy to reach from the pilot's seat--perhaps on a bracket behind the panel. Ground the receptacle's shell to the instrument panel ground bus with another piece of 22AWG wire.

You'll need to make up a short cable assembly consisting of a Radio Shack 274-1573 plug (mates with receptacle above) and banana plugs on the other end to connect with a hand-held multimeter . . . preferably an analog meter but if all you have is a digital, it will do. We'll cover this in more detail in a future update to the alternator chapter. Here's how this feature becomes really useful:

- (a)** If the alternator field voltage is zero when the output is zero, then the regulator or associated wiring has failed.
- (b)** If the alternator field voltage shows some fairly healthy reading on the order of 10 volts or more and alternator output is zero, the alternator has failed.
- (c)** If the alternator has become unstable . . . loadmeter is jumpy, panel lights flicker . . . watch the field voltage and compare it with loadmeter readings. If the field voltage and loadmeter readings swing up and down together, then the regulator has become unstable. Check for increased resistance in regulator field supply wiring and components. Breakers, switches, over-voltage relays, and connectors are all contributors to regulator instability when their resistance ages upward a few milliohms in resistance.
- (d)** If the loadmeter swings UP while the field voltage is swinging DOWN, then the alternator has some unstable connections inside . . . perhaps worn brushes?
- (e)** If field voltage is high, does not drop significantly when

engine RPM increases but bus voltage seems normal under light load and sags under heavy loads, then the alternator may have one or more diodes open/shorted.

**(f)** While operating with full system loads, carefully observe the engine RPM where alternator field voltage peaks: i.e. begin at idle RPM with all loads ON--if your bus voltage is lower than the regulator setpoint, then the alternator is turning too slow to support present loads. Now, adjust engine RPM carefully to get the highest possible reading on field voltage. At this time, the bus voltage should be at the regulator setpoint. The engine RPM is your *minimum speed for regulation* at full load. If your system is working properly and pulley ratios are appropriate, engine RPMs should be equal to or LESS than required to sustain flight.

**(g)** Should your alternator suddenly become "noisy" in that alternator whine becomes markedly worse, you may have suffered a blown diode in the alternator. Before taking the alternator off the airplane, Attach a multimeter to the alternator case and the b-lead (output terminal). Set the multimeter to read AC voltage. Run the engine up and turn everything electrical ON. If the AC voltage exceeds 500 millivolts, there's a good chance that a diode is bad. If it's less than 200 millivolts, then it's more likely that the noise is getting into your audio system via a ground loop (noise is present even when radio volume is all the way down) or failed noise filter (noise goes up and down with radio volume control).

The above paragraphs describe about 100 times more than most mechanics know about alternator troubleshooting but none of it is possible unless you can measure field voltage (sometimes in flight), observe a combination of effects and deduce their meaning. The parts cost a few dollars and the feature adds significantly to the efficient and safe maintenance of your airplane.

#### Note 9. Not used

**Note 10.** There are good reasons for not bringing high current feeders or loads into the cockpit. High performance production airplanes use a special, heavy duty fuse-like device called a *current limiter*. Alternator B-Lead protection is best accomplished with MANL or ANL series current limiters used throughout the industry for similar applications.

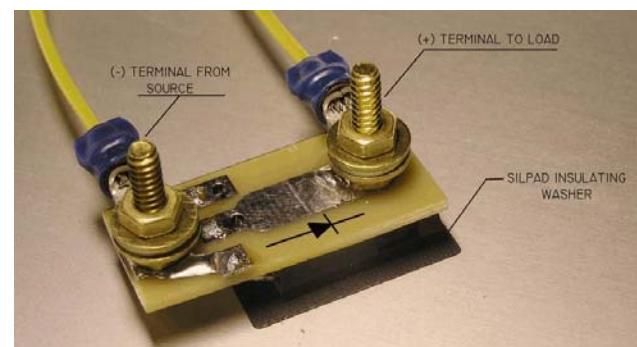
Alternator noises in the system are reduced by *not mounting the alternator breaker on the panel* in the traditional fashion. The likelihood of recovering use of the alternator should this breaker trip is very close to zero. Consider installing a current limiter as close as possible to the starter contactor and wired per the Z-figures.

ANL/MANL limiters should also be considered as supply

protection for electric hydraulic pumps.

#### Note 11. Not Used

**Note 12.** A silicon diode having a forward current rating of 20 amps or more can be used to eliminate a bus tie switch and provide automatic isolation of the power distribution bus from the endurance bus during failed alternator operations. If your endurance bus is configured per our recommendations for 3-4 amps MAXIMUM continuous load, the rectifier diode array requires no heat sinking. A Radio Shack cat #276-1185 is suitable. Its metal case may be bolted directly to the structure. If you absolutely must have higher endurance bus loading, consider ordering your endurance bus normal feed diode from us. We'll put it on a suitable heat sink for you -OR- a Digikey HS117-ND heat sink cut in half is about right for diode cooling.



AEC9001-1 Schottky Diode Assembly

For builders interested in a more efficient diode with less voltage drop, the AeroElectric Connection offers the AEC9001-1 Schottky Diode Assembly which may be reviewed at <http://aeroelectric.com>

**Note 13.** The battery minus (-) wire should go directly to the nearest ground system tie point. I recommend some combination of the Fast-On tabs ground busses (B&C or equal) screwed to firewall. Where ever possible, the battery (-) lead should bolt to the 5/16" brass stud that comes with the ground bus kit. Then a 2AWG equivalent bonding jumper to ground the engine's crankcase to the Fast-On bus.

**Note 14.** Consider installing an electric solenoid valve between the pressure side of your fuel system and the primer ports on your engine. Aircraft Spruce offers a suitable electrically operated valve for primer service. Further, consider using a 4 or 6 port primer system (depending on the number of cylinders on your engine). Two advantages: (1) no wet fuel lines in the cabin, (2) many an engine plagued with a plugged carburetor or broken mixture control has been kept running to an uneventful landing by a multi-port primer system. The electric primer system offers an opportunity to craft a completely redundant fuel delivery system!

Put a needle valve in the downstream line from valve to the primer nozzles. Set the valve to produce a 60% power fuel flow when the primer is in operation. If you loose the primary fuel delivery path, turn on the primer and adjust throttle for smoothest running engine. If you elect to incorporate the primer backup fuel delivery system, you may want to change out the 2-50 switch on-on-(on) for a 2-10 switch on-on-on so that you don't have to hold the switch in the PRIME position for operation with the second fuel delivery source.

**Note 15.** In order to take advantage of the unique switching features of special switches shown in these diagrams, a means of calling out mounting orientation is needed. Switches supplied by the AeroElectric Connection (and other quality devices) are fitted with a keyway groove along one side of the threaded mounting bushing. The numbers given on this drawing for wiring the switch assume that you mount these switches with their keyways up. Your switch should also come with a keyed and tabbed washer used to prevent rotation of the switch in the mounting hole should the nuts loosen. We recommend its use.

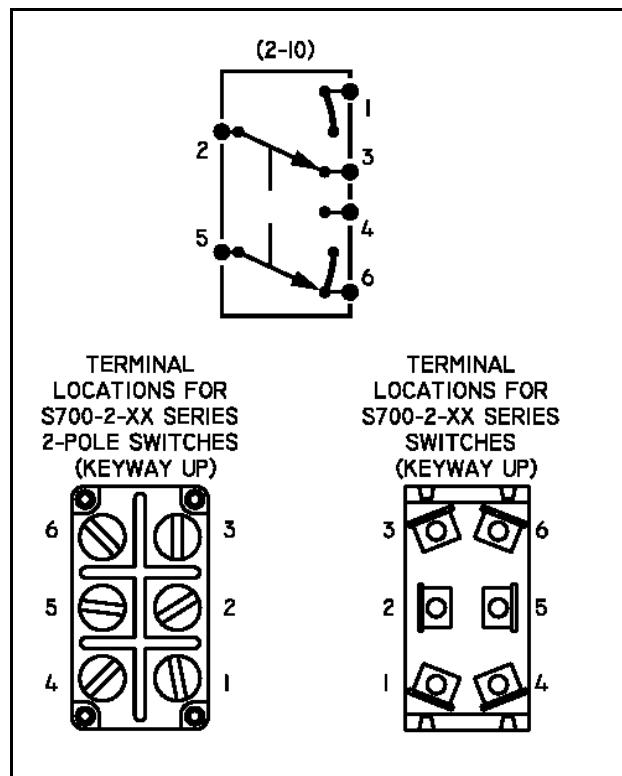
**We've discovered that since this note was first crafted some 15 years ago, Carling has modified their progressive transfer switches to conform to the convention described in military standards for such switches. Use an ohmmeter to check your progressive transfer switch of any brand to deduce the true column orientation. Just know that most switches purchased recently will conform to the Microswitch numbering convention.**

**Note 16.** The fuel boost/prime switch has special internal features. It's described as a two-pole, ON-ON-(ON) switch. An AEC S700-2-50 or equivalent switch is needed.

**Note 17.** If you have not yet selected a battery; do consider the new recombinant gas (RG) or vent regulated lead-acid (VRLA) batteries. These are truly maintenance free batteries that crank like ni-cads! Flooded batteries need to go the way of the buggy whip.

**Note 18.** B&C Specialty Products supplies a crowbar OV module ready to install (p/n OVM-14). See their website catalog or contact them directly. If you've a mind to "roll your own", check out our website for an article with a schematic and bill of materials.

**Note 19.** All of these diagrams show fuses on low cost fuse blocks. Obviously traditional panel mounted bus bars with circuit breakers are functionally interchangeable with fuses. I recommend you consider fuses carefully. There are many savings in weight, cost and time to install. The fuse blocks shown are a Bussmann products now generally available



Note 15. Terminal Locations for Microswitch vs. S700 (Carling) SEE TEXT.

from many suppliers to the OBAM aircraft community.

**Note 20.** Unlike their fielded cousins, permanent magnet alternators may run well with a battery off line if you add a computer grade electrolytic capacitor across its output for filtering. The capacitor should be 20,000 to 50,000 microFarads and rated anywhere between 15 and 50 volts. CAUTION . . . some regulators supplied with PM alternators still require a battery to be present before they will "start up" . . . if you'd like to depend on your PM alternator to operate in spite of a battery contactor failure, investigate this operation for the regulator you've selected. A different regulator -OR- some small, stand-by battery installation may be indicated.

**Note 21.** An aftermarket FORD regulator (Standard Parts VR166 or equal) is a low cost, solid state regulator suitable for use on airplanes IF you add OV protection as shown. This particular regulator has been duplicated and offered under a variety of part numbers by other suppliers. You can hit your parts guy up with this list:

TVI_Globe . . . . .	p/n	VR166
Ford_Motor . . . . .	p/n	GR540B
Standard . . . . .	p/n	VR166
Neihoff . . . . .	p/n	FF169B
Echlin . . . . .	p/n	VR440
Filko . . . . .	p/n	VRF330HD

Ampco/Wells . . . . .	p/n	VR749
KEM . . . . .	p/n	KVR202B
GP . . . . .	p/n	VR301

Another interesting feature of this part is its appearance. I'm aware of no version of this regulator that doesn't look like the adjacent photograph.

**Note 22.** Most alternators do not run well without also having a battery on line. The infamous "split rocker" switch was developed for light aircraft in the mid 1960s when generators were being phased out in favor of the much more efficient alternator. A two-pole, split-rocker switch controlled the battery master contactor with one pole and



Note 21. Generic "Ford" Regulator

alternator field excitation with the other pole. The switch halves were mechanically interlocked such that the battery could not be turned OFF without taking the alternator OFF as well. The Z-figures always show a two-pole switch as a DC PWR MASTER, one pole for the battery contactor, a second for the alternator field supply.

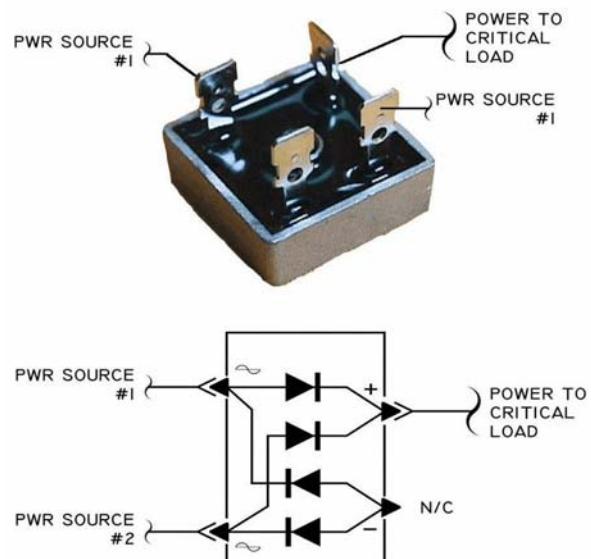
**The progressive transfer, 2-10 style switch** can emulate the popular split-rocker switch by offering an OFF-BAT-BAT+ALT function. This configuration allows battery-only ops for ground maintenance and covers in-flight situations where the pilot needs to shut down a mis-behaving alternator. See note 15.

If your system has an alternator field breaker to accommodate crowbar OV protection, **One may consider a 2-3 style switch** where the battery and alternator come ON and OFF together. This is perfectly acceptable for normal operations. In-flight shutdown of the alternator and/or battery-only ground maintenance may be conducted by pulling the alternator field breaker.

**Note 23.** Revision 11 introduces the avionics ground bus described in Chapter 18 and illustrated in the Z-figures for

the first time

**Note 24.** When you have critical loads that you would like to accommodate with dual power sources, the 4-diode bridge rectifier offers an easy to acquire, easy to mount, easy to wire solution. The figure for this note illustrates which terminals are used. Figure Z-19 shows one example of how the device is used.



**NOTE 24. USING DIODE BRIDGE TO JOIN CRITICAL POWER FEEDERS**

If your critical system draws more than 4 but less than 8 amps, the diode bridge should be mounted on a metallic surface for heat sinking. If the loads are heavier, say 8 amps up to the 25 or 30 amp rating of the device, perhaps a finned heat sink is called for. Consult the membership of the AeroElectric List for guidance in these special cases.

In any case, the diode bridge should be located as close as practical to the critical system's input power connection.

**Note 25. Making the SD-8 Come-Alive without a battery:** Subsequent to some excellent 'skunk works' efforts on the part of Jim McCulley, the 'Connection is pleased to offer a work-around to older SD-8 alternator installations that encourages this useful product to come on line without benefit of a battery. Adding a pair of diodes and a start-up bias resistor as shown in Z-25, the SD-8 will come up and run as soon as the engine is started.

I've suggested the diode bridge rectifier for this application but you can use wired-leaded devices like 1N5400 series devices from Radio Shack and others. The advantage of the diode-bridge is that splices between dynamo and regulator lead wires can happen in the same PIDG terminals used to

wire the rectifier.

Suitable parts include the following Digikey catalog numbers:

1 each 1GBC1204/1 Diode Bridge  
1 each ALSR3F1.0K 1,000 Ohm/3W  
1 each ALSR3F3.0K 3,000 Ohm/3W  
2 each 1N5400 3A, 50V Diode Rectifier

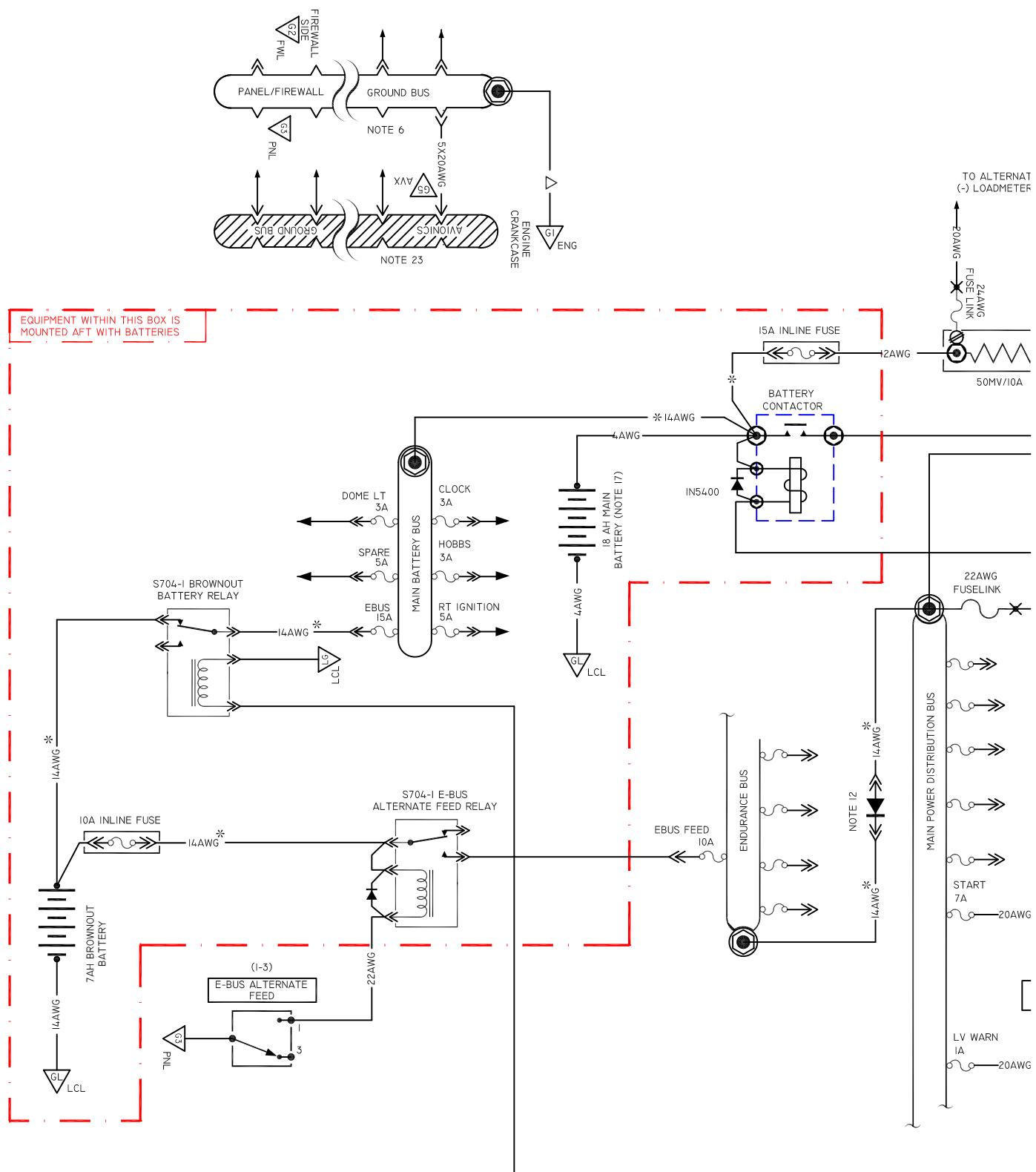
These parts are chosen more for their mechanical configuration and robustness than for electrical ratings. Many other styles of parts may be substituted. With these added parts, one may connect a voltmeter across the 22,000 uFd filter capacitor. A few seconds after the engine is started, one should observe that the voltage across the capacitor jumps up to about 6 volts at engine idle. The voltage rises with RPM until the regulator takes over to maintain output at about 14.2 volts at cruise RPM.

