Appendix Z
Power Distribution Diagrams and Options

What's New . . .

Revision 11K offers a new configuration of the SD-8 PM alternator installation that will allow the alternator to come on line and run self-excited without the aid of a battery. See Figure Z-25 and Note 25.

Revision K fixes some errors and added Figure Z-19 for automotive conversions with electronic fuel injection and ignition systems. Figure Z-20 is a new figure to illustrate power distribution for the smaller Jabiru engines.

This revision introduces the avionics ground bus discussed in the new chapter 18. This bus is also described schematically in the Z-figure diagrams.

Figure Z-32 is a new figure that illustrates how to add a disconnect relay for the e-bus alternate feed when your e-bus is loaded to more than 3-4 amps. For example, if you go with Figure Z-13/8 and your continuous e-bus loads are up to and including the output of an SD-8 alternator, then it would be a good idea to add the e-bus alternate feed relay adjacent to the battery bus as shown.

This is the first issue to show architectures that include the new E-Mag and P-Mag products from Emagair.com. In my never humble opinion, these are the next great thing in aircraft ignition systems. P-mags are featured in figure Z-13 and Figure Z-33 has been added to show variations on the theme to support the E/P-Mag's maintenance and hand-propping features.

I have retracted my recommendations concerning alternators with built in regulators. Conversations on the AeroElectric-List and more research in our shop suggest that OV protection for internally regulated alternators proposed in the past several revisions have design deficiencies that need to be fixed. Until we have time to pursue and solve this problem, I've removed suggestions for incorporation of internally regulated alternators from these pages.

There are individuals within the OBAM aircraft community who have expressed a lot of faith in the reliability of internally regulated alternators. Their faith is not without foundation . . . there's a ton of anecdotal evidence to support their beliefs.

The problem is that I have no physical evidence that allows an engineer to identify and confirm the reliability or failure modes of these devices. Further, I have no technique to offer for incorporating the internally regulated alternator in a manner that allows the pilot to turn it ON or OFF at any time under any conditions. This feature has been a part of generator and externally regulated alternator control philosophy since day-one. It's another of many projects and we'll eventually get the data we need to do a aircraft quality installation of an internally regulated alternator. In the mean time, I have no considered recommendation for the use of internally regulated alternators in airplanes.

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 and the builder's desire and budget for 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 18+ years that the 'Connection has been supporting the owner built and maintained (OBAM) aircraft industry.

Features shown are thoughtfully crafted and making changes without thinking through the adverse effects of those changes on the 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.** 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.

Note:
Figure 21 does not exist in this revision. This number has been reserved for future expansion of power distribution diagrams.

A note 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 13 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 shelves. The suppliers I work with have Internet sites and we deal 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 ten years. Features from these drawings may be mixed and matched to suit individual builder needs.

Early on 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. If you have AutoCAD capability but no Internet access, you may order CD ROM with all the drawings, and all downloadable articles from the website.

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.

A Short Discussion on the "Endurance" Bus

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

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 mode such that save arrival was assured after you have a clearance to land. Then, you can re-close the battery master and run any accessories you like on what ever 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 allow 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 a.h. 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 a.h. battery . . . it WILL be less, probably more like 12-15 a.h.

Consider further that you'll want to periodically test the battery so as to KNOW it's 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 battery only endurance. Worse yet, the pilots of those airplanes don't have a clue.

So, 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 over-lapping 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 Z1 through Z10 are depicted earlier issues up through revision Revision 9 of the AeroElectric Connection. To avoid confusion with queries about drawings in older issues, I renumbered the original drawings beginning with Z-11 so that it would be immediately obvious when a reader was referring to data from an older book.

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.

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 the Beech Bonanzas and Cessna 210s. If your builder's budget can stand up 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 also a popular option on present production Bonanzas at Raytheon. 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 - it's not a bad option for OBAM aircraft but consider Z-14 before you opt for Z-12.

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 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 what ever 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. Long-Ez and Vari-Ez projects were B&C's customers about 15 years ago when 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 more classic 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 with the 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 electrical system with an 18 a.h. battery and dual P-mags. 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 capacity but 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 can 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 the two electrical systems with crossfeed capability doesn't necessarily mean that all electrical equipment can be operated at all times . . . if your alternators are 60 and 20 amps as I've 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 small effort and expense of installing this kind of electrical system.

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 a an all metal or tubular fuselage aircraft, the builder might consider grounding the battery locally to 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- you can we suggest 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 Z17. Small Rotax System (or Aircraft with SD-8 Altenrator 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 is reserved for future expansion.

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 engine start and when start button is released.

Using the relay to buffer the panel mounted start button or switch from the very high inrush currents typical of modern starters, a 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.

(Deleted)

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.

Figure Z-26 Ignition Switch Options - Two Magnetos with Keylock Switch If you really gotta have a keylocked 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 little 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 systems 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 system should enjoy a direct connection to the ship's battery. If you have dual electronic ignition, then dual batteries are in order.

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 a.h. 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-33 P-Mag Maintenance Mode and Hand Propping Option. E-Mags and P-Mags are a unique product in that as the factory points out, have TWO switchable functionsPower and control. Their installation manuals suggest separate switches but in a quest for the minimalist panel, I crafted the drawing for P-Mags in Figure Z-33 which is repeated in Figure Z-13/8.

. . . now, be aware that the sequence of switching functions depicted have been commented on by the good folks at E-Magair suggesting that switch movements should bring power on first followed by activating the magneto.

My wiring diagram shows the opposite sequence, ignition "active" first followed by supporting power. The reason is quite simple. There are separate but divergent interests in the ownership and operation of the p-mag:

(1) When sitting at the end of the runway doing a pre-flight, the PILOT'S interest is "are the built in alternators for each P-Mag functioning?" By wiring as I've suggested, moving the switch from full up to the mid position deprives a P-Mag of electrical support and (if the run-up RPMS are high enough), the ignition will not falter when dropped to the mid position. Of course, the opposite ignition needs to be completely OFF at this time.

Pre-flight test sequence would be:

RUN-UP RPM . . . . . Set

L-IGN Switch . . . . OFF

R-IGN Switch . . . . ON but no BAT (mid position)
Note engine does not falter

L-IGN Switch . . . . ON but no BAT (mid position)

R-IGN Switch . . . . OFF
Note engine does not falter

Both IGN Switches . . . . BAT

(2) A secondary interest is what might be called the maintenance mode for ground ops where the mechanic wants to have the systems powered but inactive for using a P-mag's built-in timing features -OR- for hand propping the engine where again, it's useful to be able to hear the timing buzzer.

In this mode, you MUST have battery power available to the P-Mags even when in the inactive state. The diagram shows a third switch (accessible through the oil check/ filler door?) that places temporary power on both ignitions while leaving absolute control over activity in the hands of whoever has access to pilot's controls on the panel.

If one chooses this architecture, then a light on the panel should be included to alert the pilot should the switch be left in the maintenance position. Not a big risk from a fight operations and safety perspective but it WOULD run the battery down.

This figure adds a switch to allow powering up the e-mag/p-mag product while leaving it de-activated. This feature activates the built in aural timing buzzer needed for timing the ignition system -AND- for proper pre-positioning the prop for hand-propping the engine.

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 keyswitch cannot be used to control 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." Hmmm . . . well guess what, what looks like a piece of wire is indeed a piece of wire . . . and rather ordinary at that. After lots of e-mail, phone calls and literature searching I've deduced the rationale behind design and incorporation of fusible links.

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. Hmmm . . . 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; fuseholder 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 feedpaths 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 about what you're going 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 heatshrink 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 but 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, overvoltage 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. The high performance airplanes use a special, heavy duty fuse-like device called a ***current limiter***. We've upgraded our recommendations for alternator b-lead protection from the JJS/JJN series fast fuses to 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 the breaker (or fuse) as close as possible to the starter contactor.