**Note 26. Do's and Don'ts of Grounding.** The addendum illustration to Figure Z-15\_3.1 speaks to the most common questions about achieving quality grounds in an airframe.

Grounding systems in an airframe can have multiple, linearly connected gathering points that can satisfy the design goal of "single point grounds" for individual systems. It's important that potential victims to noise (Comm and nav radios. Audio systems. Instrumentation systems) concentrate their various system grounds in one location. The example figure shows how potentially antagonistic loads may be grounded remotely on a metal airframe as long as potential victims enjoy single point grounds.

I've illustrated some no-no's in red that show a headset circuit and components of an oil pressure gage grounded across two nodes. While both cases may be "grounded" and function as desired under some conditions, they are at-risk for interference from tiny but significant voltages that exist between two "connected" but not "co-located" grounds in the system.

Devices wired in green illustrate devices that have been properly grounded including a number of accessories that are locally grounded to metal airframes.



*Figure Z-10/8 All Electric Airplane on a Budget with P-Mags & Brownout Battery*

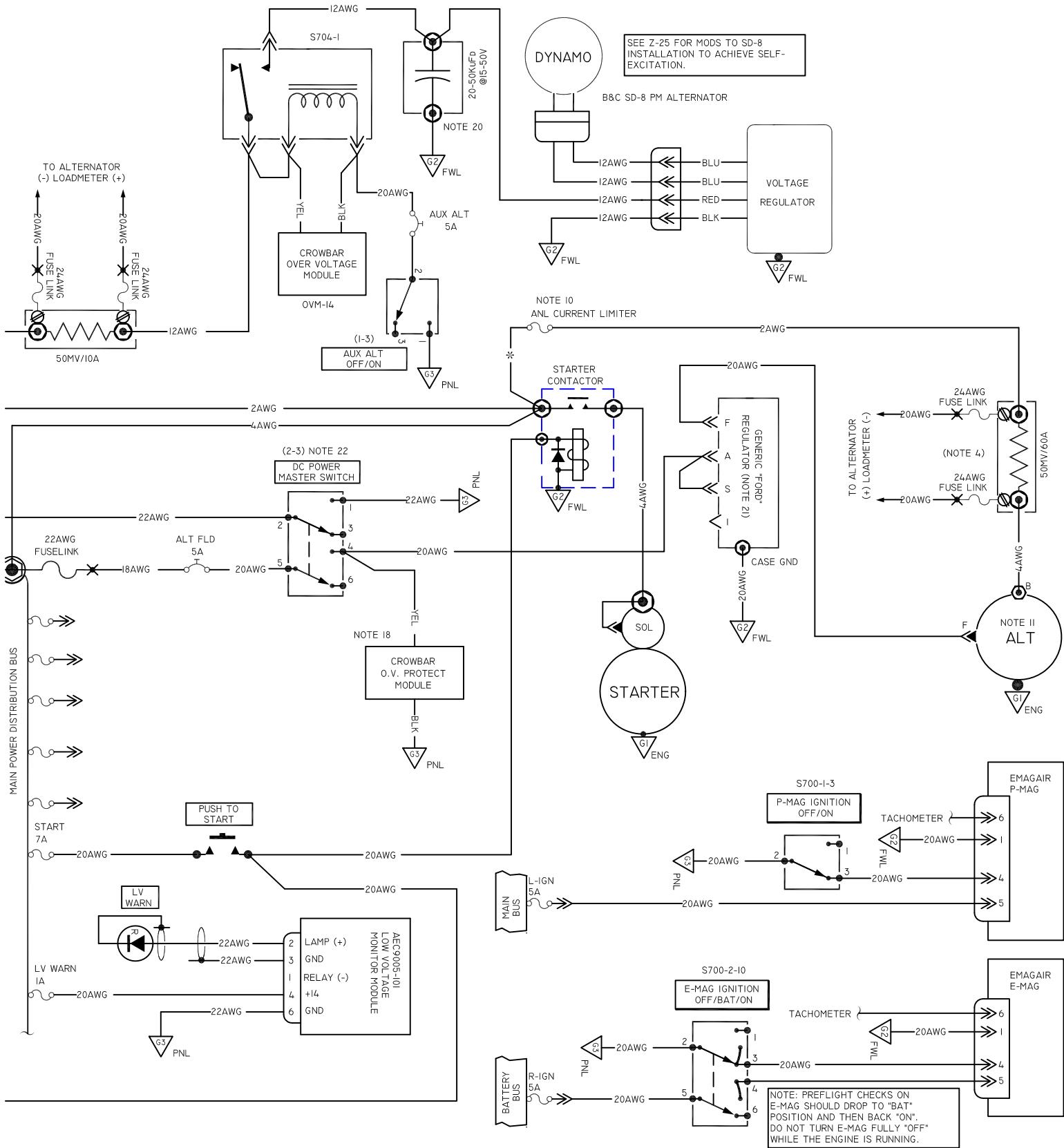
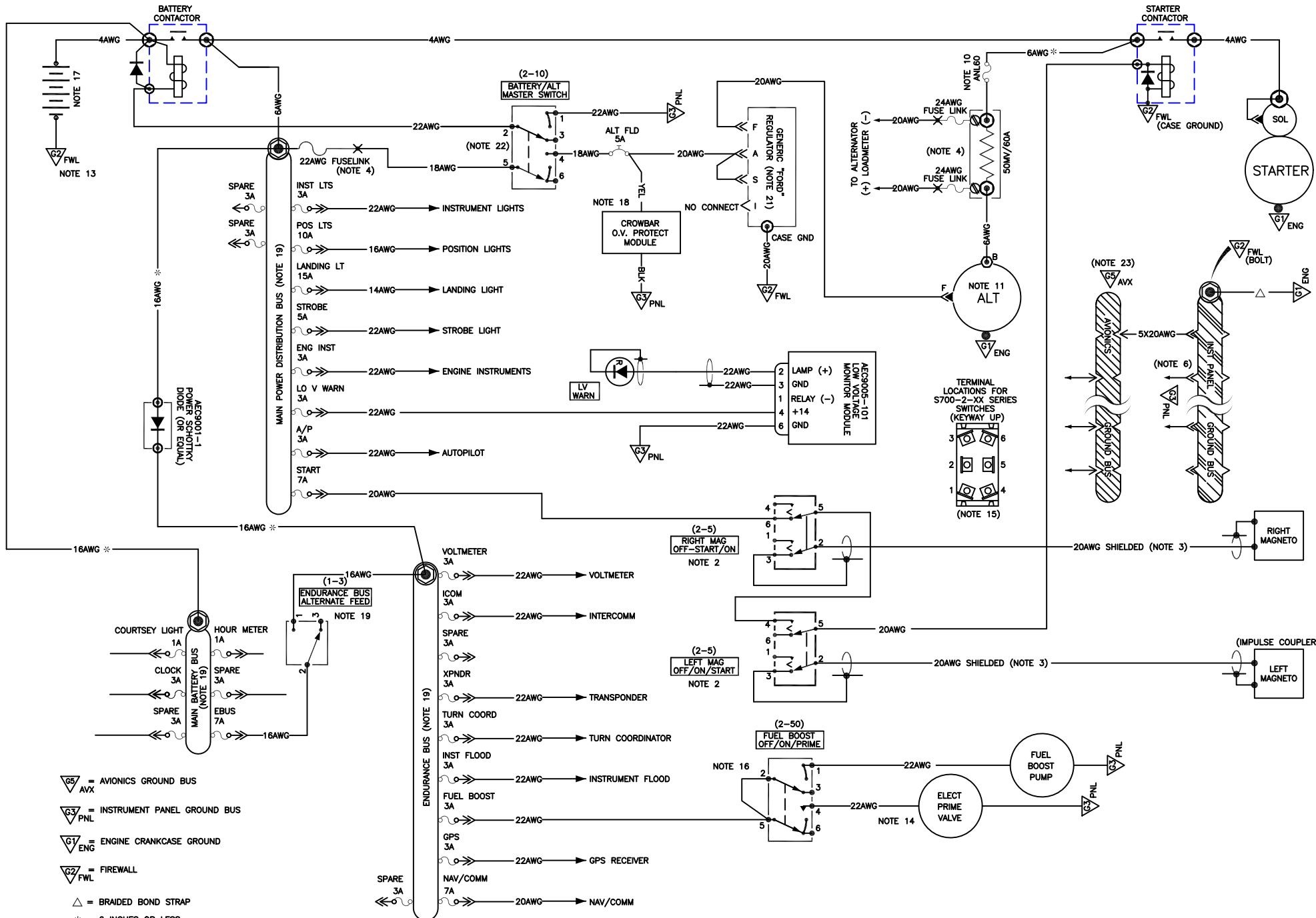


Figure Z-11. Generic Light Aircraft Electrical System



 G5 = AVIONICS GROUND BUS

**G3** = INSTRUMENT PANEL GROUND BUS

 **ENG** = ENGINE CRANKCASE GROUND

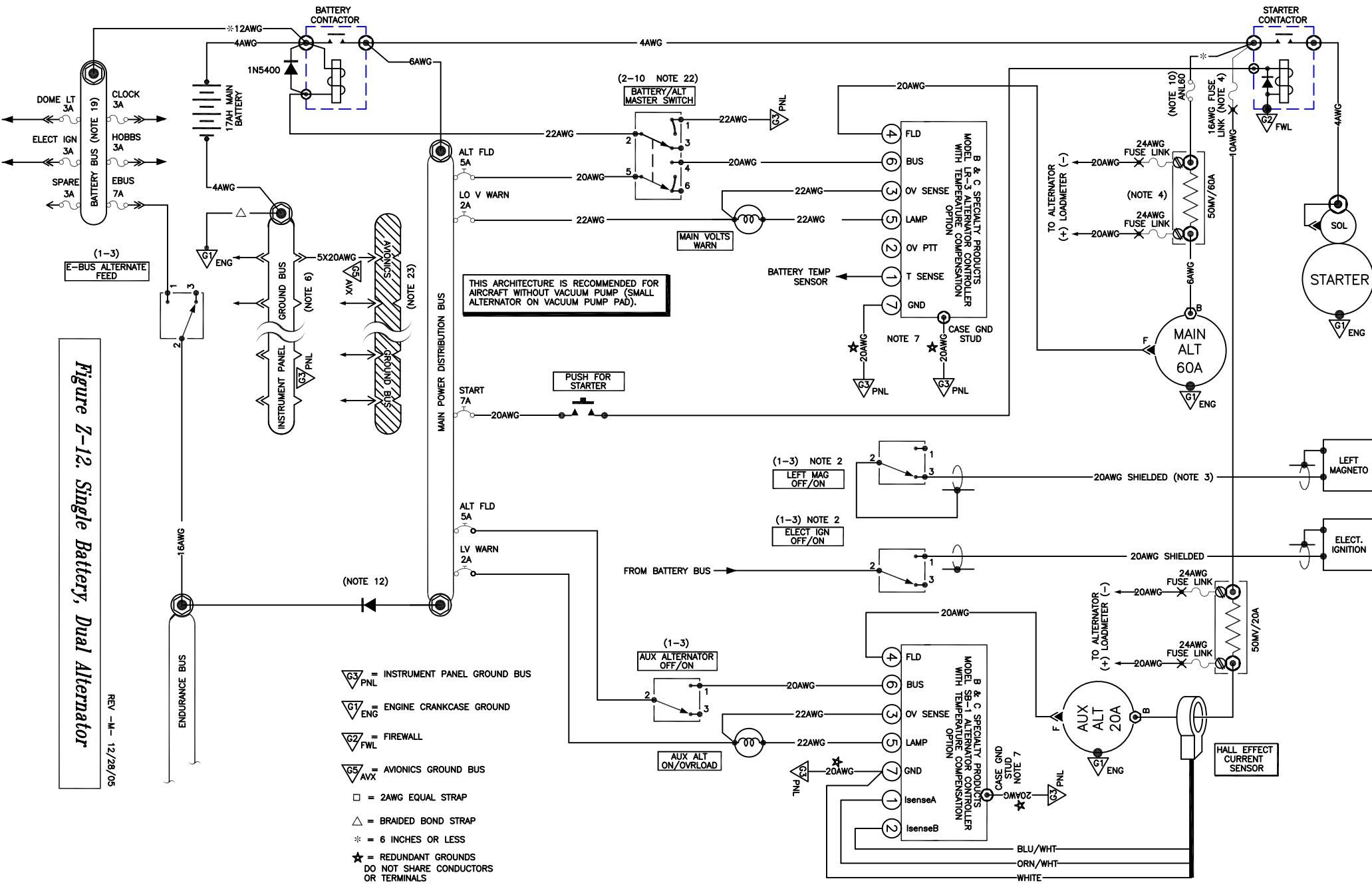
 = FIREWALL

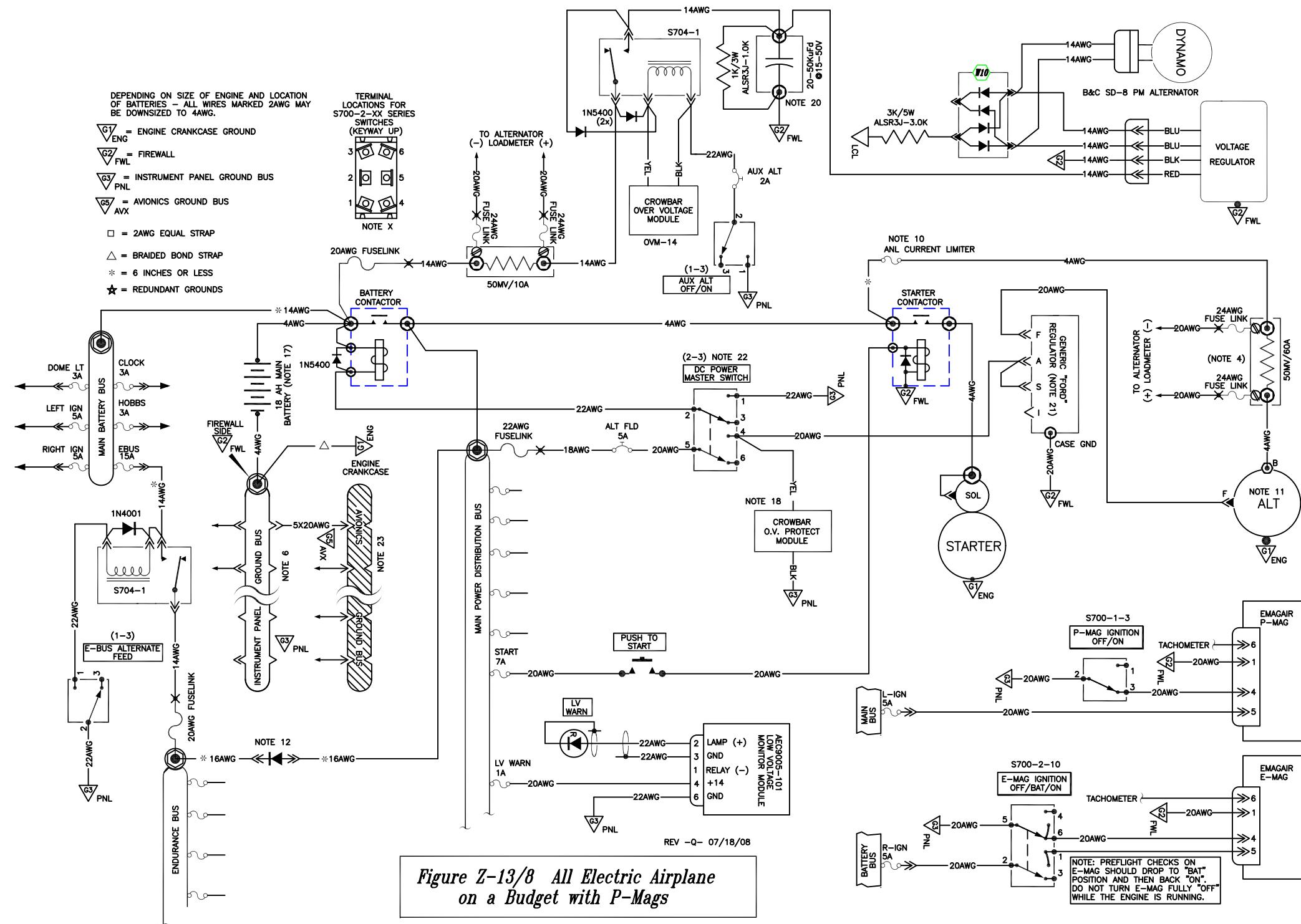
△ = BRAIDED BOND STRAP

\* = 6 INCHES OR LESS

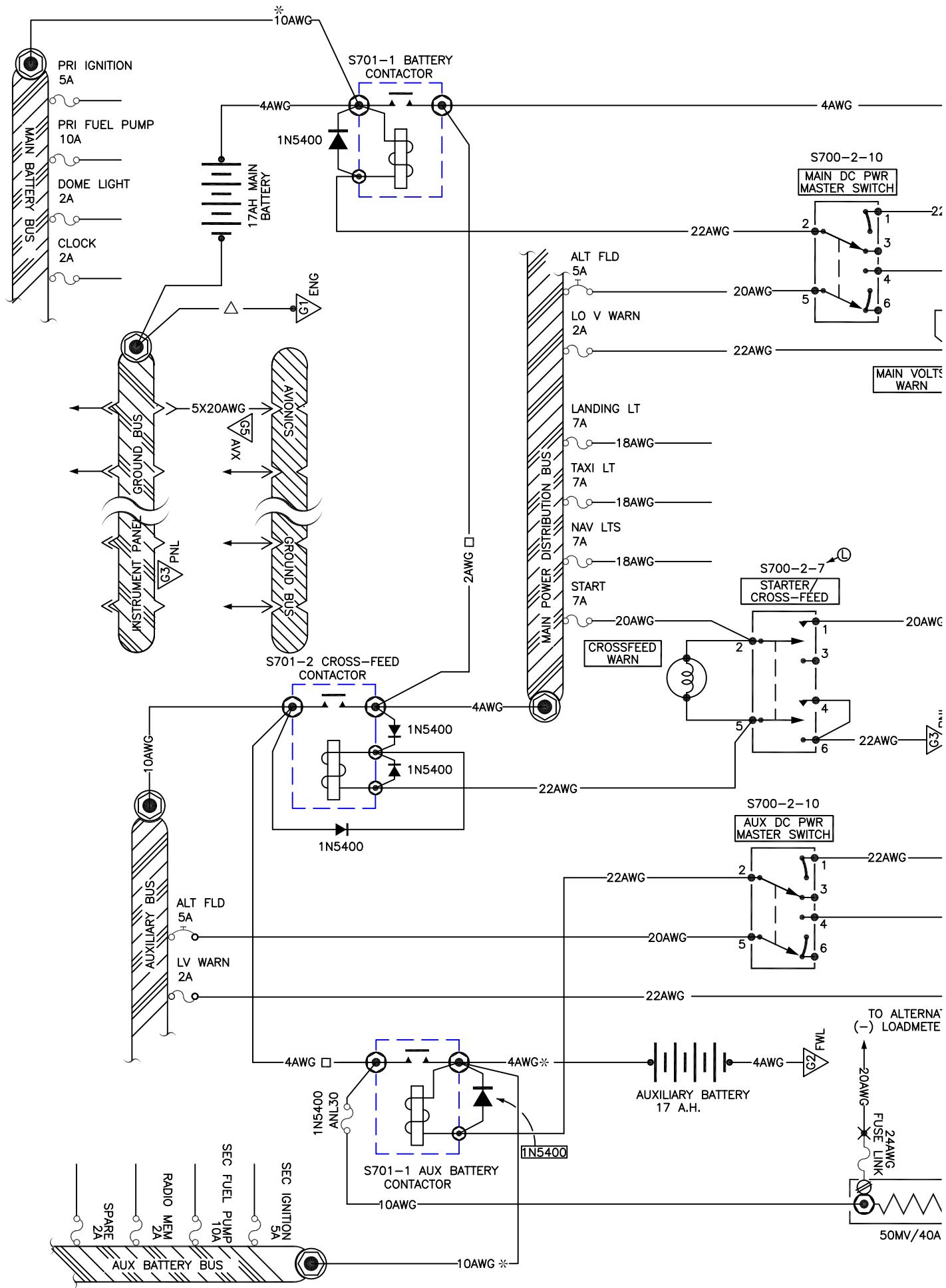
Figure Z-12. Single Battery, Dual Alternator

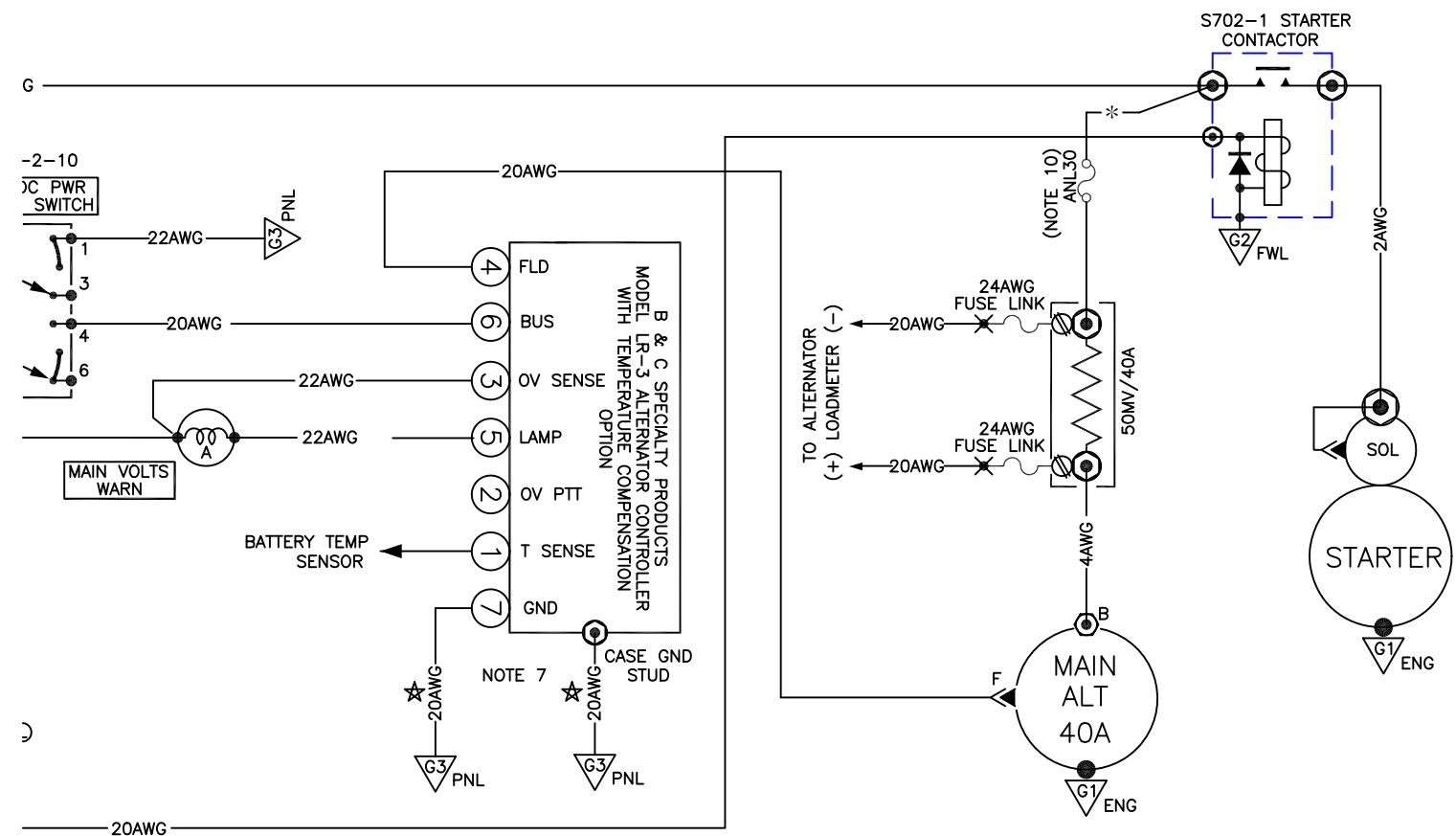
REV -M- 12/28/05





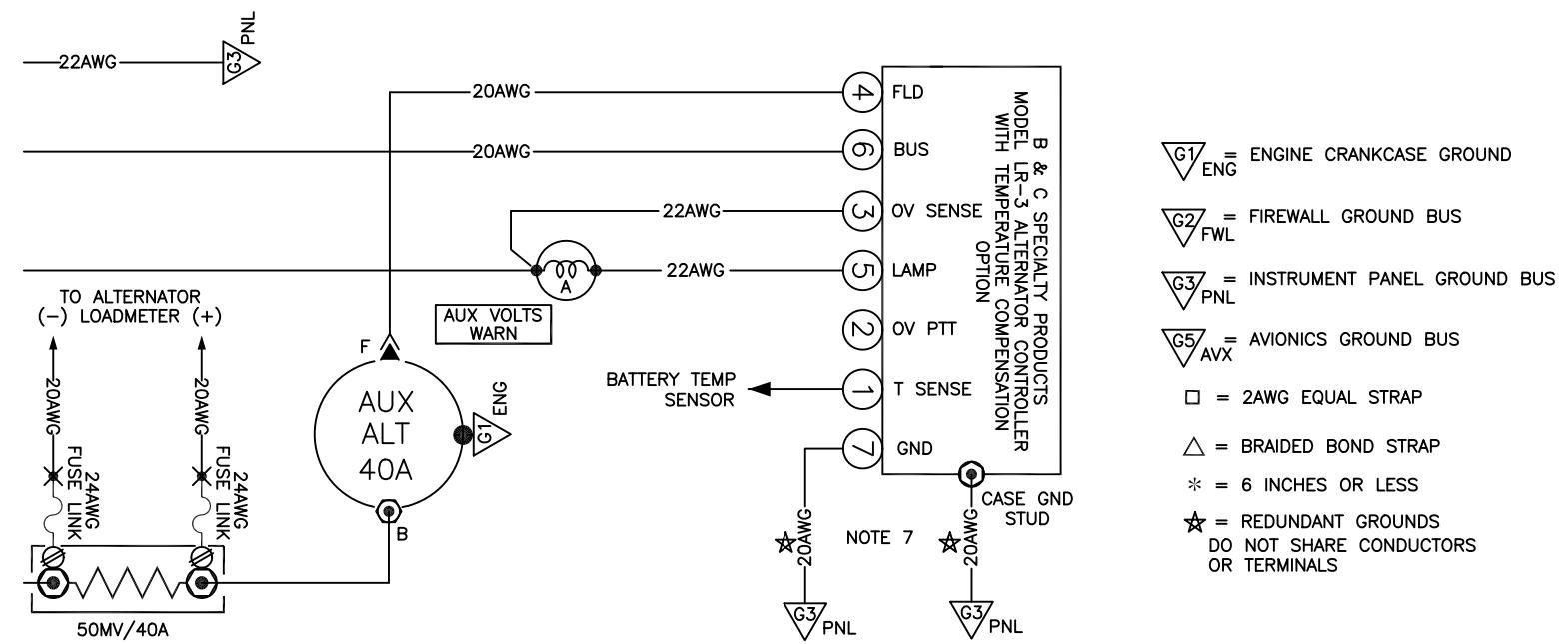
*Figure Z-13/8 All Electric Airplane  
on a Budget with P-Mags*





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*Figure Z-14 Dual Battery, Dual Alternator, Split Bus*



**G1 ENG** = ENGINE CRANKCASE GROUND

**G2 FWL** = FIREWALL GROUND BUS

**G3 PNL** = INSTRUMENT PANEL GROUND BUS

**G5 AVX** = AVIONICS GROUND BUS

□ = 2AWG EQUAL STRAP

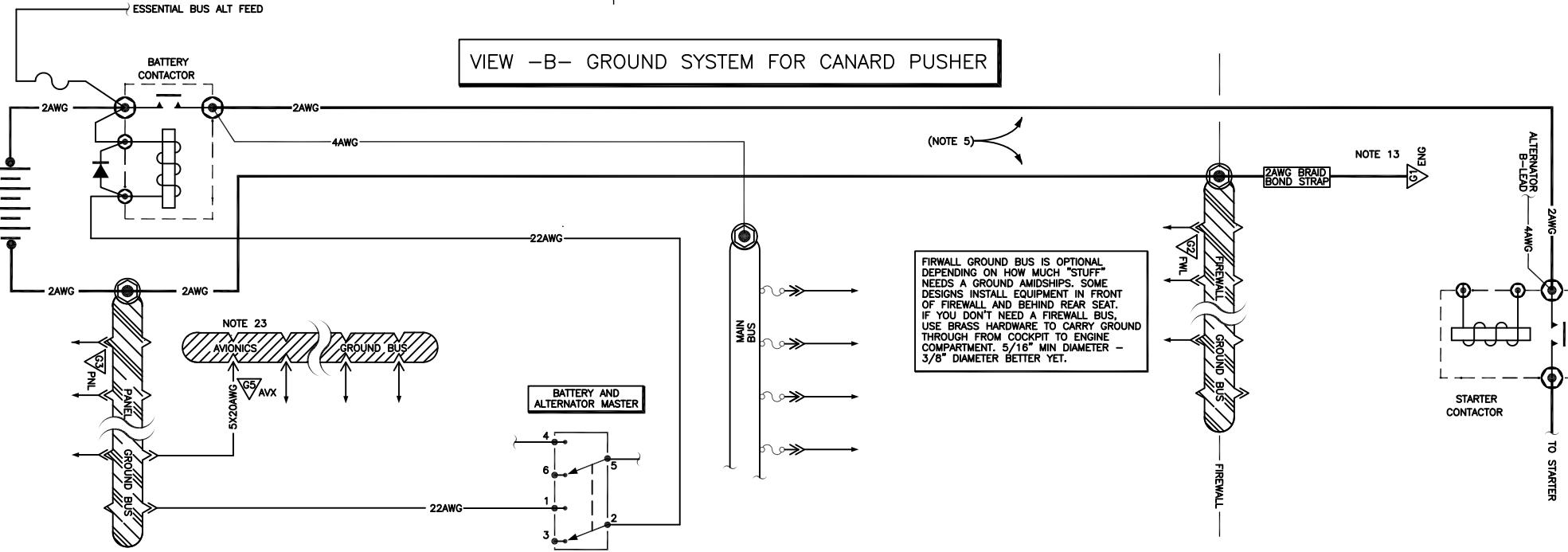
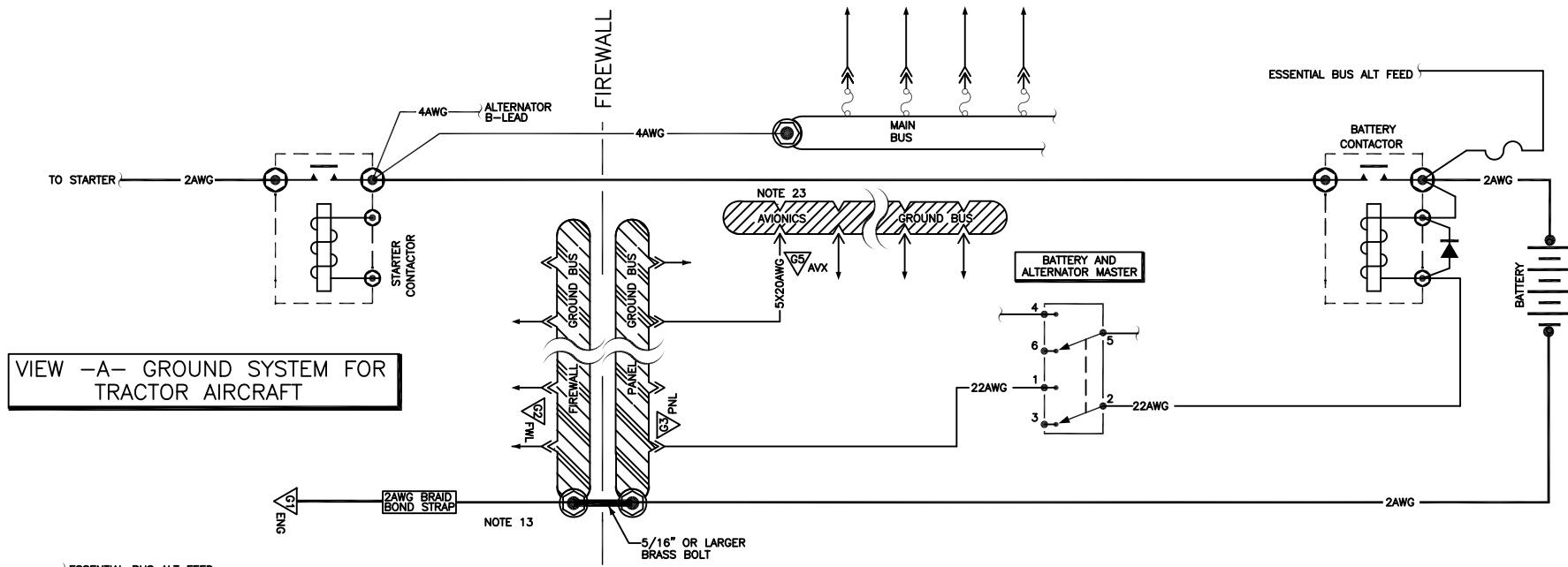
△ = BRAIDED BOND STRAP

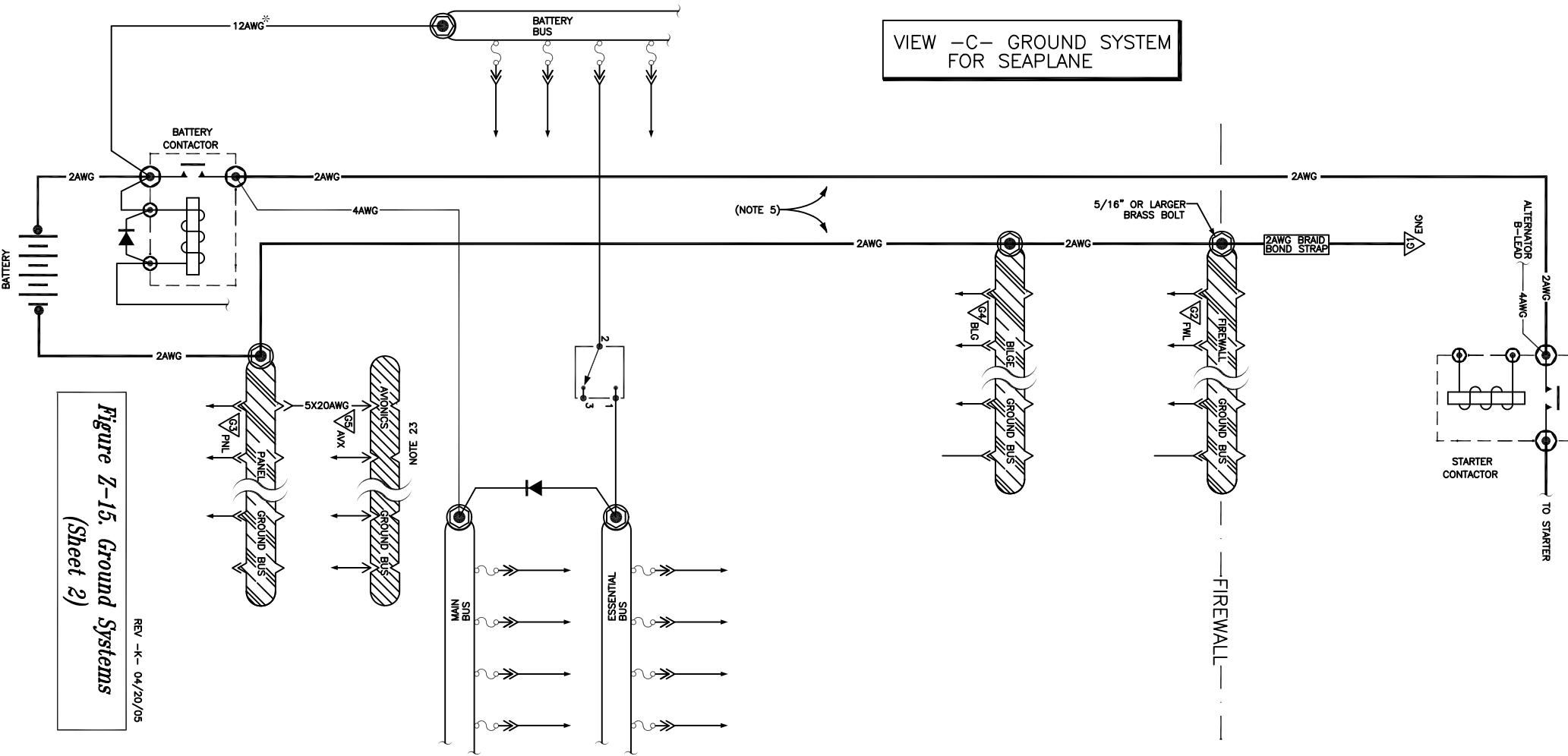
\* = 6 INCHES OR LESS

★ = REDUNDANT GROUNDS  
DO NOT SHARE CONDUCTORS  
OR TERMINALS

Figure Z-15. Ground Systems (Sheet 1)