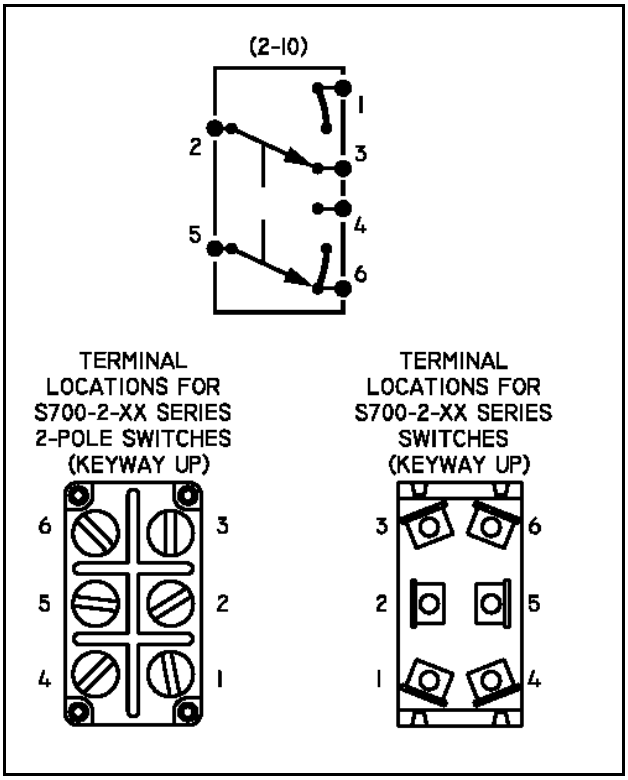
ANL limiters should also be considered as supply protection for electric hydraulic pumps.

Note 11. Deleted

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 heatsink for you -OR- a Digikey HS117-ND heat sink cut in half is about right for diode cooling.

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!



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

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.

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.

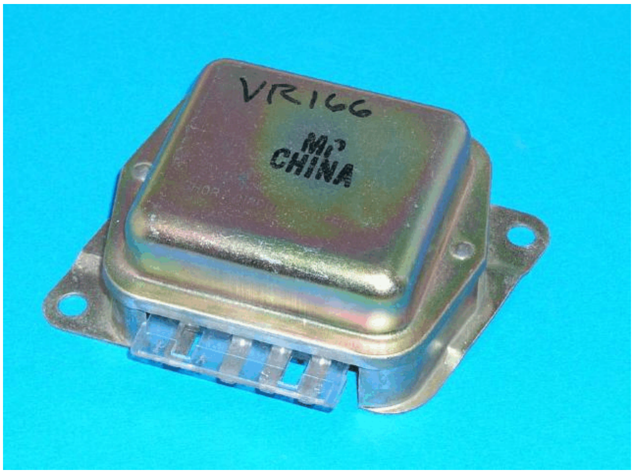
Note17. If you have not yet selected a battery; do consider the new recombinant gas (RG) or vent regulated lead-acid (VRLA) batteries. These are truly maintenance free batteries that crank like ni-cads! Flooded batteries need to go the way of the buggywhip.

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 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



Generic "Ford" Regulator

VR166 or equal) is a low cost, solid state regulator suitable for use on airplanes IF you add OV protection as shown. The 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.

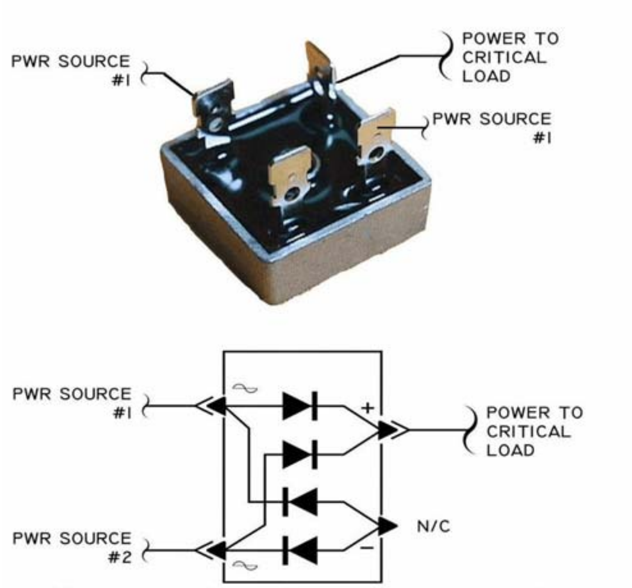
Note 22. Most alternators do not run well without also having a battery on line. The infamous "split rocker" switch was developed for light aircraft in the mid 1960s when generators were being phased out in favor of the much more efficient alternator. The two-pole, split-rocker controlled the battery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

One may also consider the 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 which is part of every crowbar over voltage protection system.

Note 23. Revision 11 introduces the avionics ground bus described in Chapter 18 and illustrated on these figures for the first time

Note 24. When you have critical loads that you would like



NOTE 24. USING DIODE BRIDGE TO JOIN CRITICAL POWER FEEDERS

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.

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 point were the system being supported accepts input power.

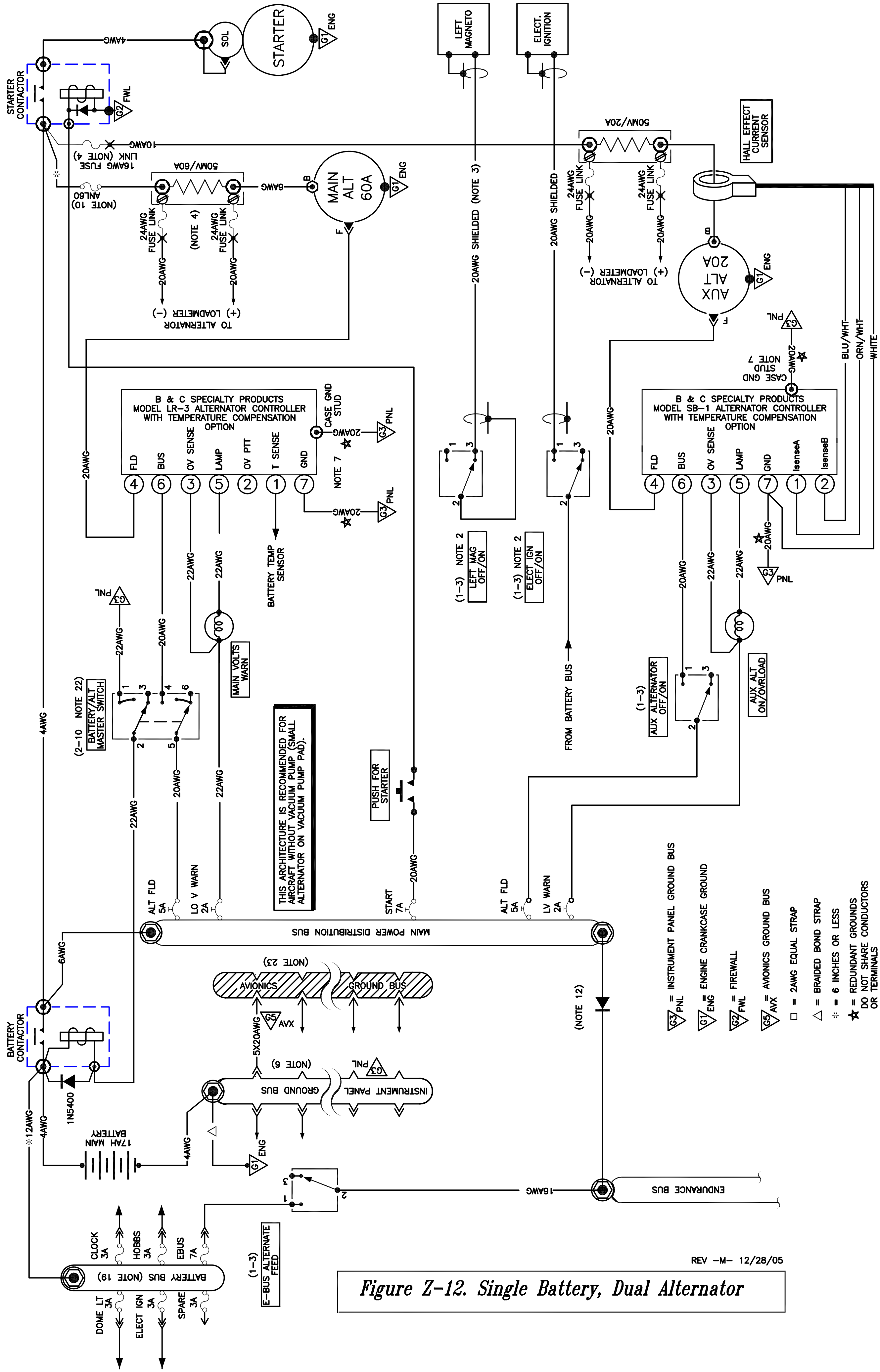
Note 25. Making the SD-8 Come-Alive without a battery: Subsequent to some excellent 'skunk werks' efforts on the part of Jim McCulley, the 'Connection is pleased to offer a work-around to older SD-8 alternator installations that encourages this useful product to come on line without benefit of a battery. 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 1GBPC1204/1 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.