-k- 04/20/05





*Figure Z-15. Ground Systems (Sheet 2)*

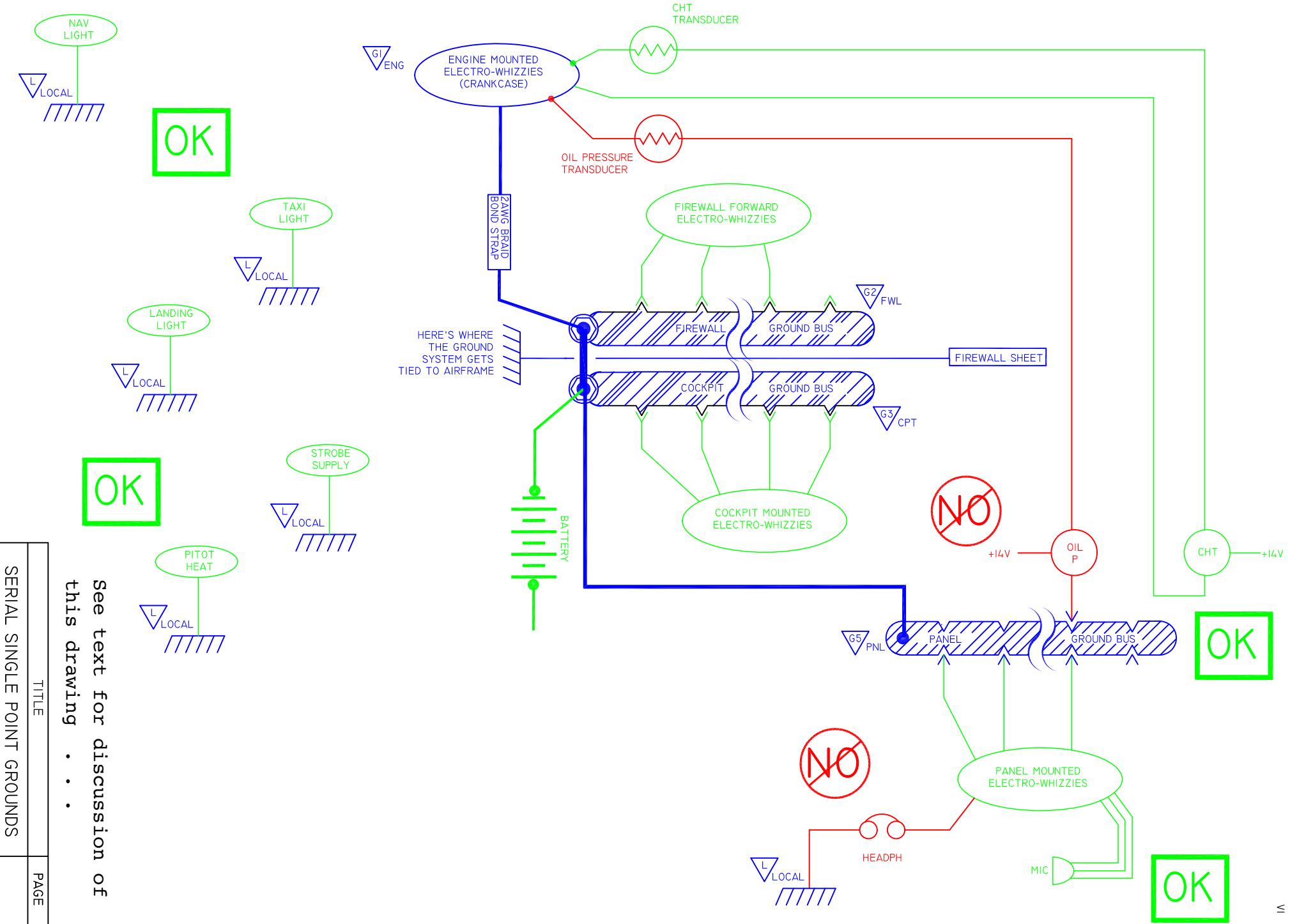


Figure Z-16. Rotax 912/914 System

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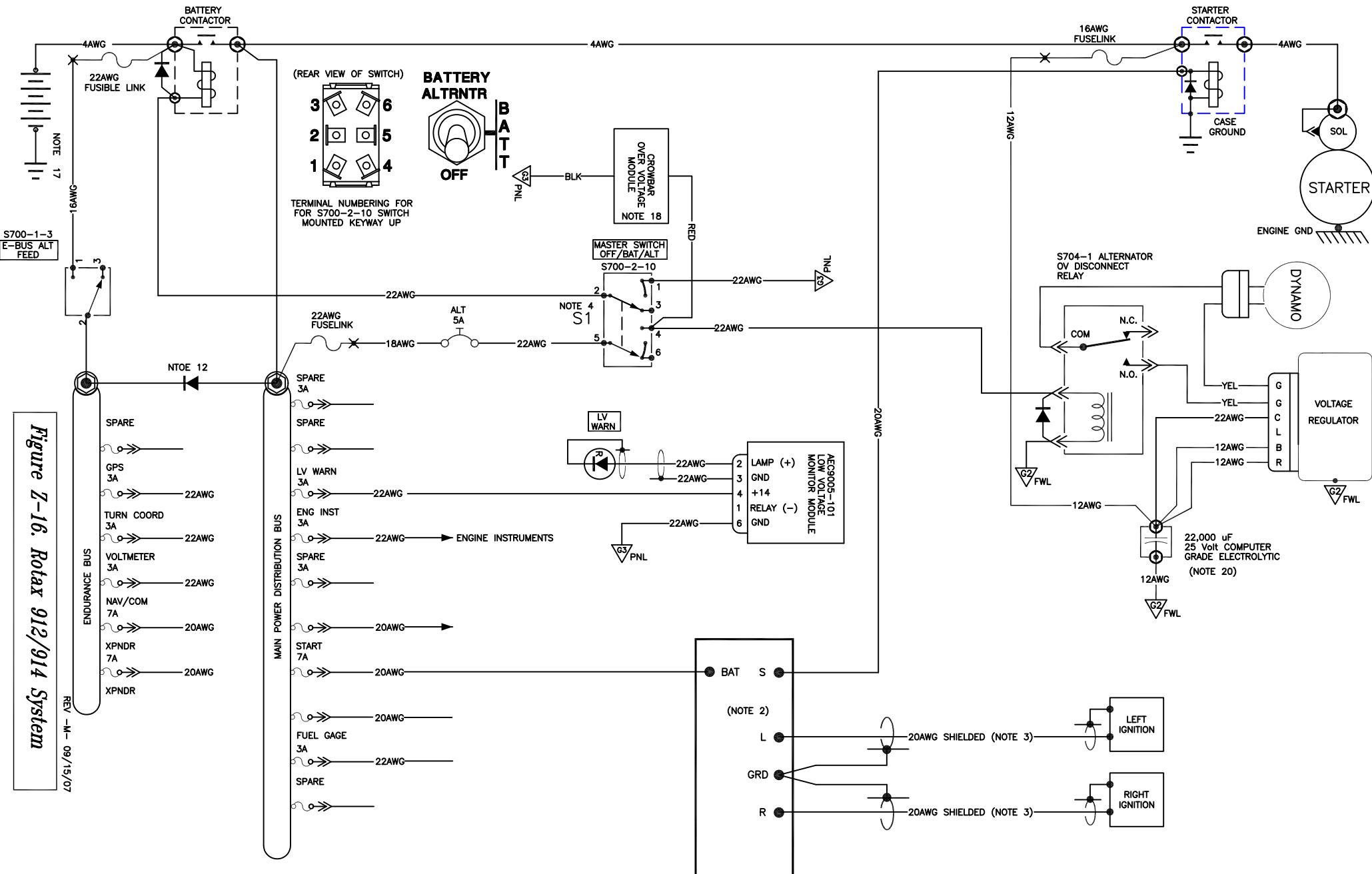


Figure Z-17. Small Rotax System (or Aircraft with B&C SD-8 Alternator as Primary Engine Driven Power).

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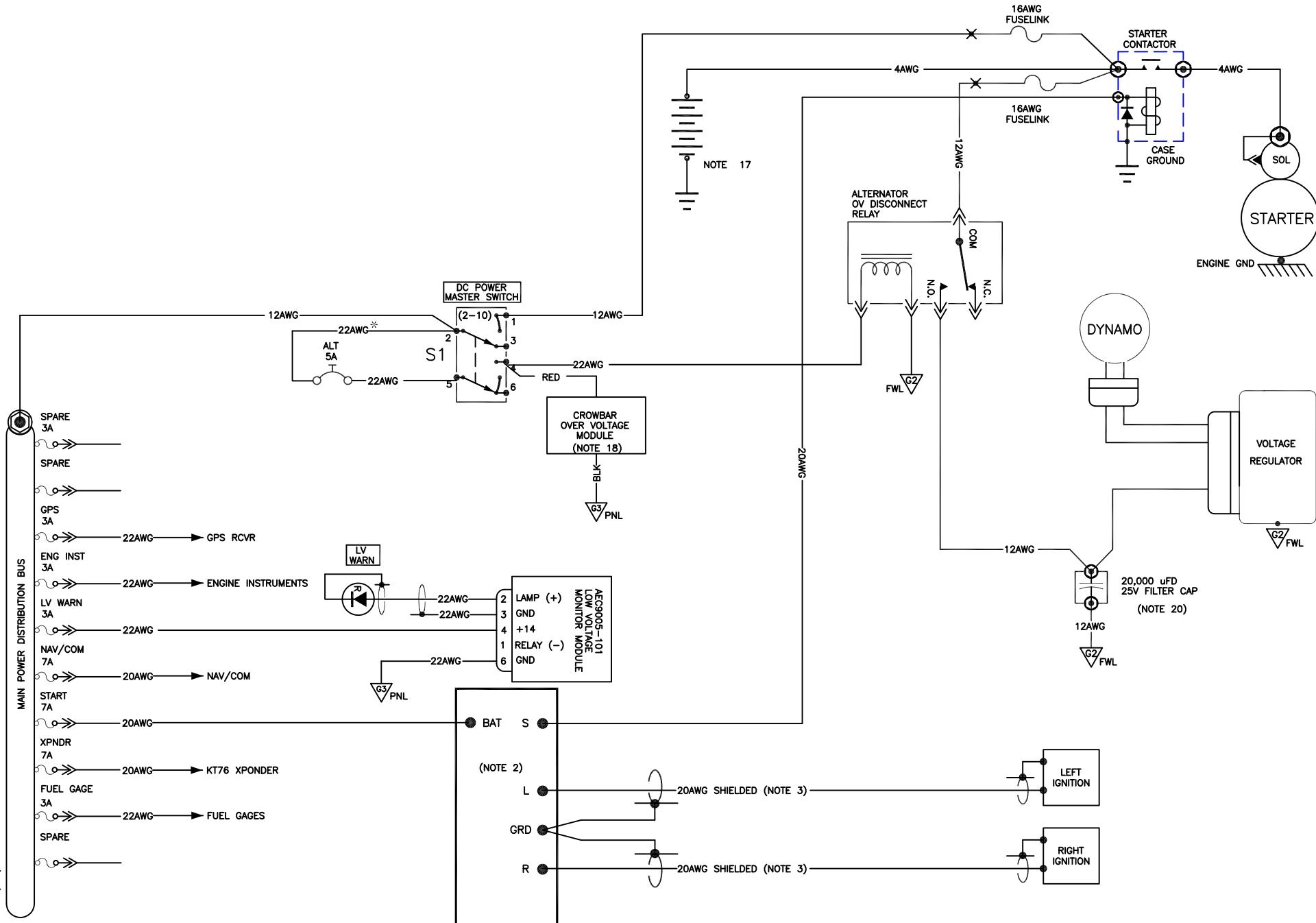
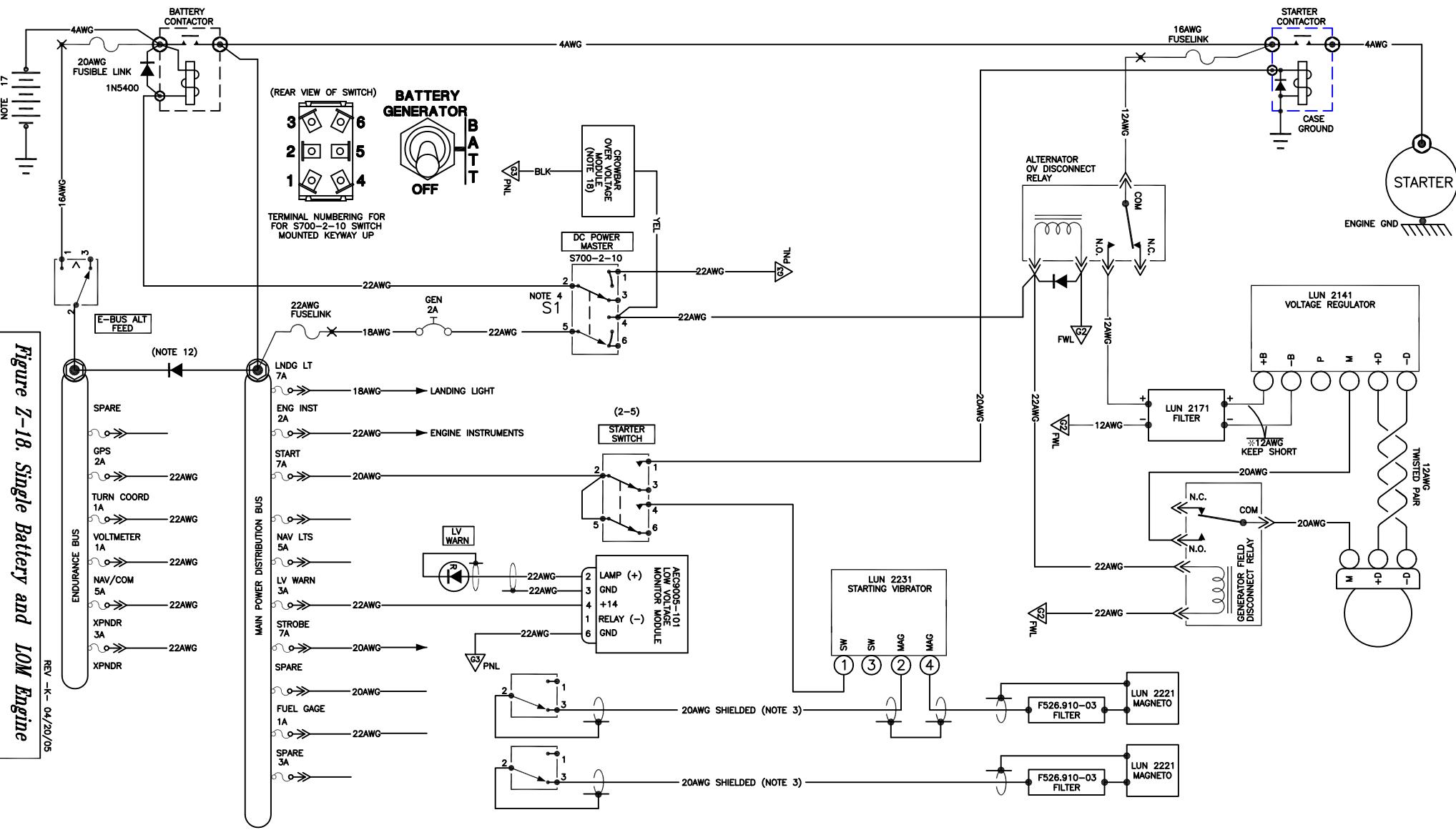
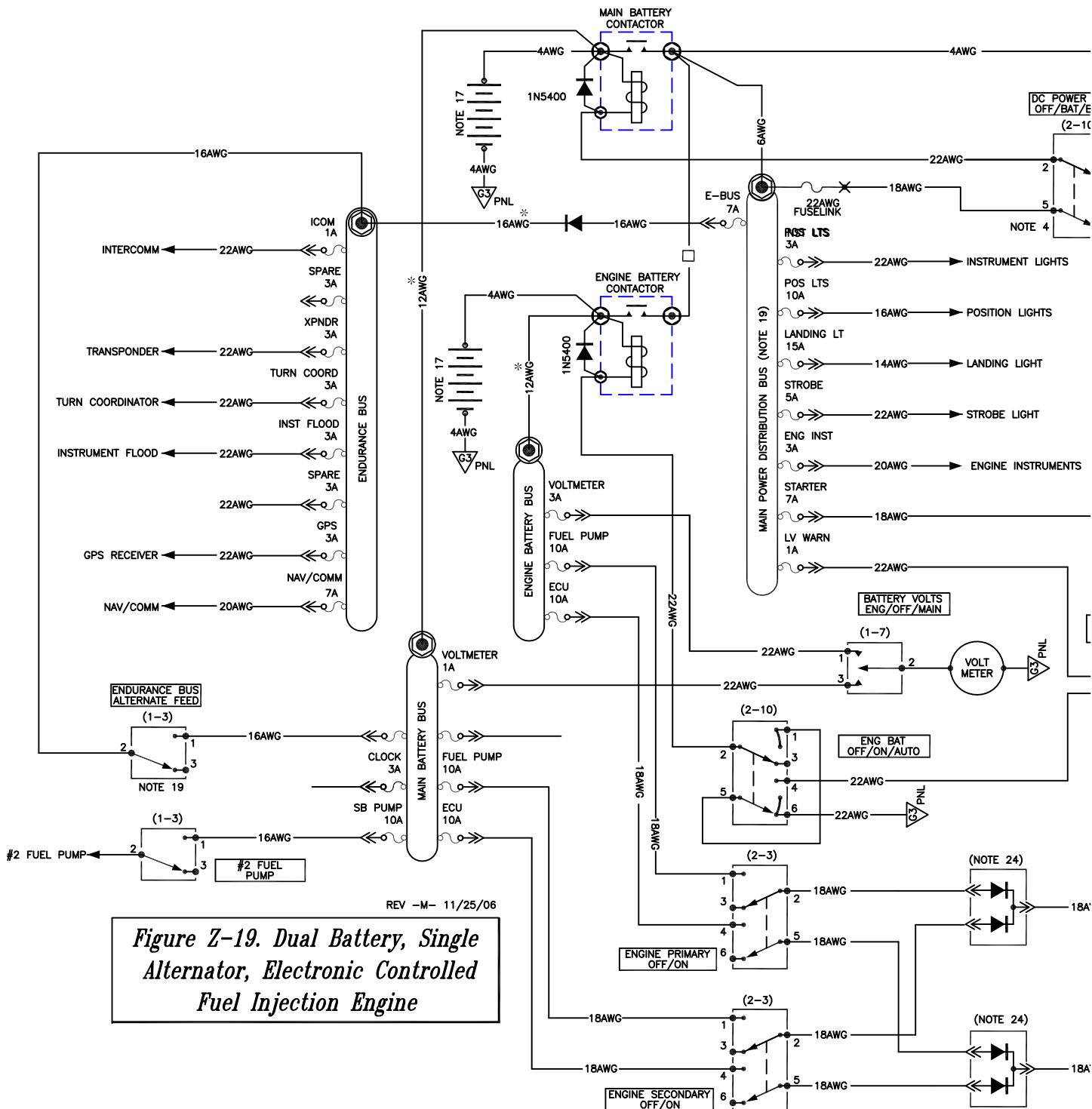
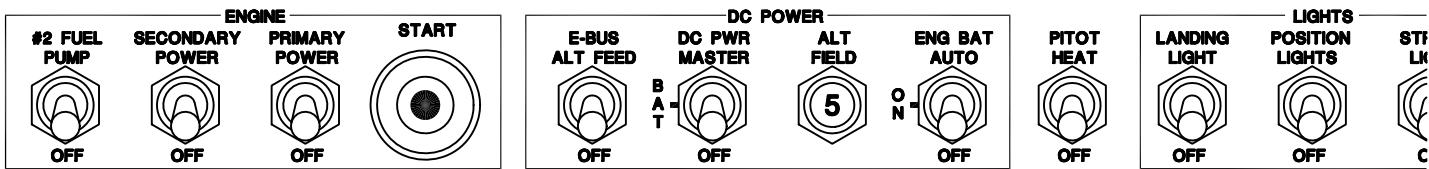


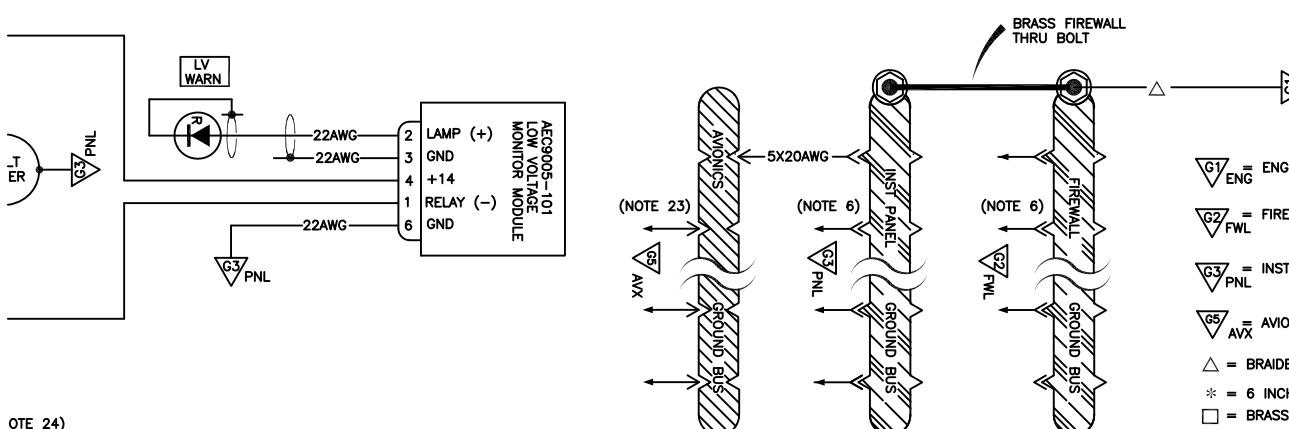
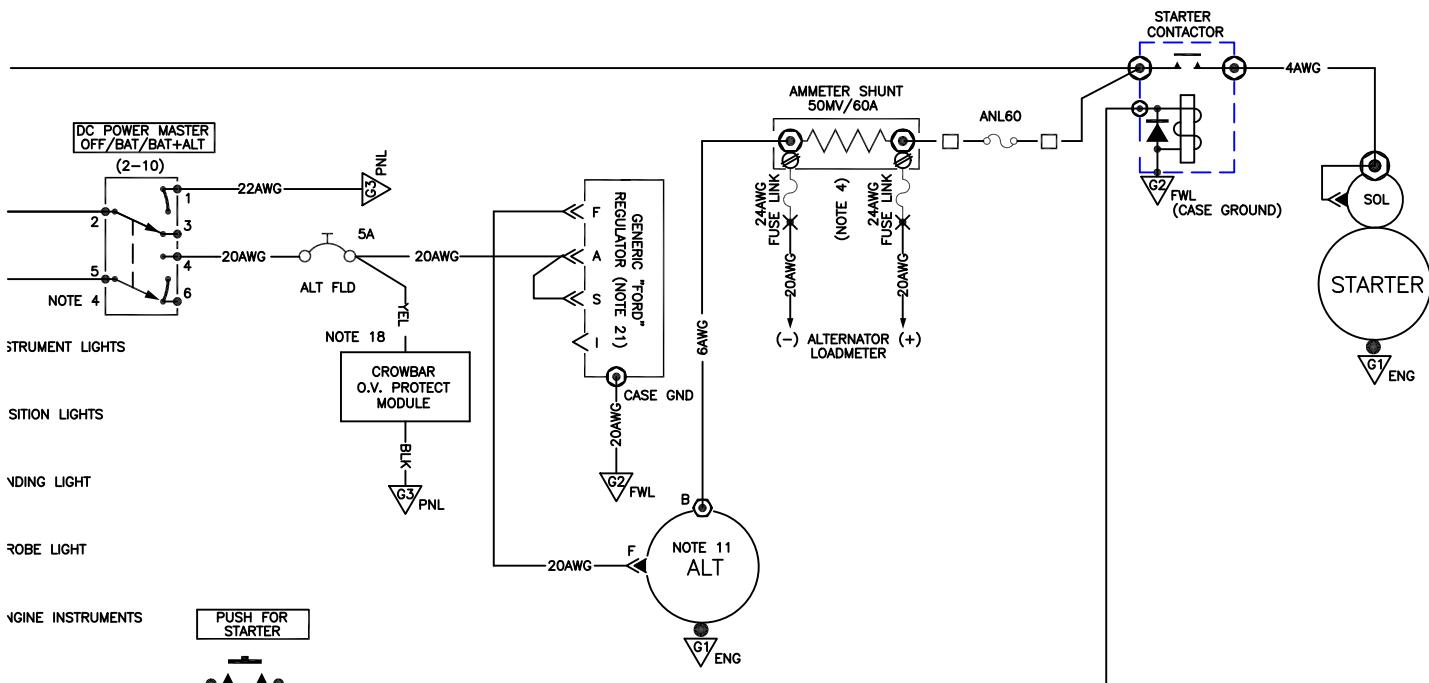
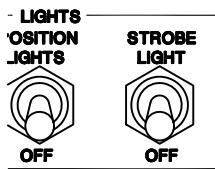
Figure Z-18. Single Battery and LOM Engine

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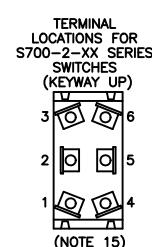


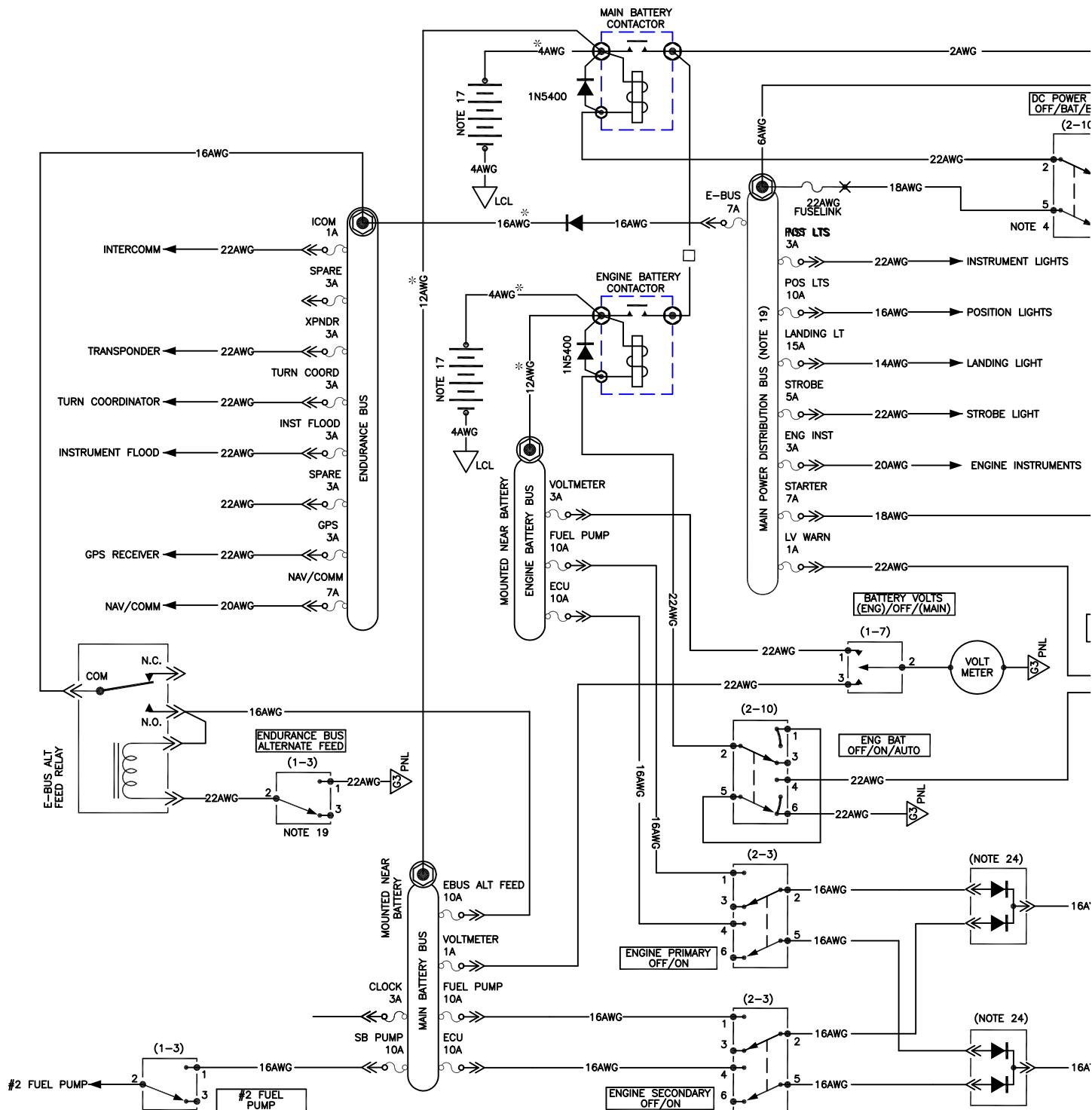
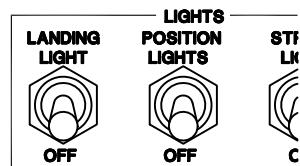
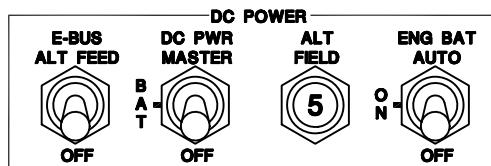
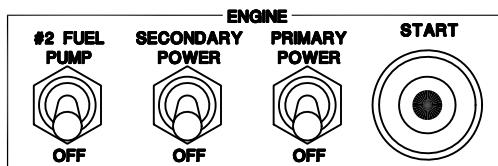


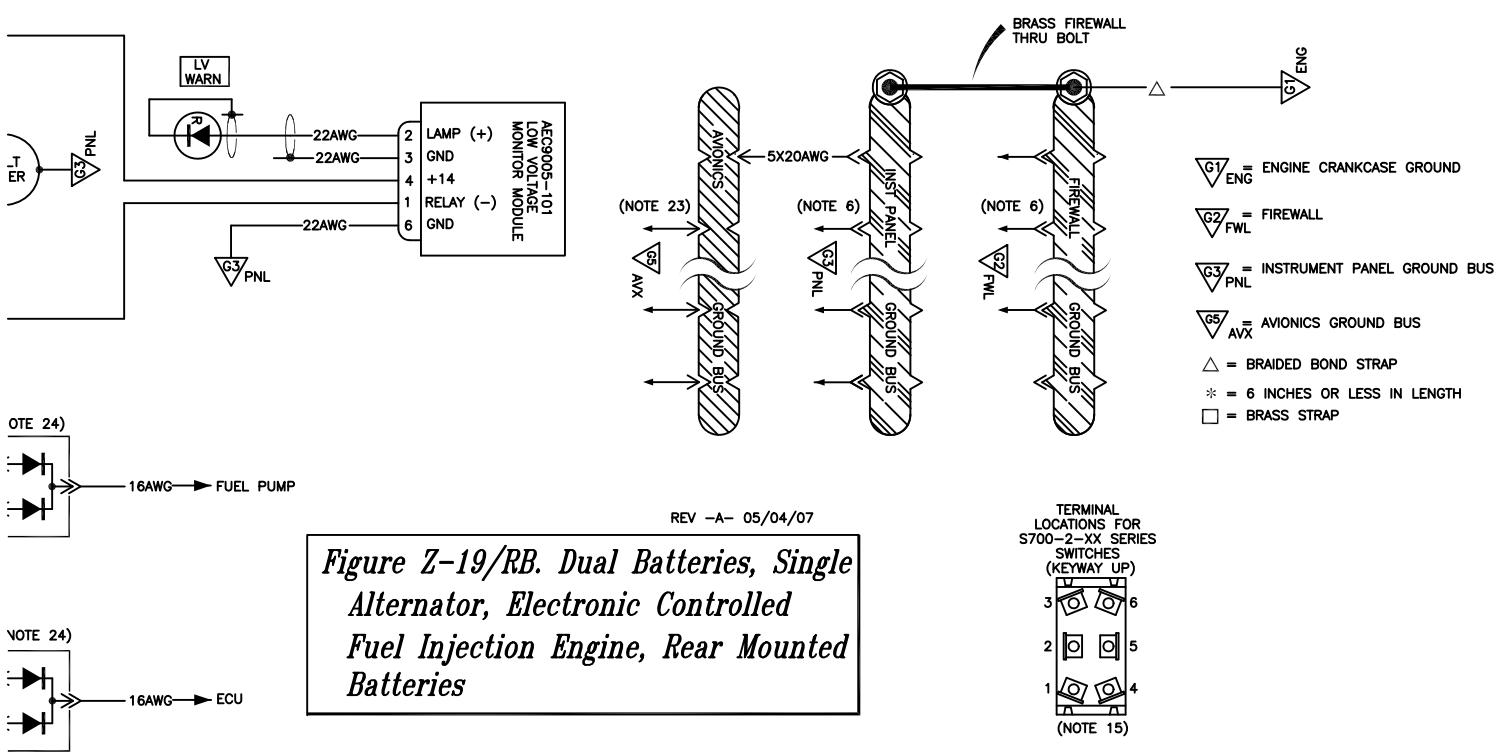
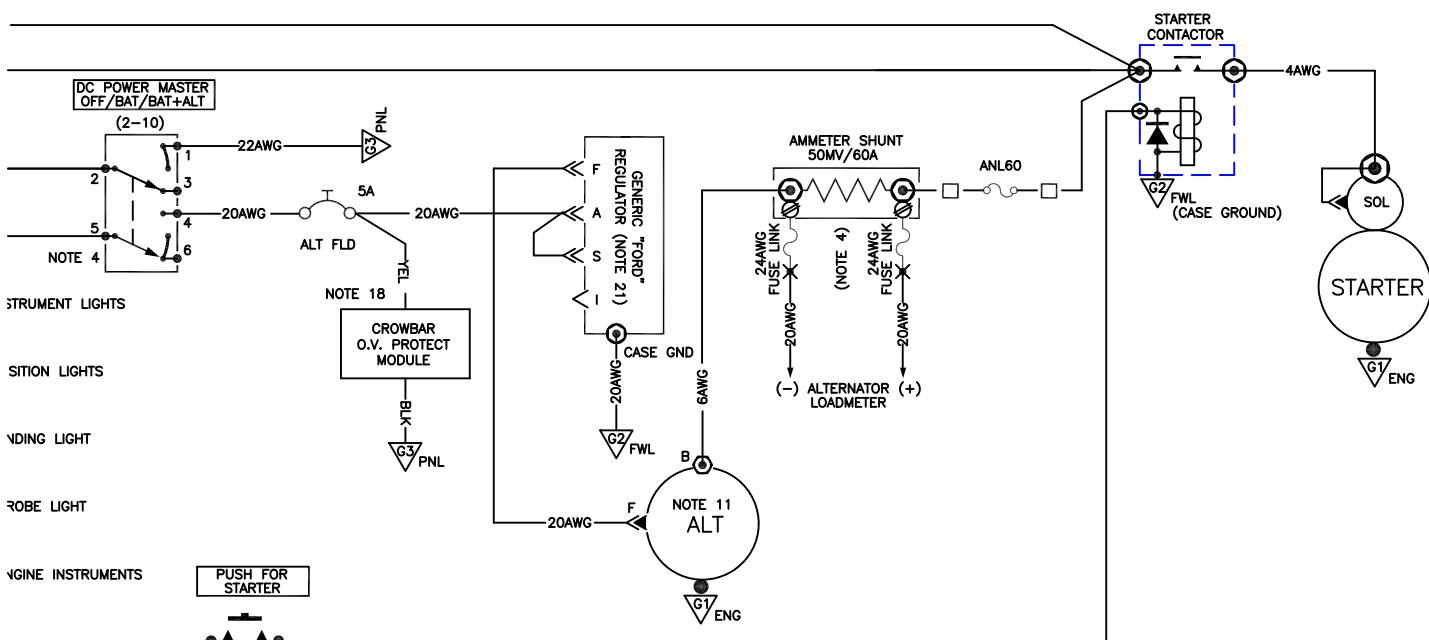
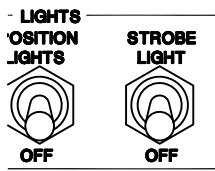
*Figure Z-19. Dual Battery, Single Alternator, Electronic Controlled Fuel Injection Engine*



 **G1** = ENGINE CRANKCASE GROUND  
 **G2** = FIREWALL  
 **G3** = INSTRUMENT PANEL GROUND BUS  
 **G4** = AVIONICS GROUND BUS  
 **G5** = BRAIDED BOND STRAP  
 **G6** = 6 INCHES OR LESS  
 **G7** = BRASS STRAP