REV –M– 12/28/05

Figure Z-12. Single Battery, Dual Alternator

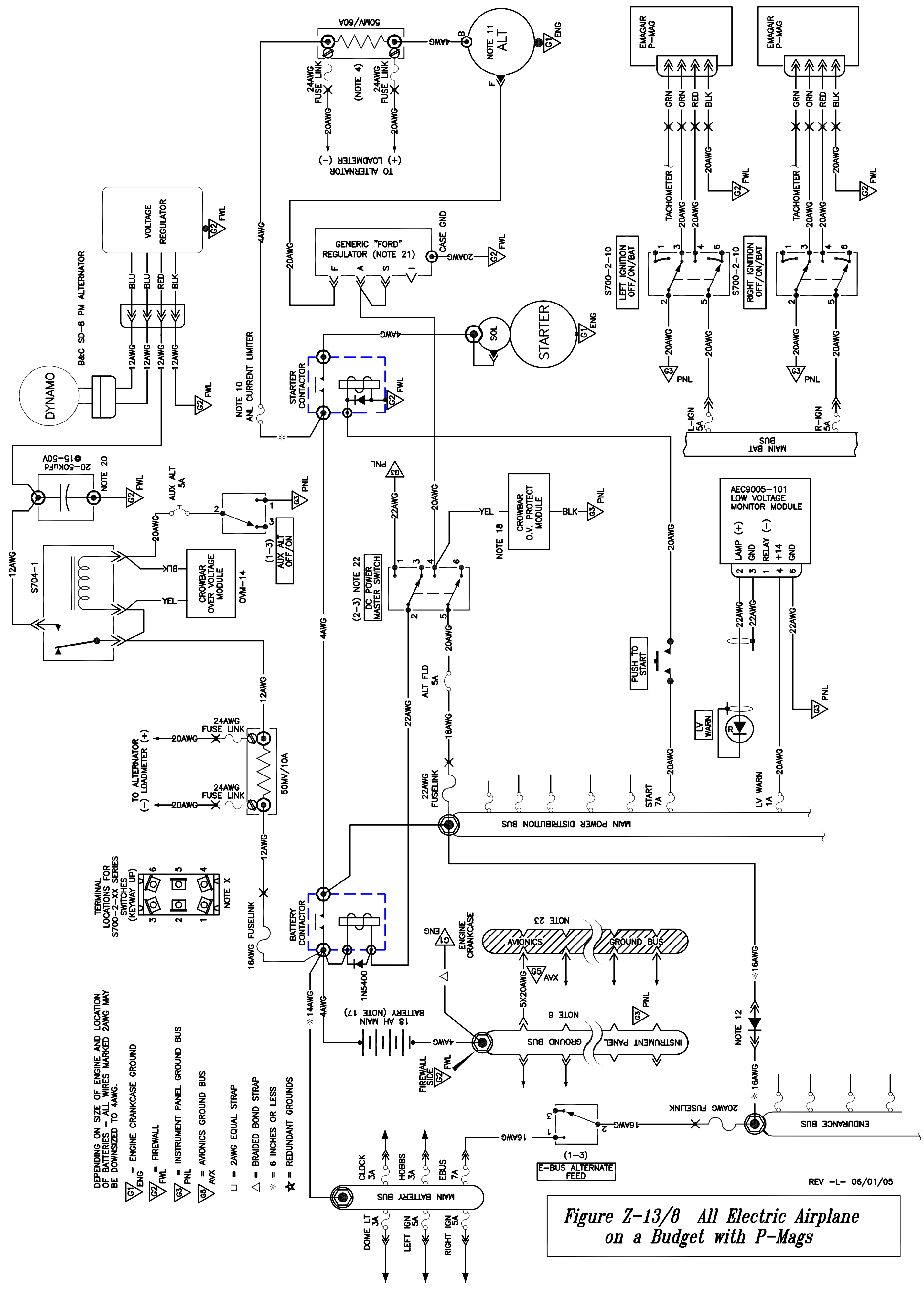
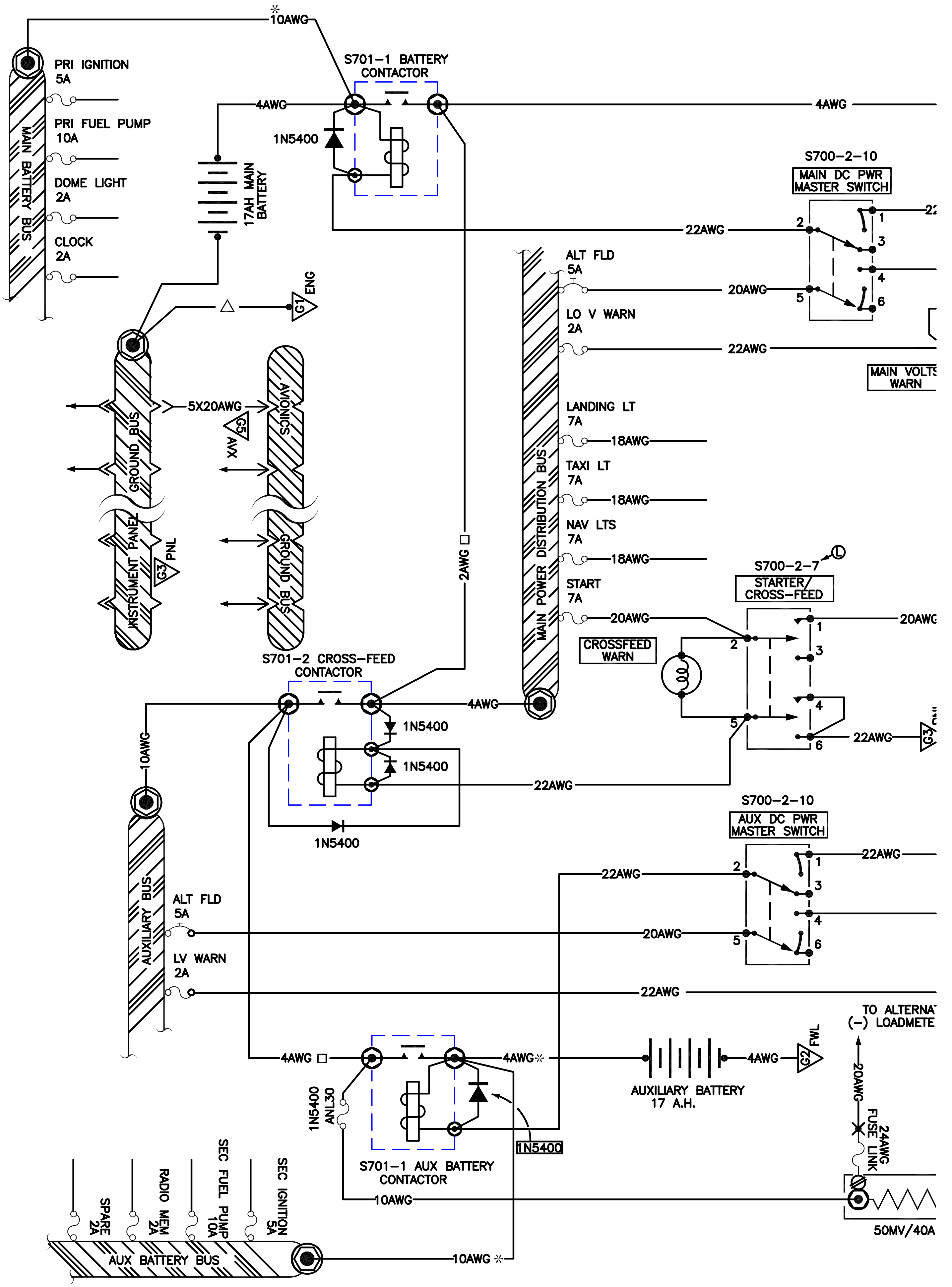
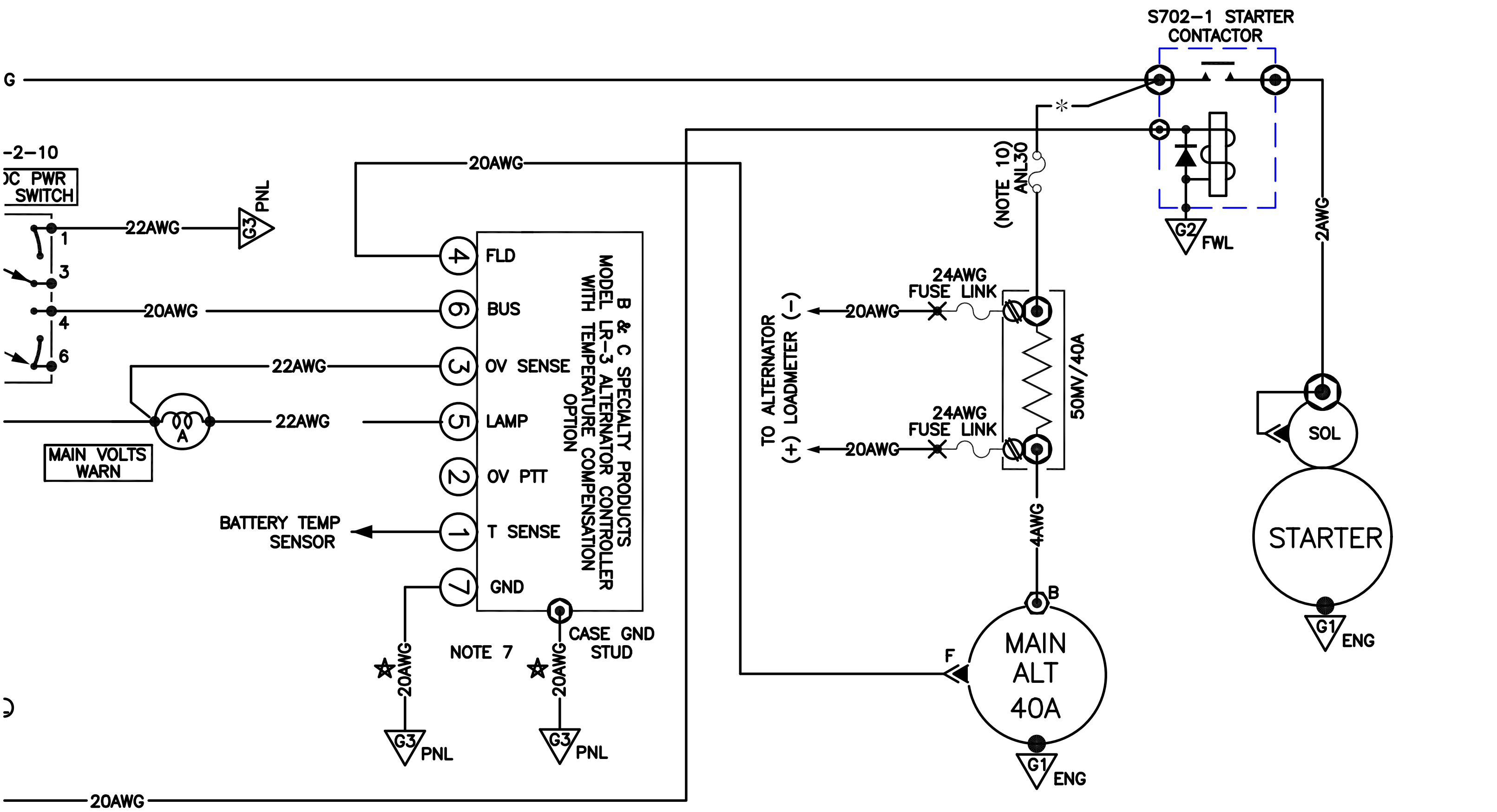