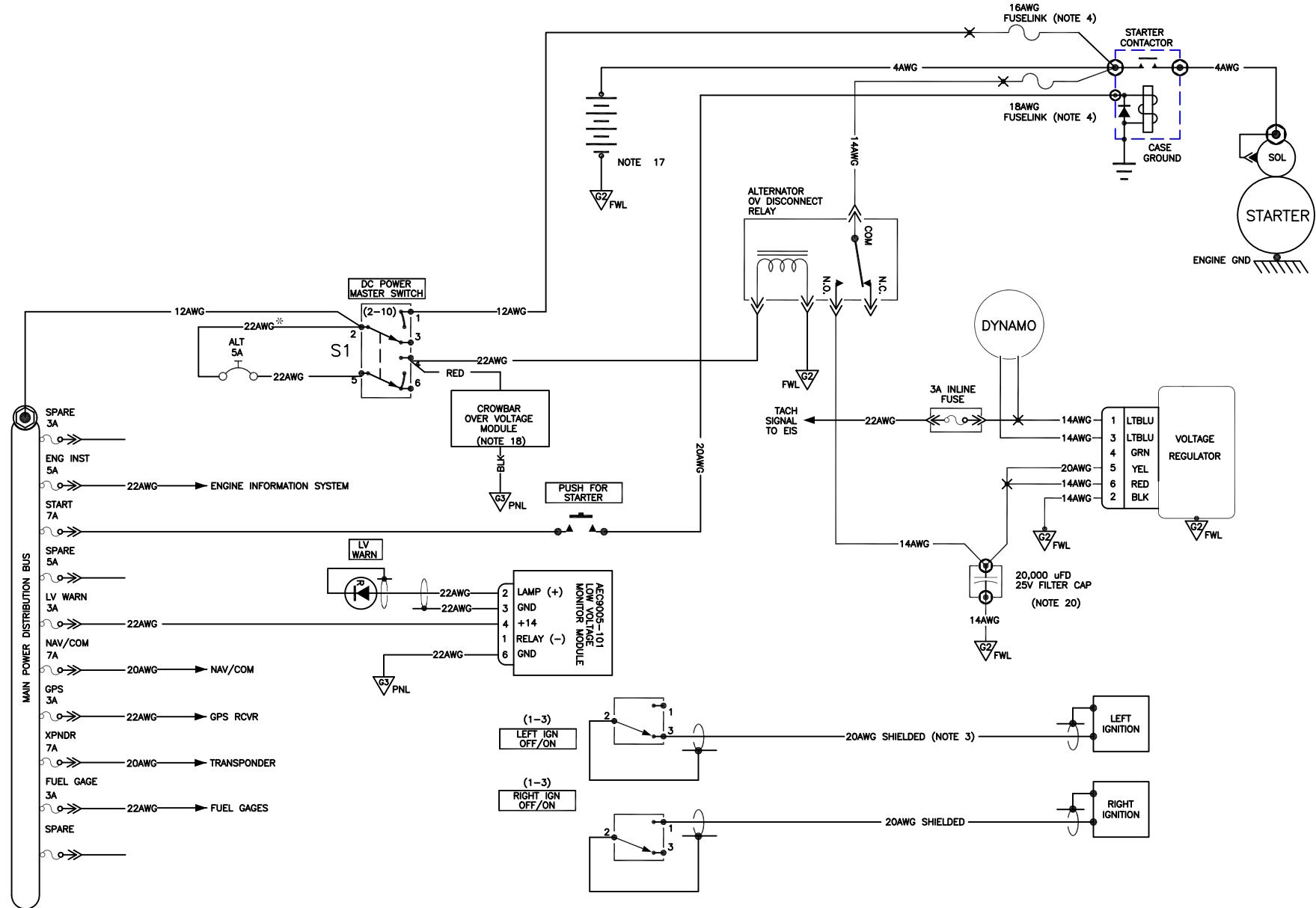




*Figure Z-19/RB. Dual Batteries, Single Alternator, Electronic Controlled Fuel Injection Engine, Rear Mounted Batteries*

Figure Z-20. Small Jabiru System

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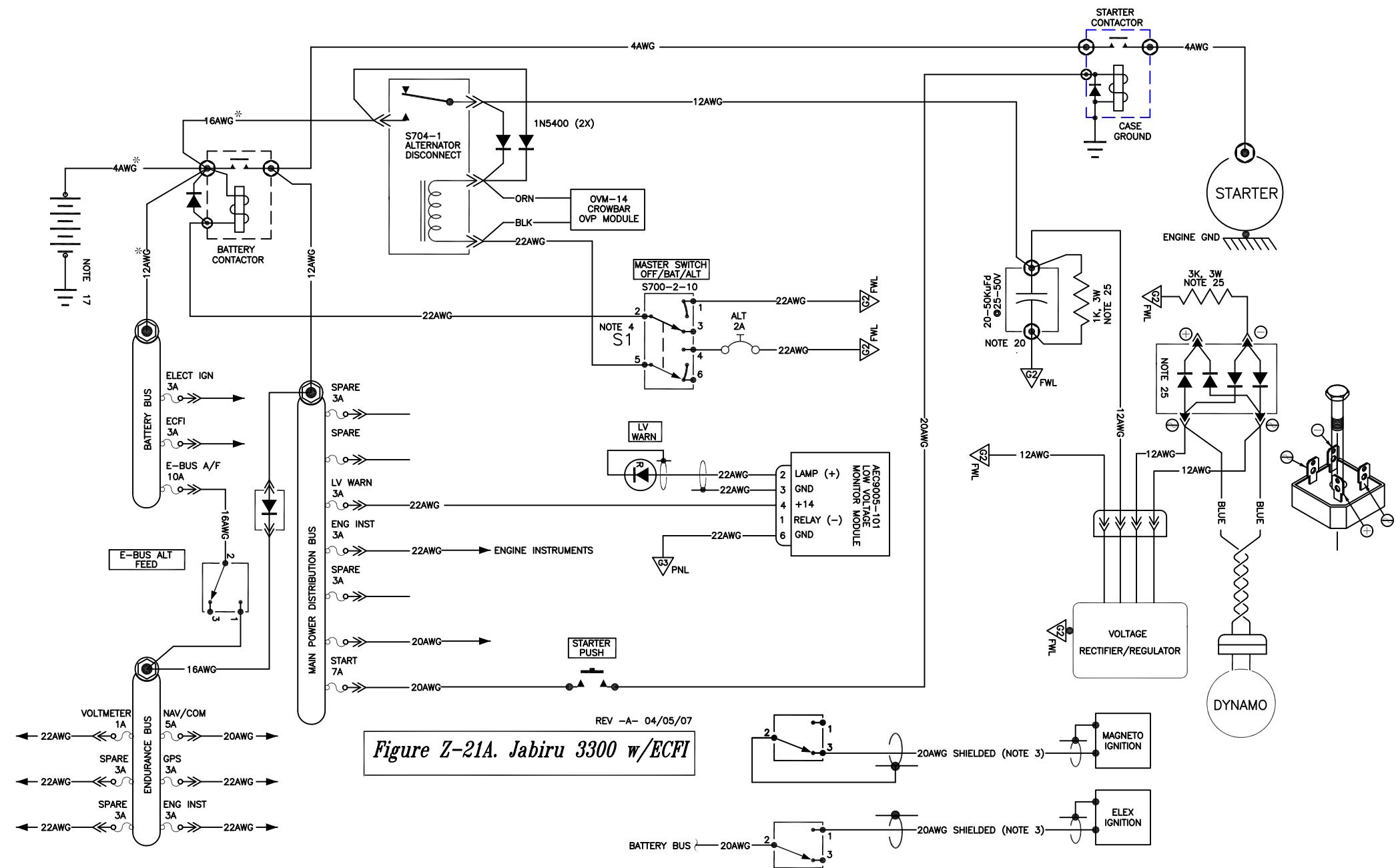


Figure Z-21A. Jabiru 3300 w/ECFI

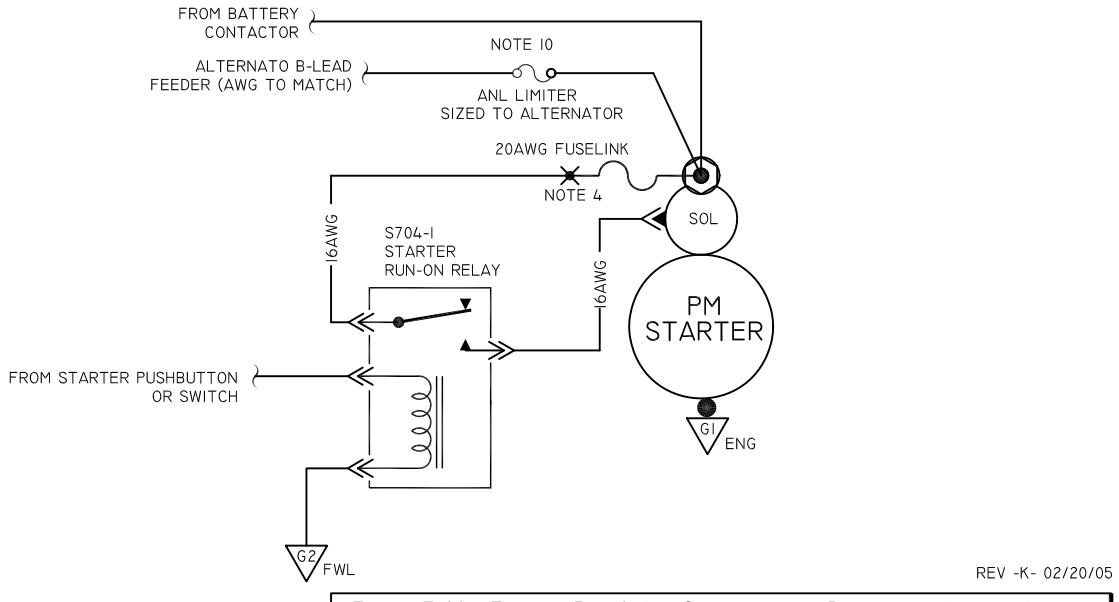
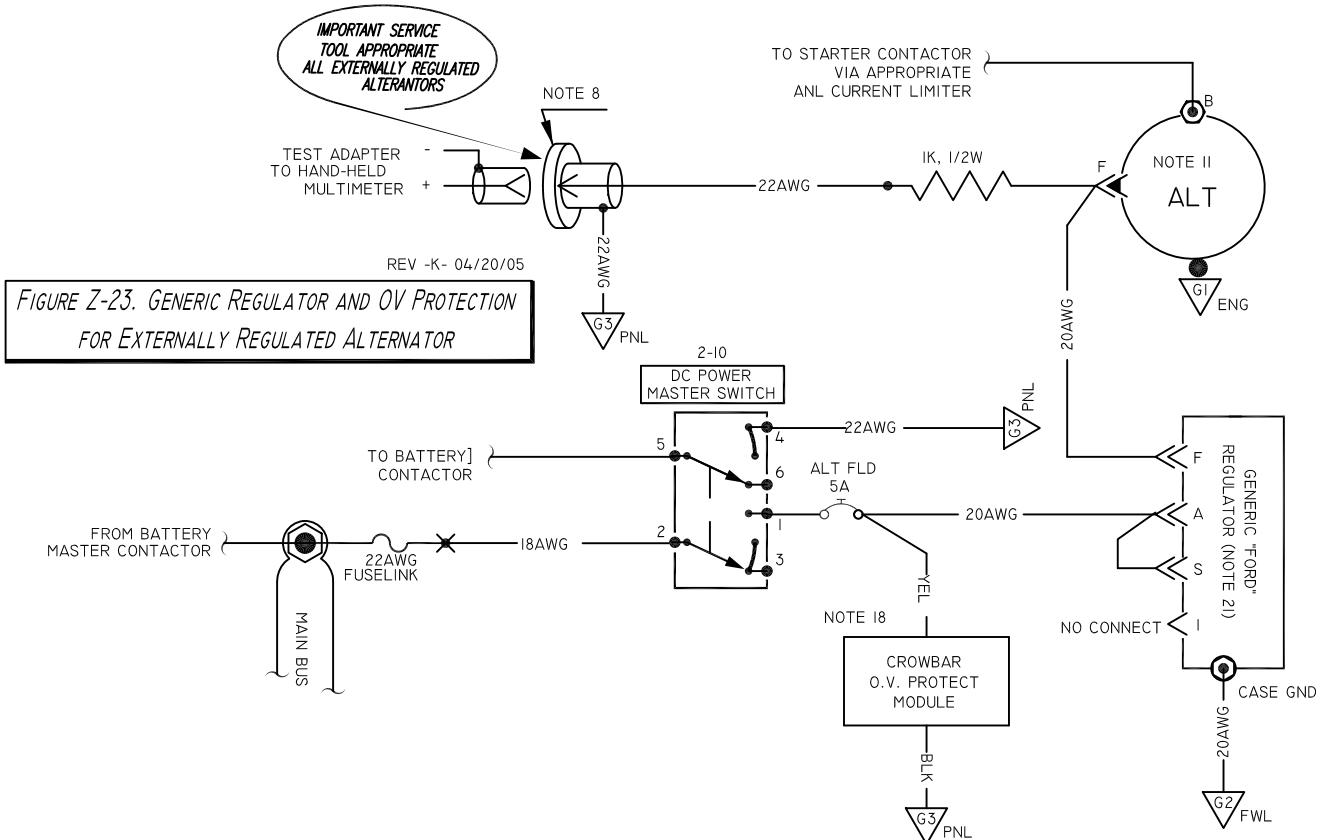


FIGURE Z-22. FIX FOR "RUN-ON" IN STARTERS WITH PERMANENT MAGNET MOTORS.



# INTERIM

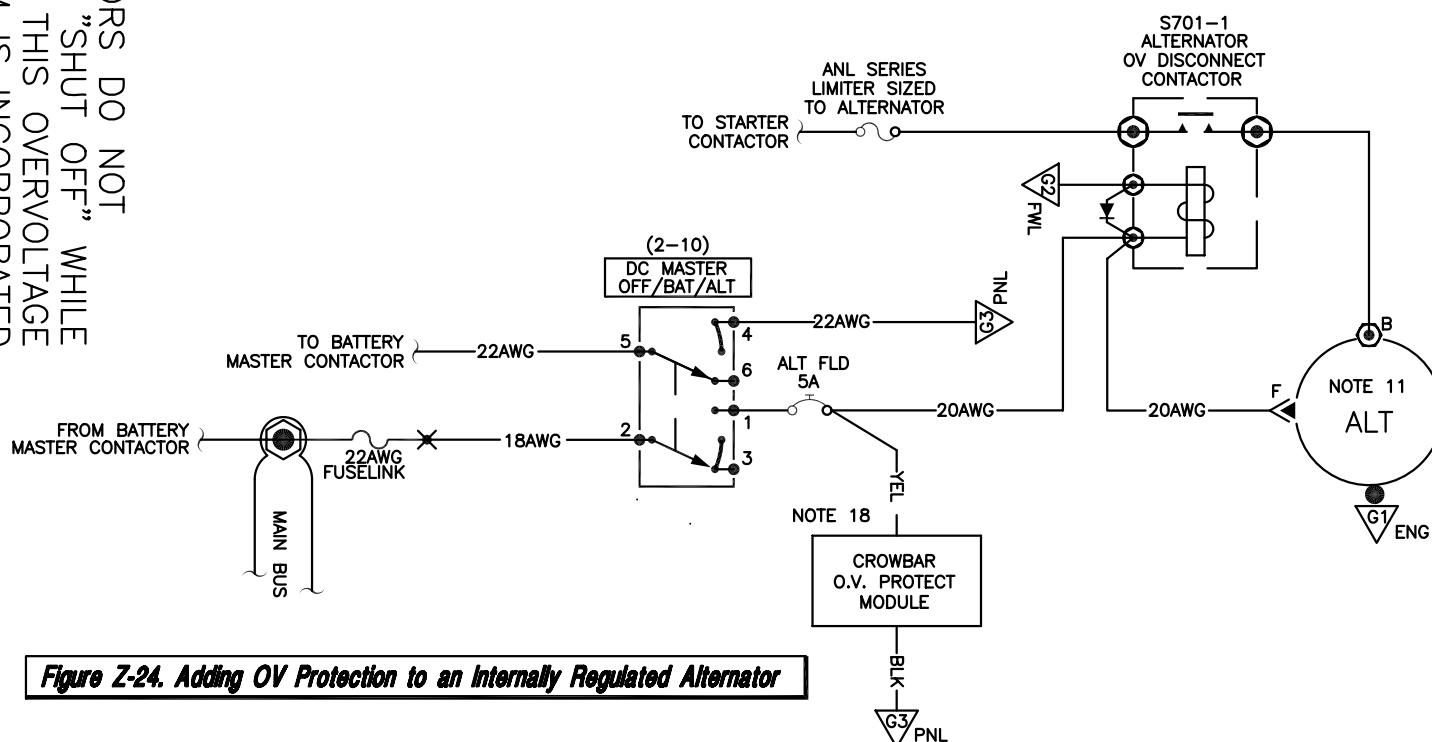


Figure Z-24. Adding OV Protection to an Internally Regulated Alternator

NOTE:  
SOME ALTERNATORS DO NOT  
TOLERATE BEING "SHUT OFF" WHILE  
UNDER LOAD. IF THIS OVERVOLTAGE  
CONTROL SYSTEM IS INCORPORATED,  
IT'S IMPORTANT NOT TO SHUT THE ALTERNATOR  
"OFF" ANY TIME THE ENGINE IS RUNNING  
EXCEPT EMERGENCIES.

THE PROPOSED SYSTEM DESCRIBED ON  
THE NEXT PAGE WILL EASILY REPLACE  
THE INTERIM SYSTEM AND HAS NO  
PROHIBITIONS AS TO WHEN AND HOW  
THE ALTERNATOR IS SWITCHED ON OR  
OFF.