Figure Z-13/8 All Electric Airplane on a Budget with P-Mags

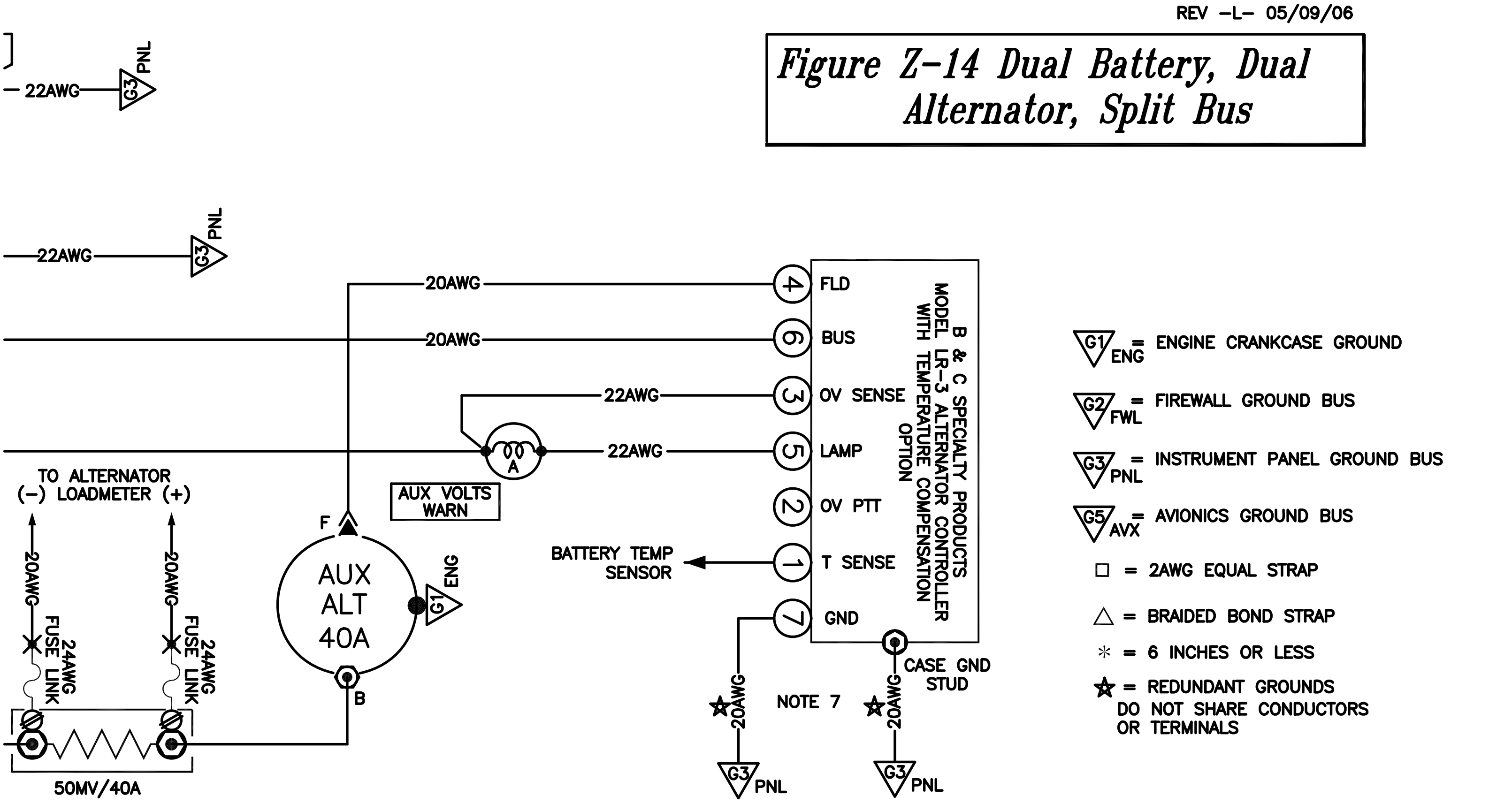


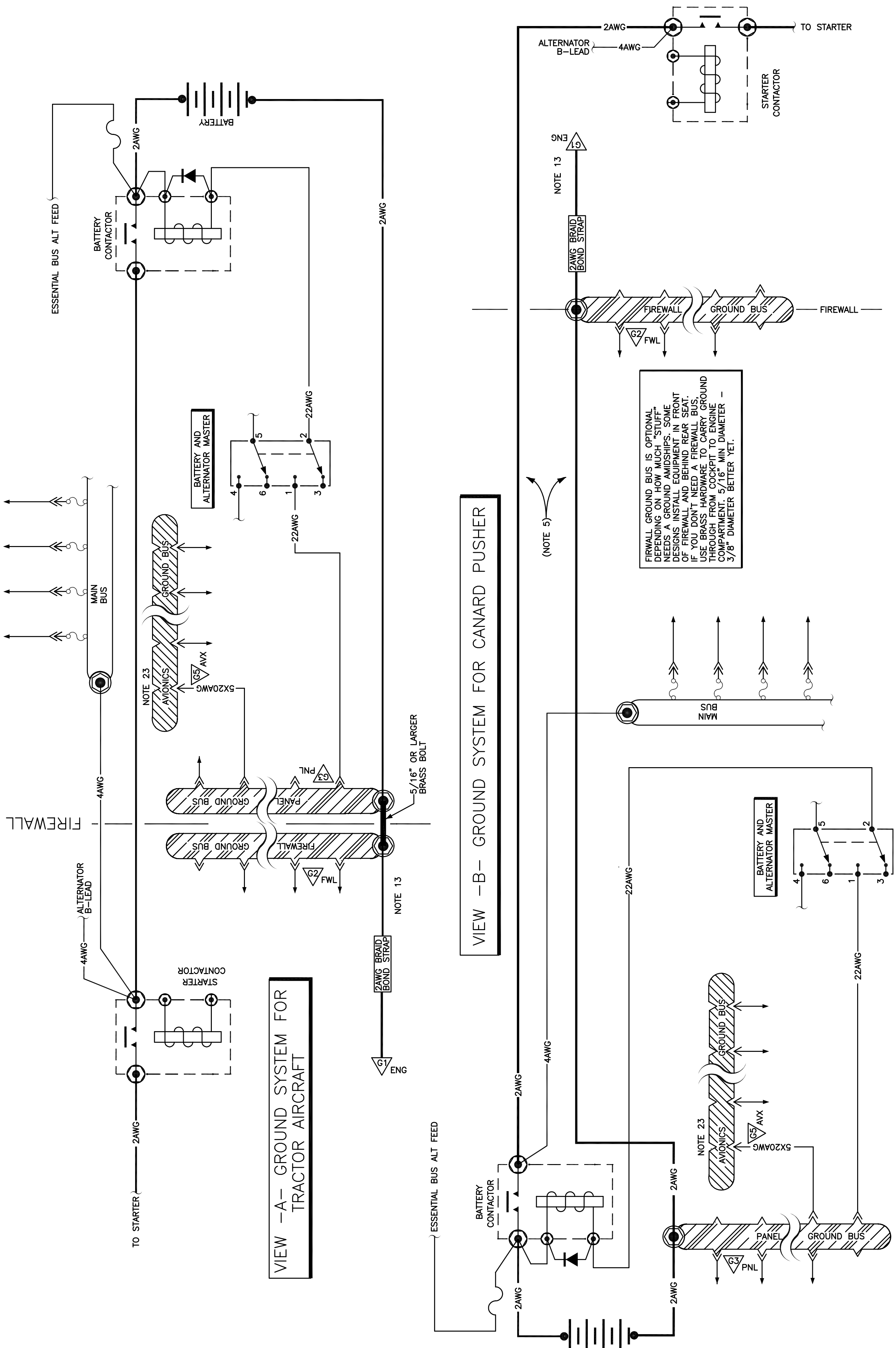
10AWG
PRI IGNITION
5A
PRI FUEL PUMP
10A
DOME LIGHT
2A
CLOCK
2A
MAIN BATTERY BUS
S701-1 BATTERY
CONTACTOR
4AWG
1N5400
17AH MAIN
BATTERY
4AWG
S700-2-10
MAIN DC PWR
MASTER SWITCH
22AWG
ALT FLD
5A
20AWG
LO V WARN
2A
22AWG
MAIN VOLTS
WARN
G1
ENG
5X20AWG
G5
AVX
AVIONICS
GROUND BUS
INSTRUMENT PANEL
G3
PNL
GROUND BUS
2AWG
LANDING LT
7A
18AWG
TAXI LT
7A
18AWG
NAV LTS
7A
18AWG
START
7A
20AWG
MAIN POWER DISTRIBUTION BUS
S700-2-7
STARTER/
CROSS-FEED
20AWG
CROSSFEED
WARN
S701-2 CROSS-FEED