# INTERIM

# PRELIMINARY

# PRELIMINARY

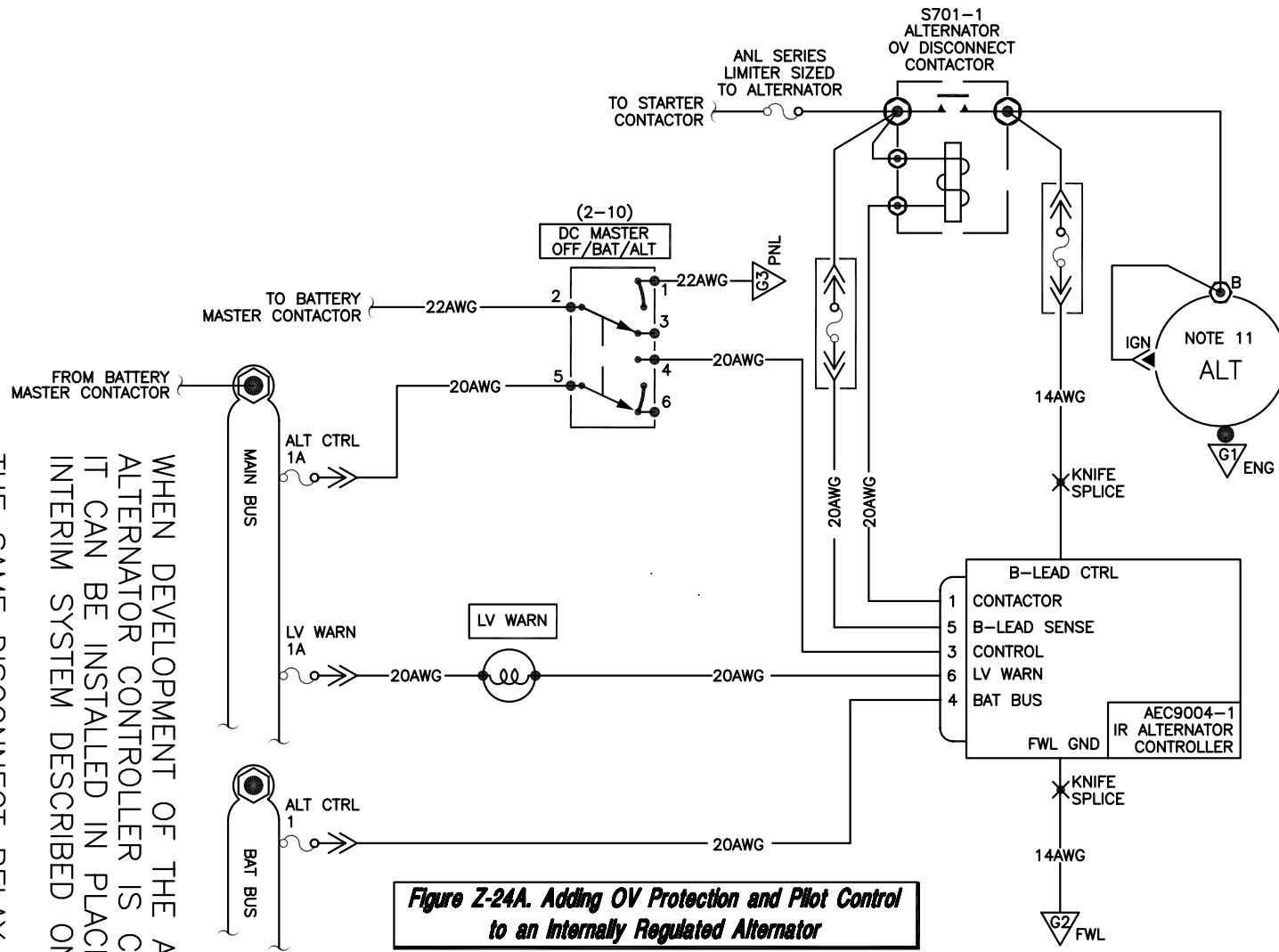
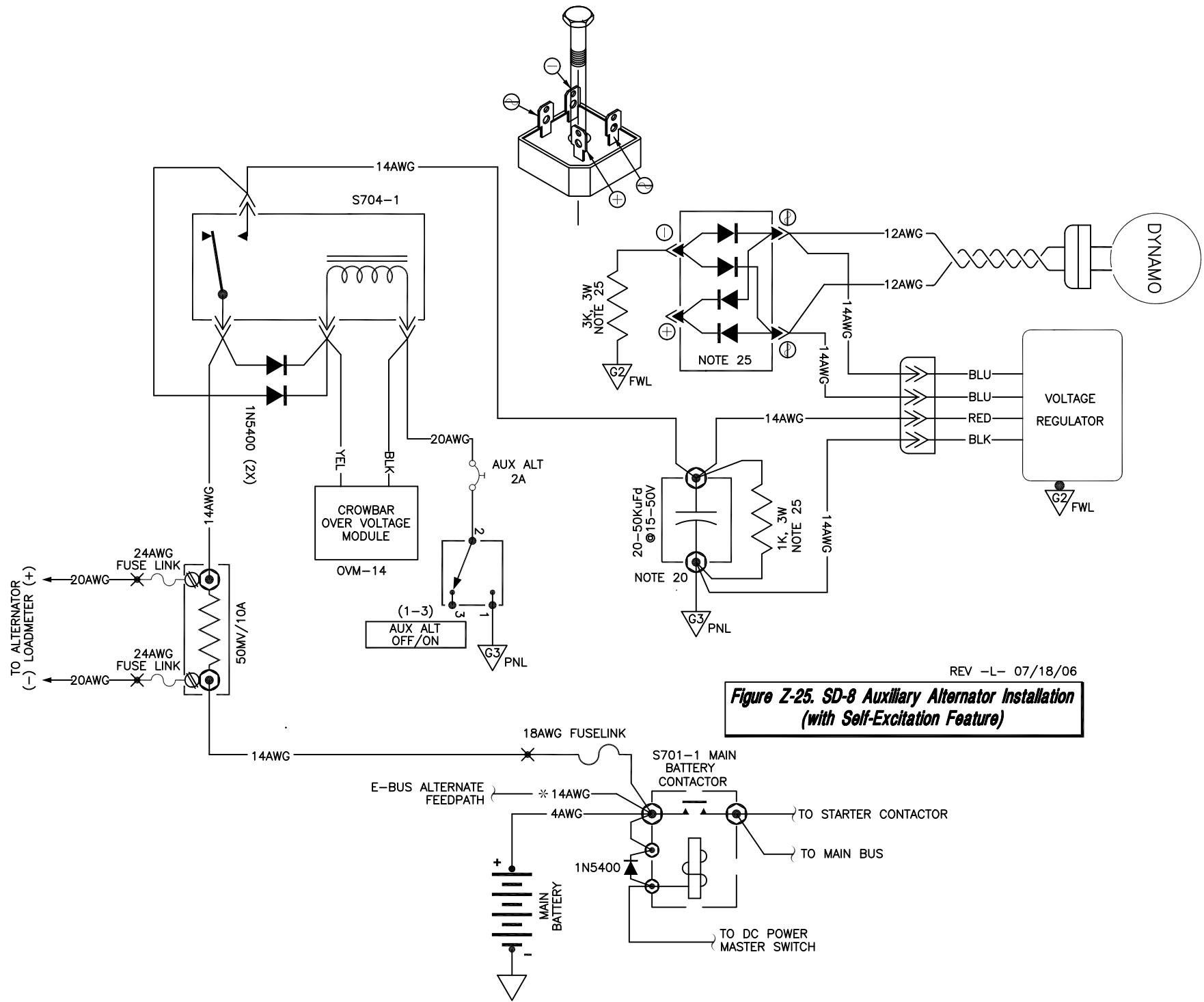


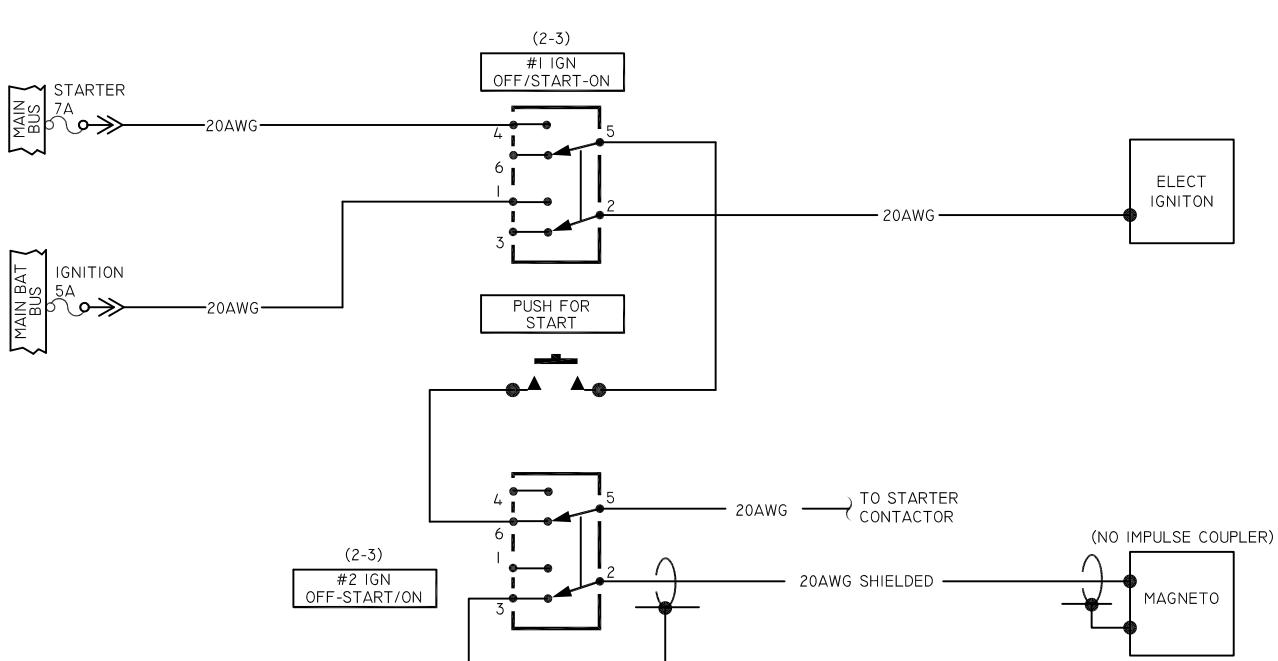
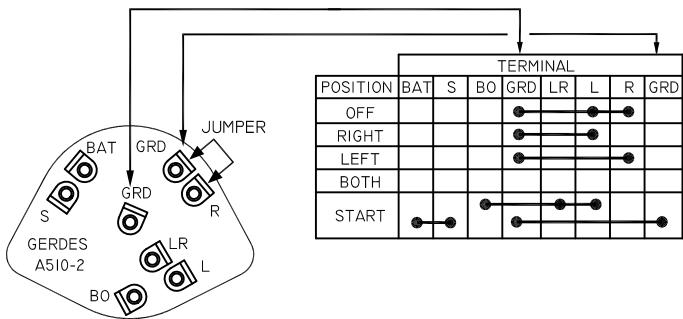
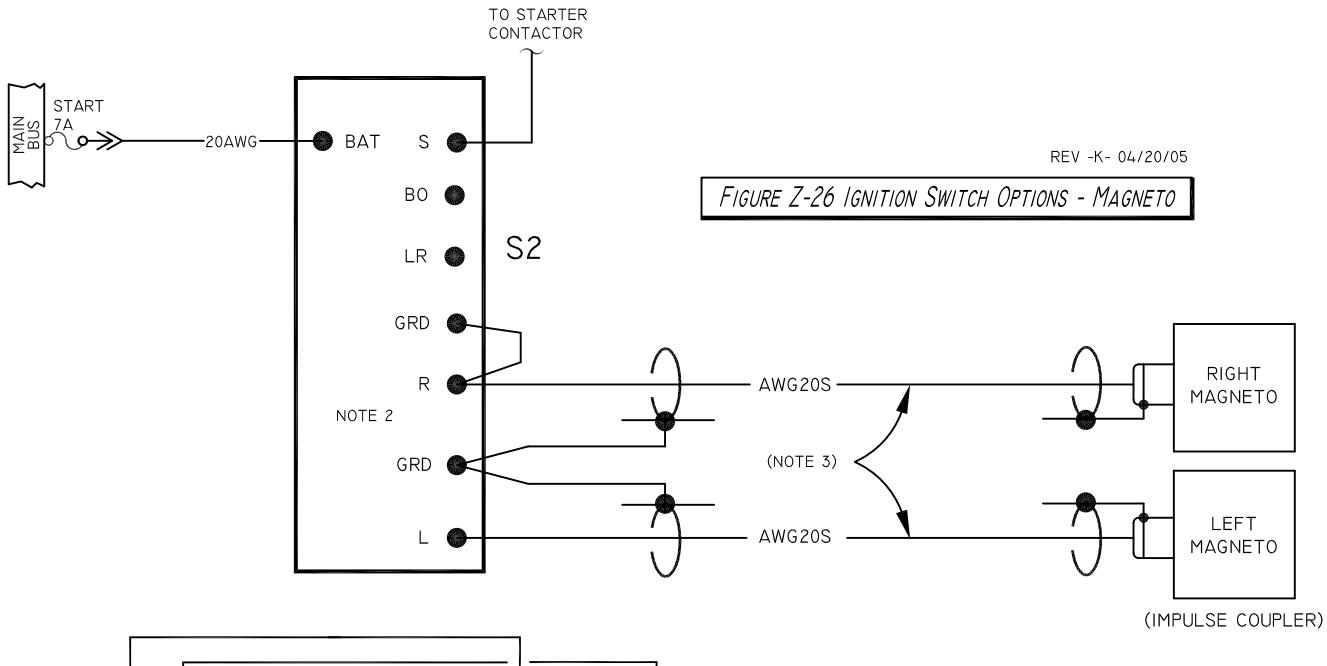
Figure Z-24A. Adding OV Protection and Pilot Control to an Internally Regulated Alternator

WHEN DEVELOPMENT OF THE AEC9004 ALTERNATOR CONTROLLER IS COMPLETE, IT CAN BE INSTALLED IN PLACE OF THE INTERIM SYSTEM DESCRIBED ON PAGE 1.0

THE SAME DISCONNECT RELAY AND CONTROL SWITCH ARE USED. THE OVM-14 MODULE IS DISCARDED. THE AEC9005 CONTROL MODULE ADDED AND A L.V. WARNING LIGHT IS ADDED.