CONTACTOR
4AWG
1N5400
1N5400
10AWG
22AWG
22AWG
G3
1N5400
S700-2-10
AUX DC PWR
MASTER SWITCH
22AWG
22AWG
AUXILIARY BUS
ALT FLD
5A
20AWG
LV WARN
2A
22AWG
TO ALTERNATOR
(-) LOADMETER
4AWG
4AWG
AUXILIARY BATTERY
17 A.H.
4AWG
G2
FWL
20AWG
24AWG
FUSE LINK
1N5400
ANL30
1N5400
S701-1 AUX BATTERY
CONTACTOR
10AWG
50MV/40A
SPARE
2A
RADIO MEM
2A
SEC FUEL PUMP
10A
SEC IGNITION
5A
AUX BATTERY BUS
10AWG



REV -L- 05/09/06

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





REV -K- 04/20/05

Figure Z-15. Ground Systems (Sheet 1)

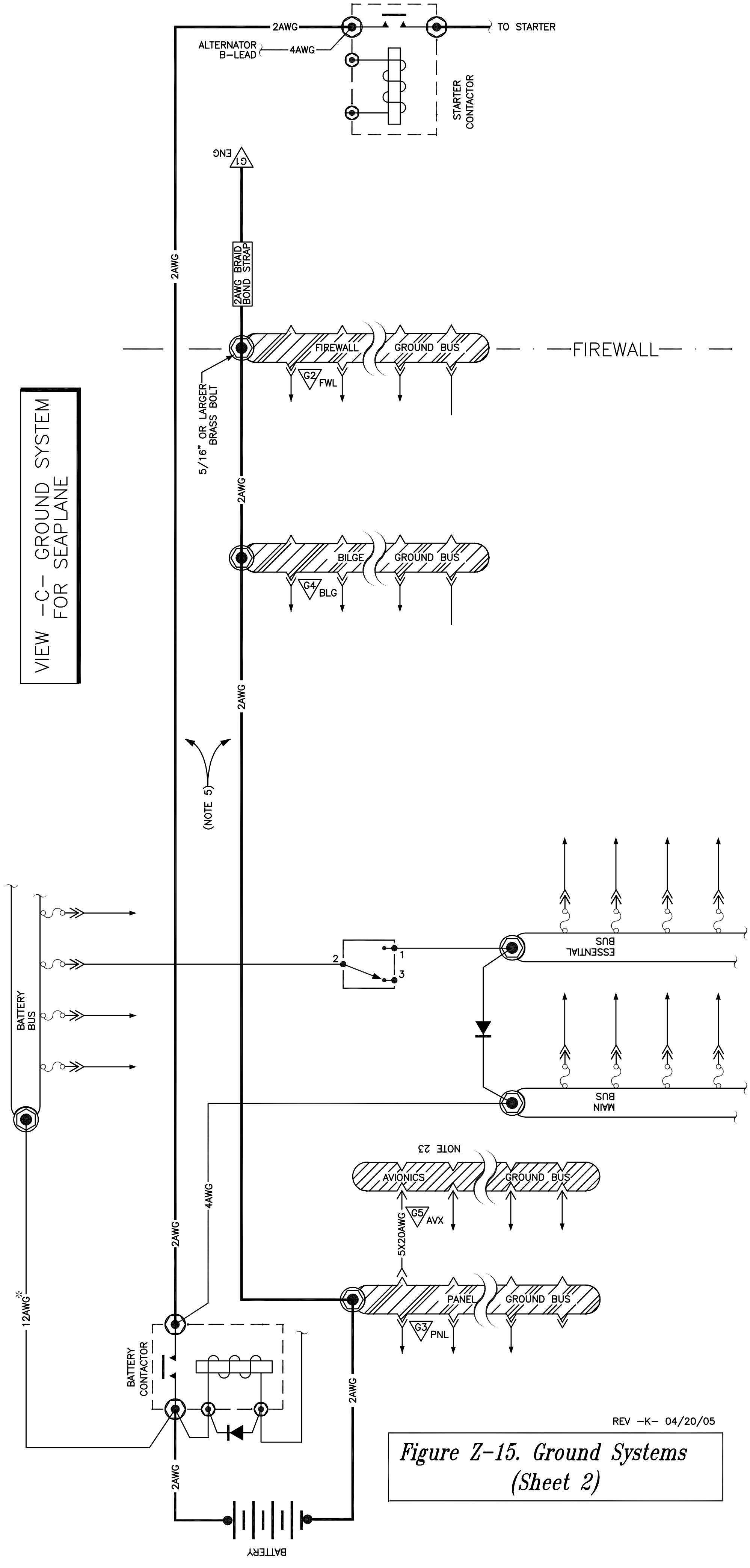


Figure Z-15. Ground Systems (Sheet 2)