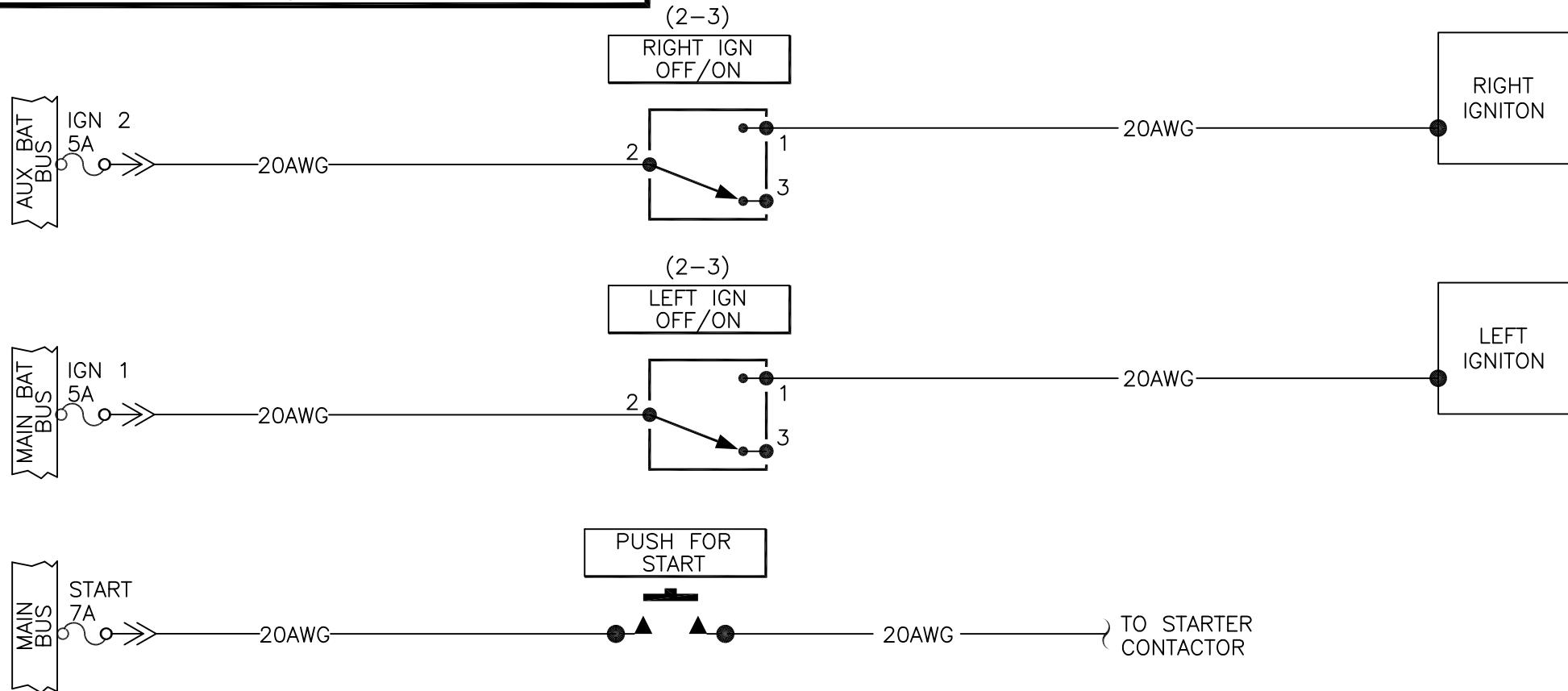


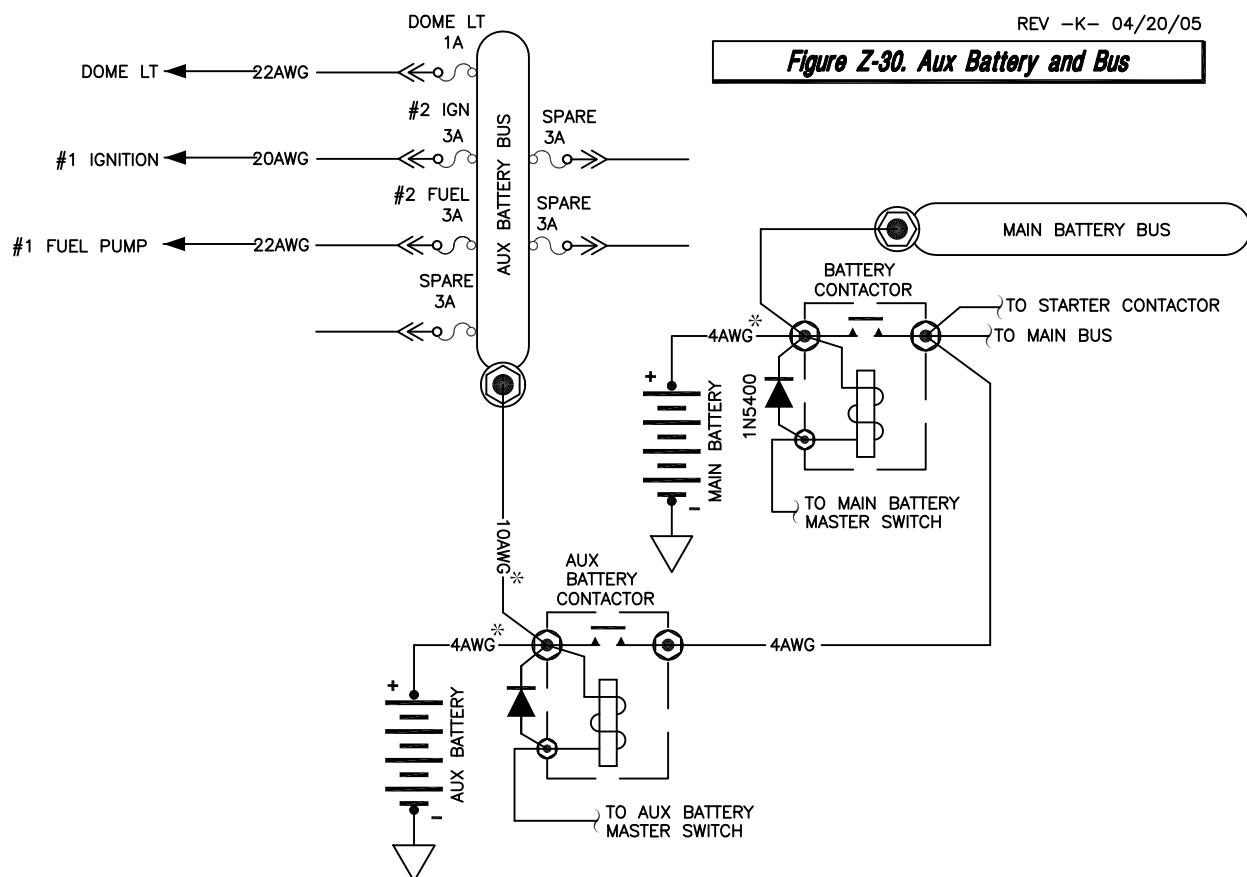
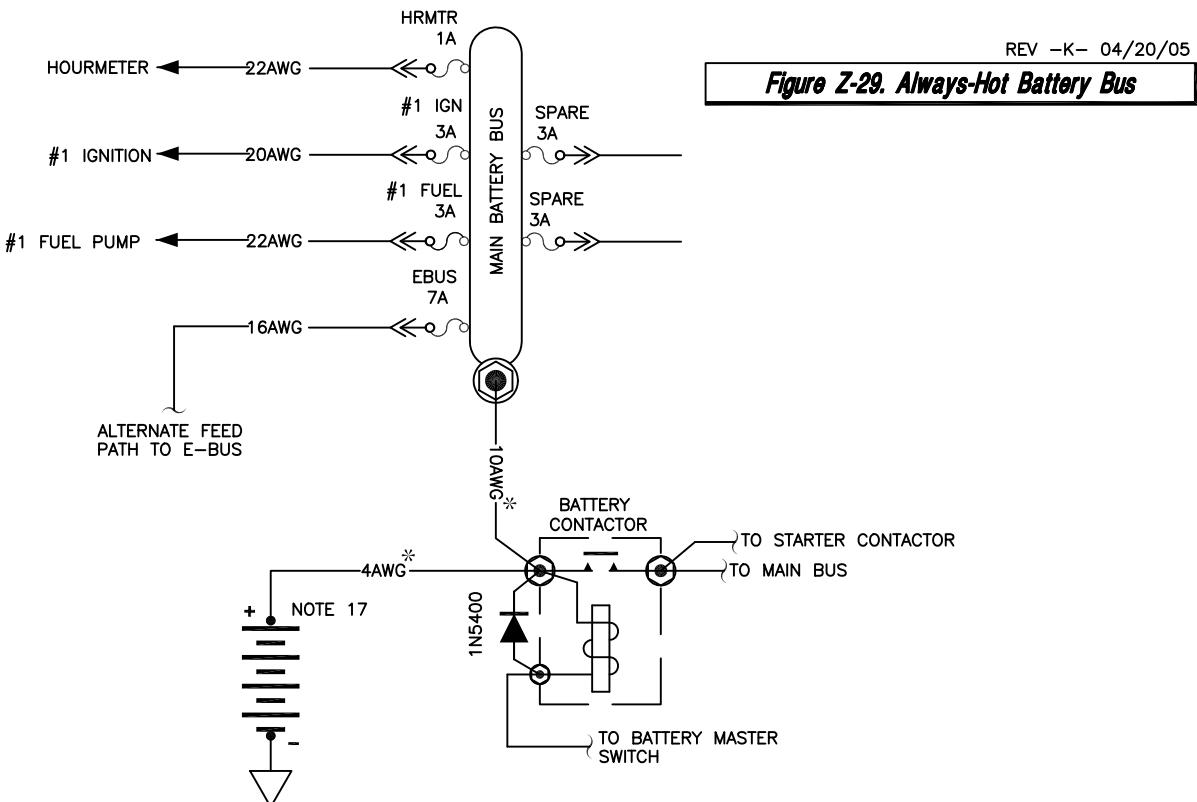
**Figure Z-25. SD-8 Auxiliary Alternator Installation (with Self-Excitation Feature)**

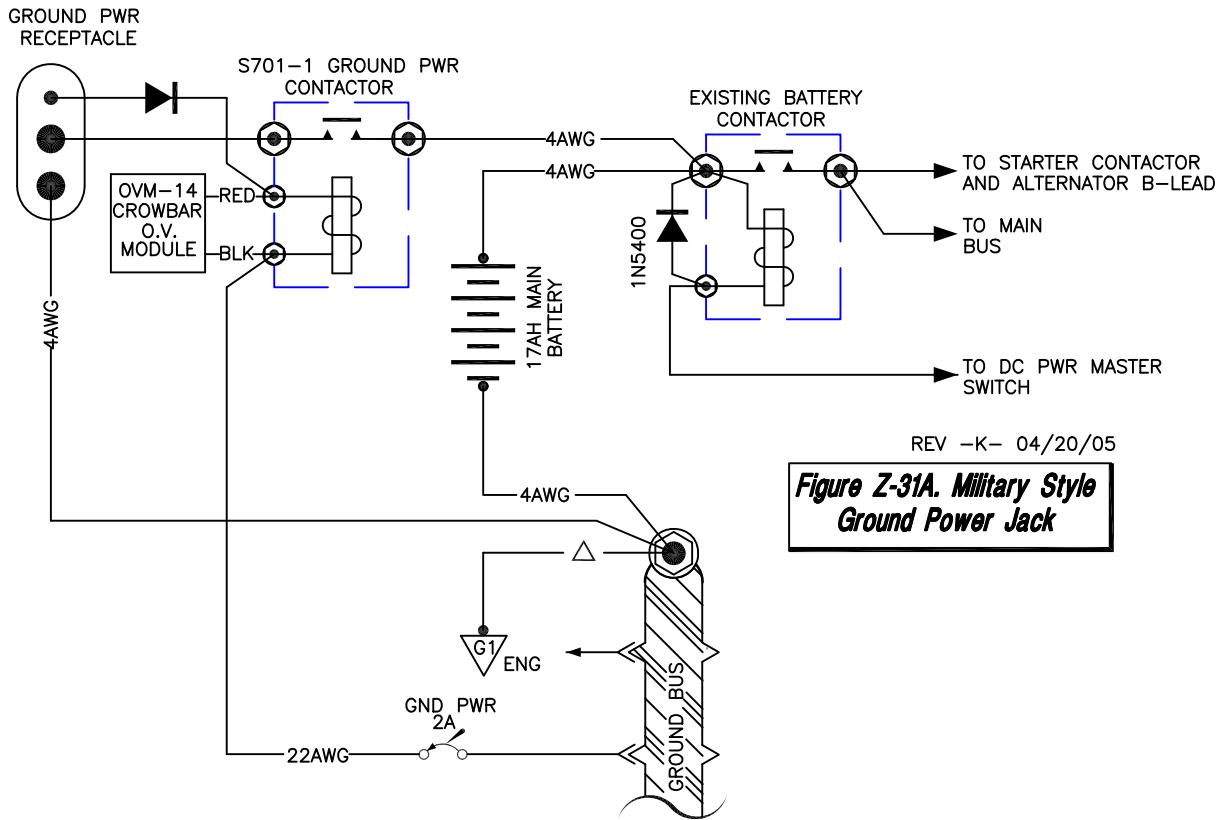


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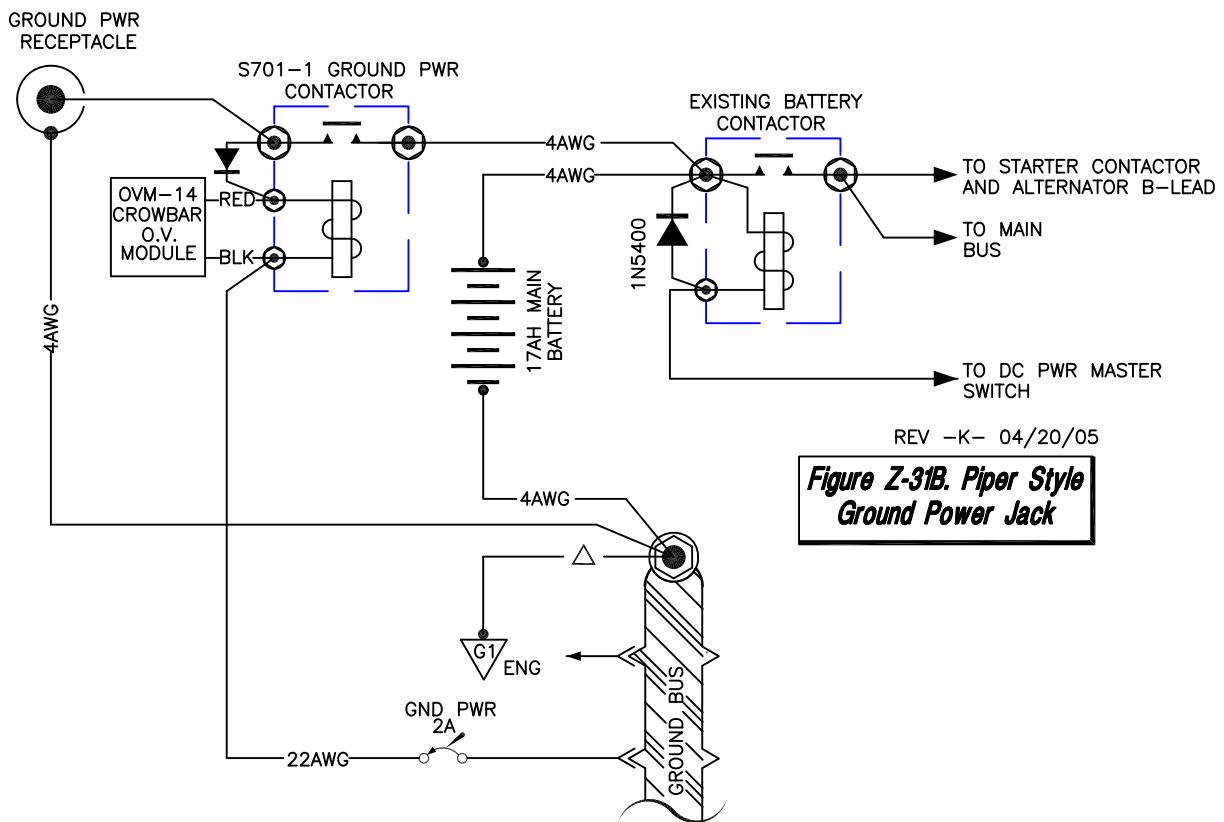
**Figure Z-28. Dual Electronic Ignition with One Alternator**



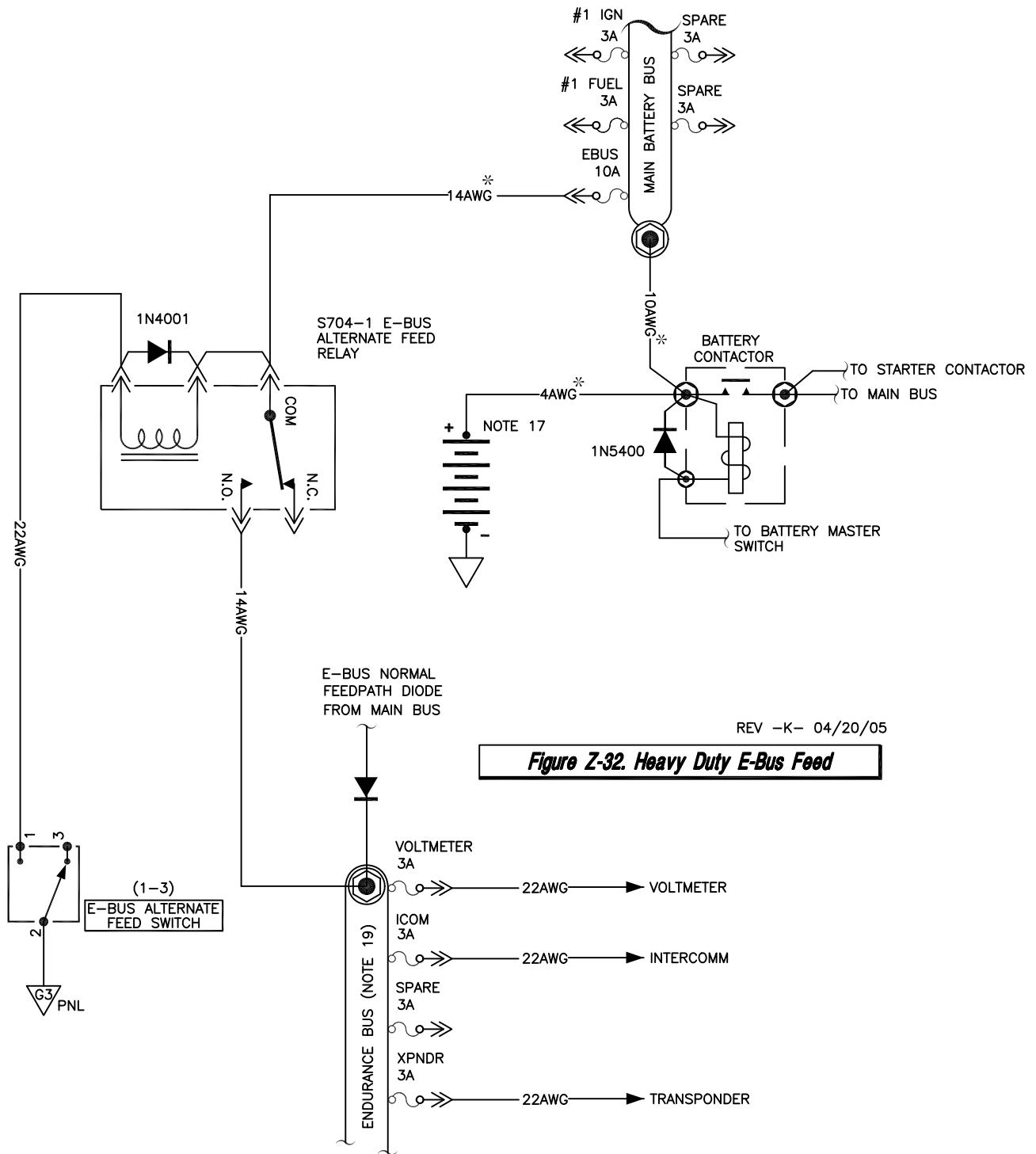


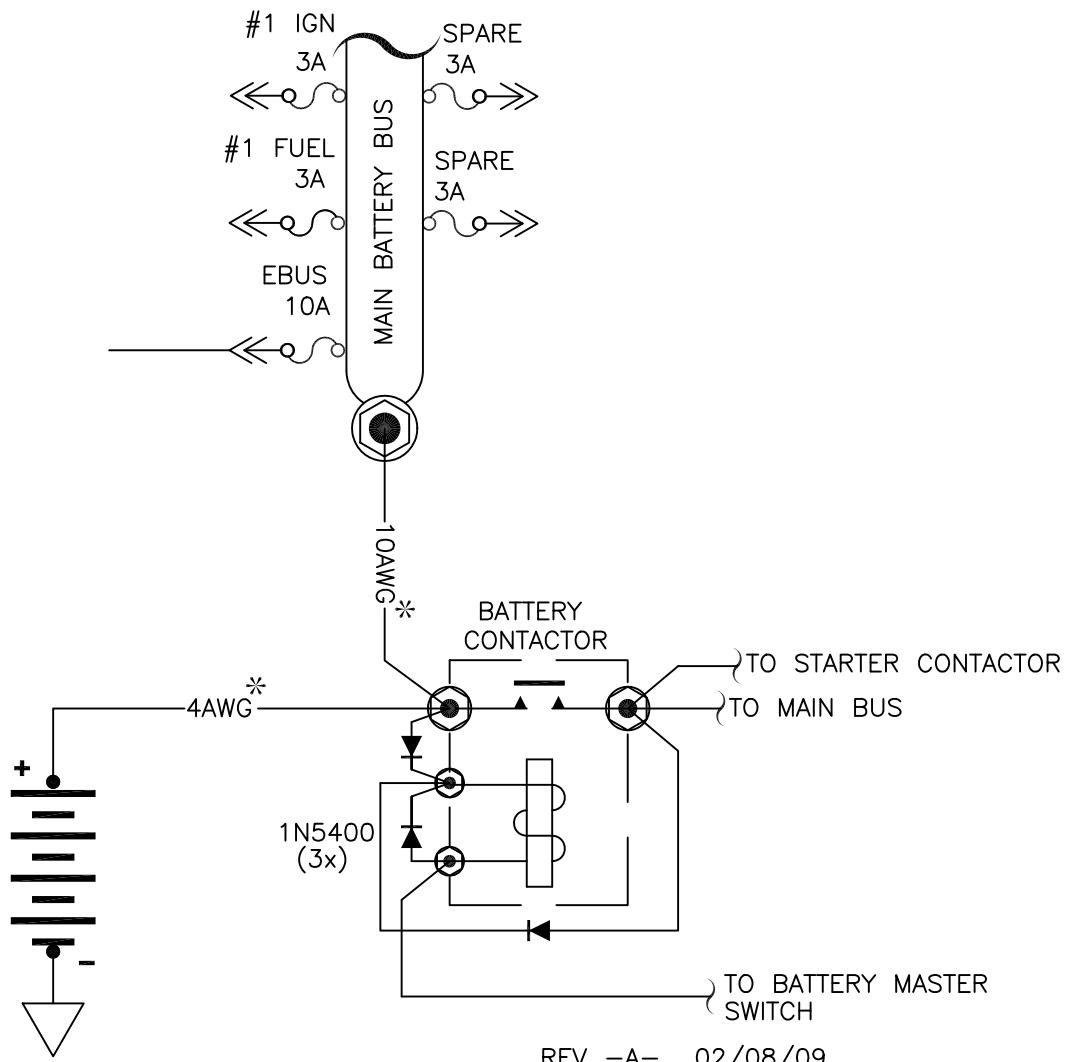


**Figure Z-31A. Military Style  
Ground Power Jack**



**Figure Z-31B. Piper Style  
Ground Power Jack**





**Figure Z-33. Dual Power Path for Battery Contactors**