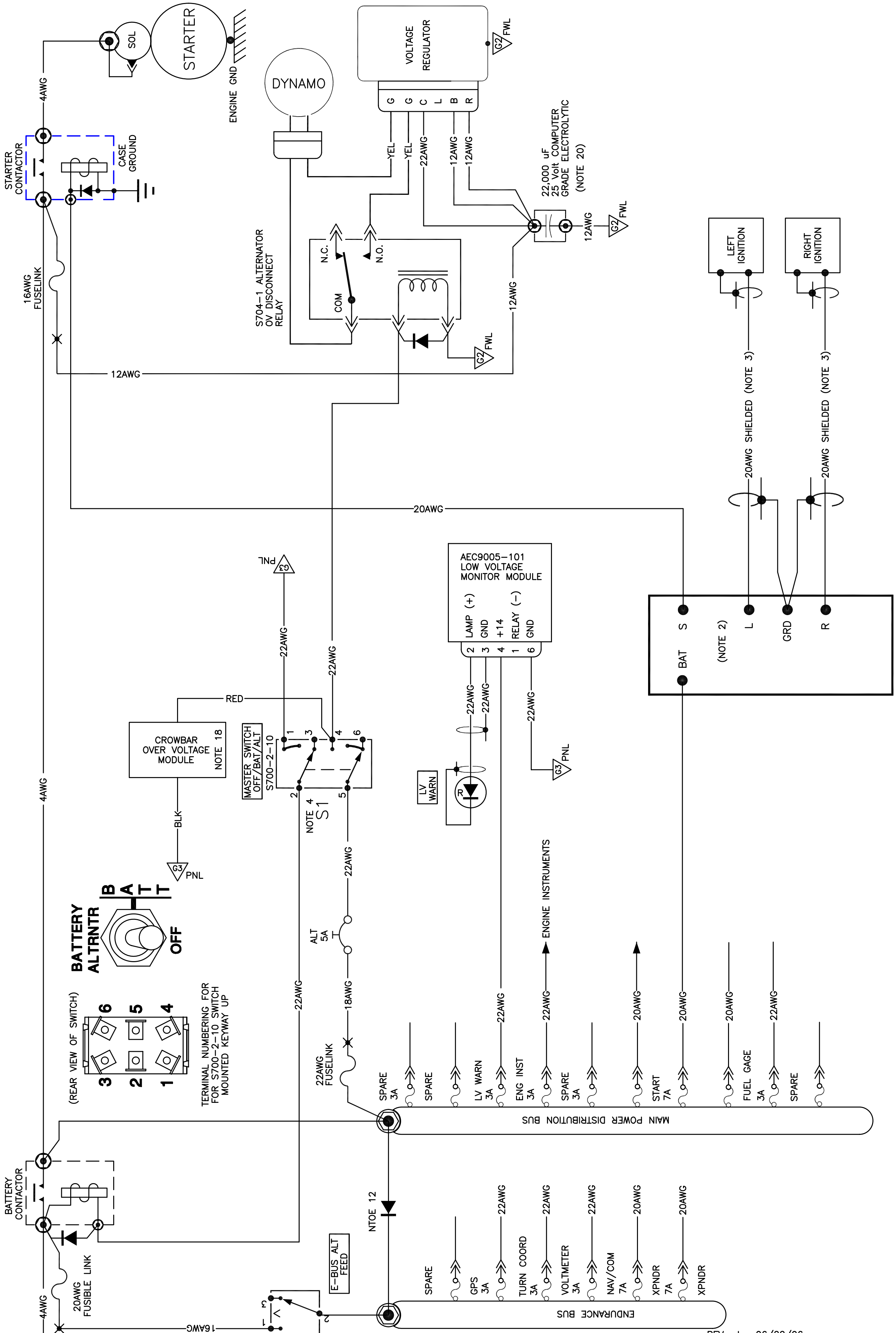


Figure Z-16. Rotax 912/914 System

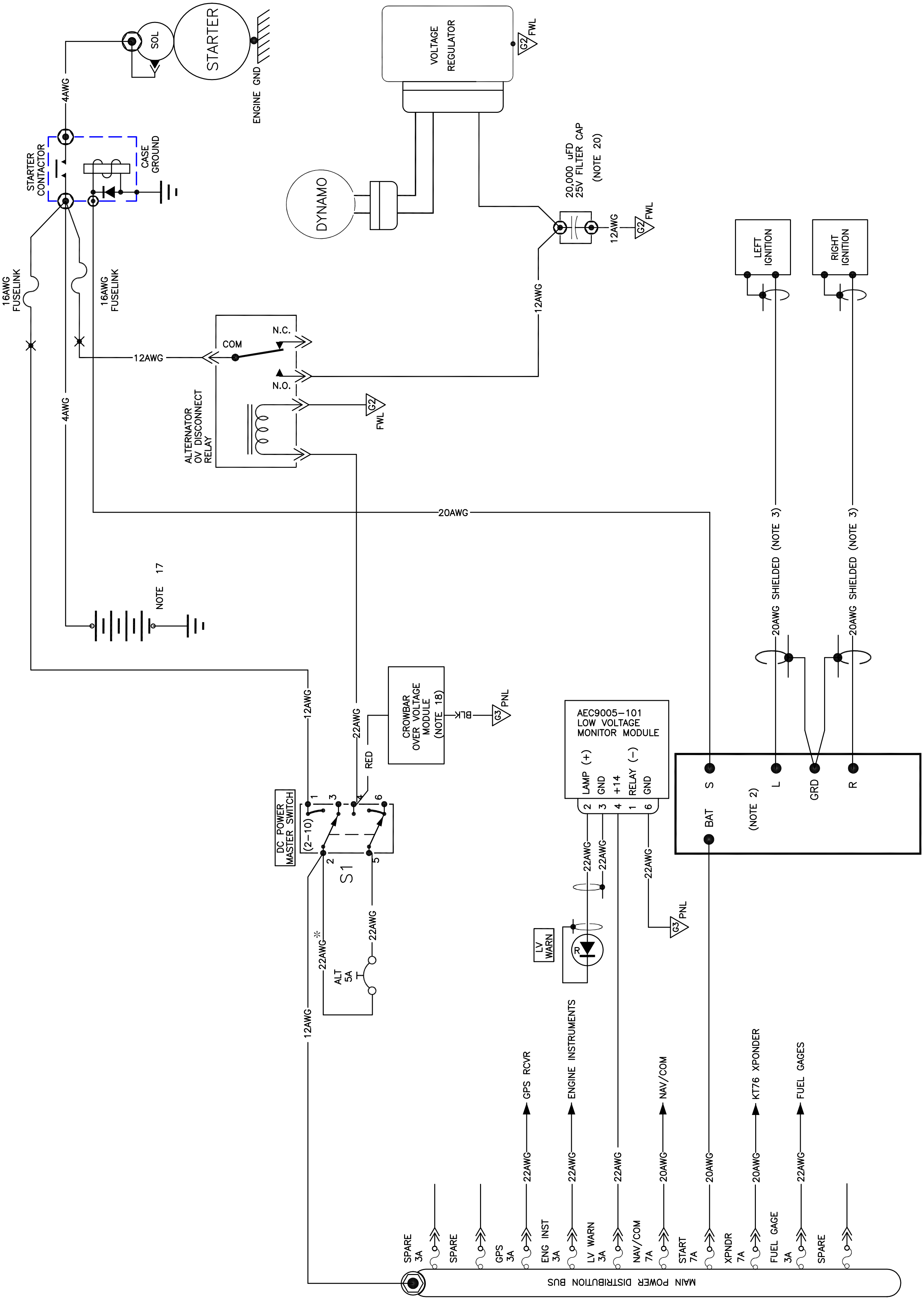


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Figure Z-17. Small Rotax System (or Aircraft with B&C SD-8 Alternator as Primary Engine Driven Power).

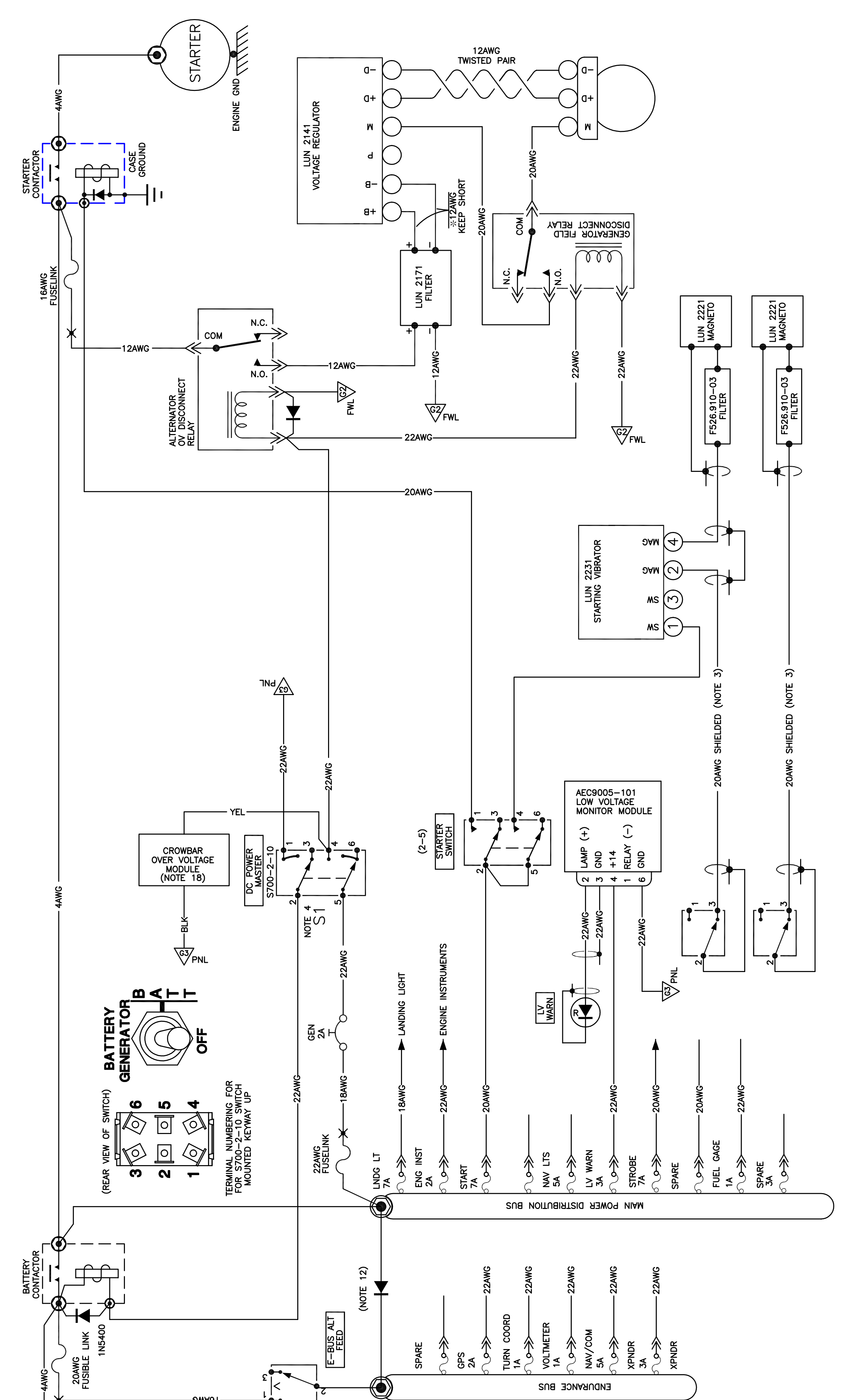

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Figure Z-18. Single Battery and LOM Engine

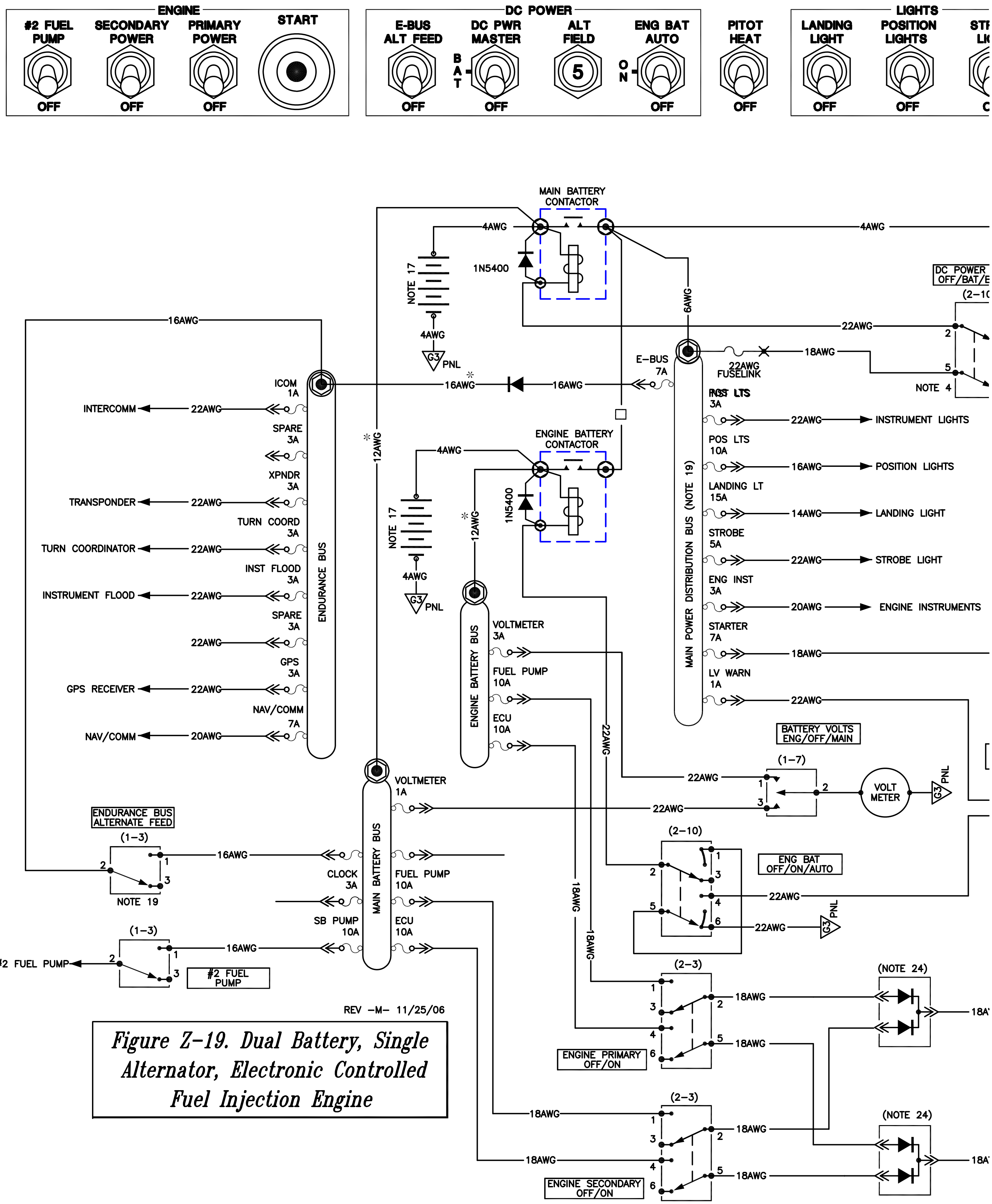
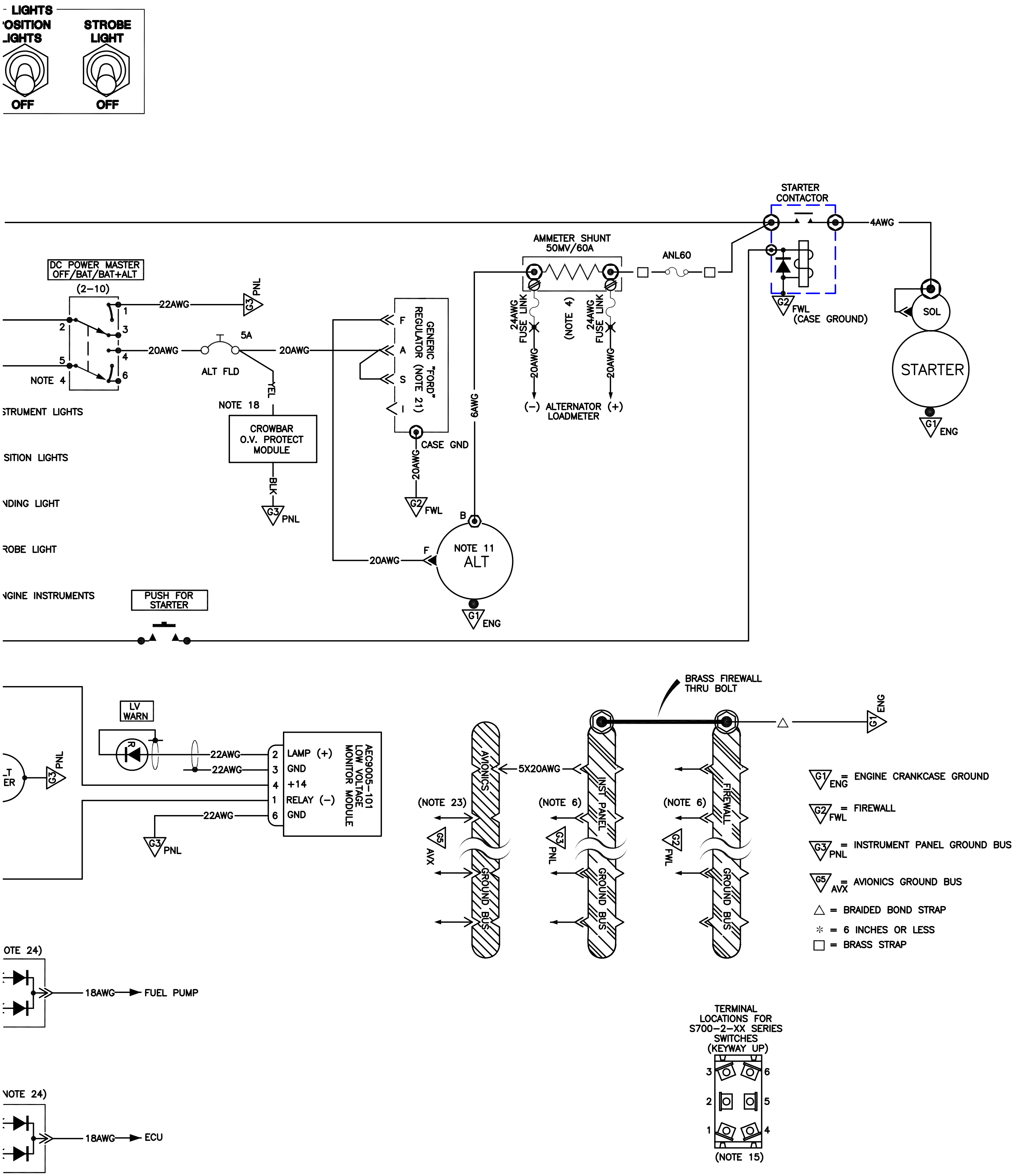


Figure Z-19. Dual Battery, Single Alternator, Electronic Controlled Fuel Injection Engine



LIGHTS
POSITION LIGHTS
STROBE LIGHT
OFF
OFF
STARTER CONTACTOR
4AWG
AMMETER SHUNT 50MV/60A
ANL60
DC POWER MASTER OFF/BAT/BAT+ALT
(2–10)
22AWG
G3 PNL
20AWG
5A
ALT FLD
NOTE 4
YEL
NOTE 18
CROWBAR O.V. PROTECT MODULE
BLK
G3 PNL
GENERIC "FORD" REGULATOR (NOTE 21)
F
A
S
I
CASE GND
20AWG
G2 FWL
6AWG
24AWG FUSE LINK
(NOTE 4)
24AWG FUSE LINK
20AWG
20AWG
(−) ALTERNATOR (+)
LOADMETER
G2 FWL
(CASE GROUND)
SOL
STARTER
G1 ENG
INSTRUMENT LIGHTS
POSITION LIGHTS
LANDING LIGHT
STROBE LIGHT
ENGINE INSTRUMENTS
B
F
NOTE 11
ALT
20AWG
G1 ENG
PUSH FOR STARTER
LV WARN
R
22AWG
22AWG
G3 PNL
22AWG
G3 PNL
2 LAMP (+)
3 GND
4 +14
1 RELAY (−)
6 GND
AEC9005-101 LOW VOLTAGE MONITOR MODULE
BRASS FIREWALL THRU BOLT
G1 ENG
5X20AWG
AVIONICS GROUND BUS
INST PANEL GROUND BUS
FIREWALL GROUND BUS
(NOTE 23)
(NOTE 6)
(NOTE 6)
G5 AVX
G3 PNL
G2 FWL
G1 ENG = ENGINE CRANKCASE GROUND
G2 FWL = FIREWALL
G3 PNL = INSTRUMENT PANEL GROUND BUS
G5 AVX = AVIONICS GROUND BUS
△ = BRAIDED BOND STRAP
✳ = 6 INCHES OR LESS
□ = BRASS STRAP
(NOTE 24)
18AWG
FUEL PUMP
(NOTE 24)
18AWG
ECU
TERMINAL LOCATIONS FOR S700-2-XX SERIES SWITCHES (KEYWAY UP)
3 6
2 5
1 4
(NOTE 15)

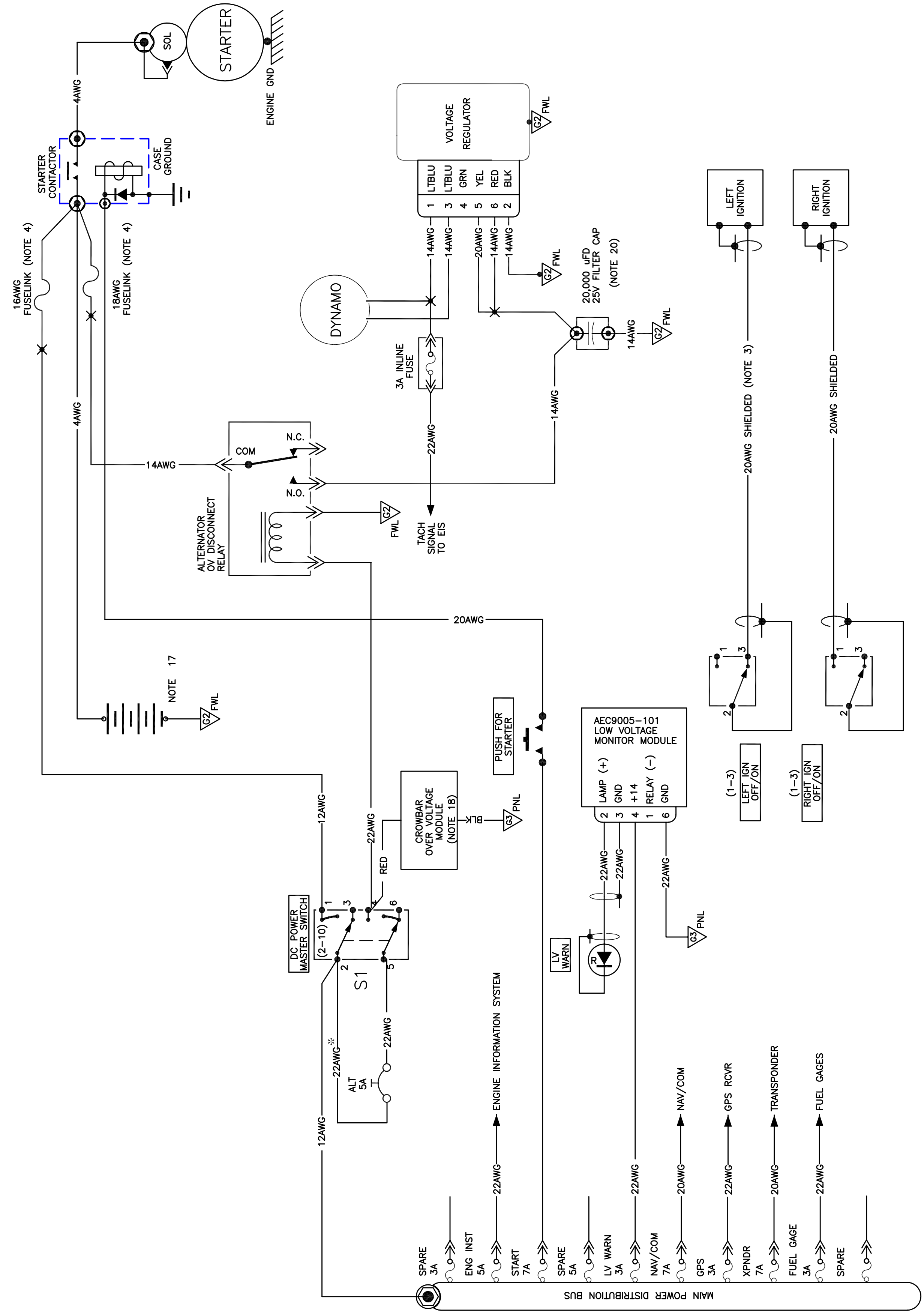


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Figure Z-20. Small Jabiru System

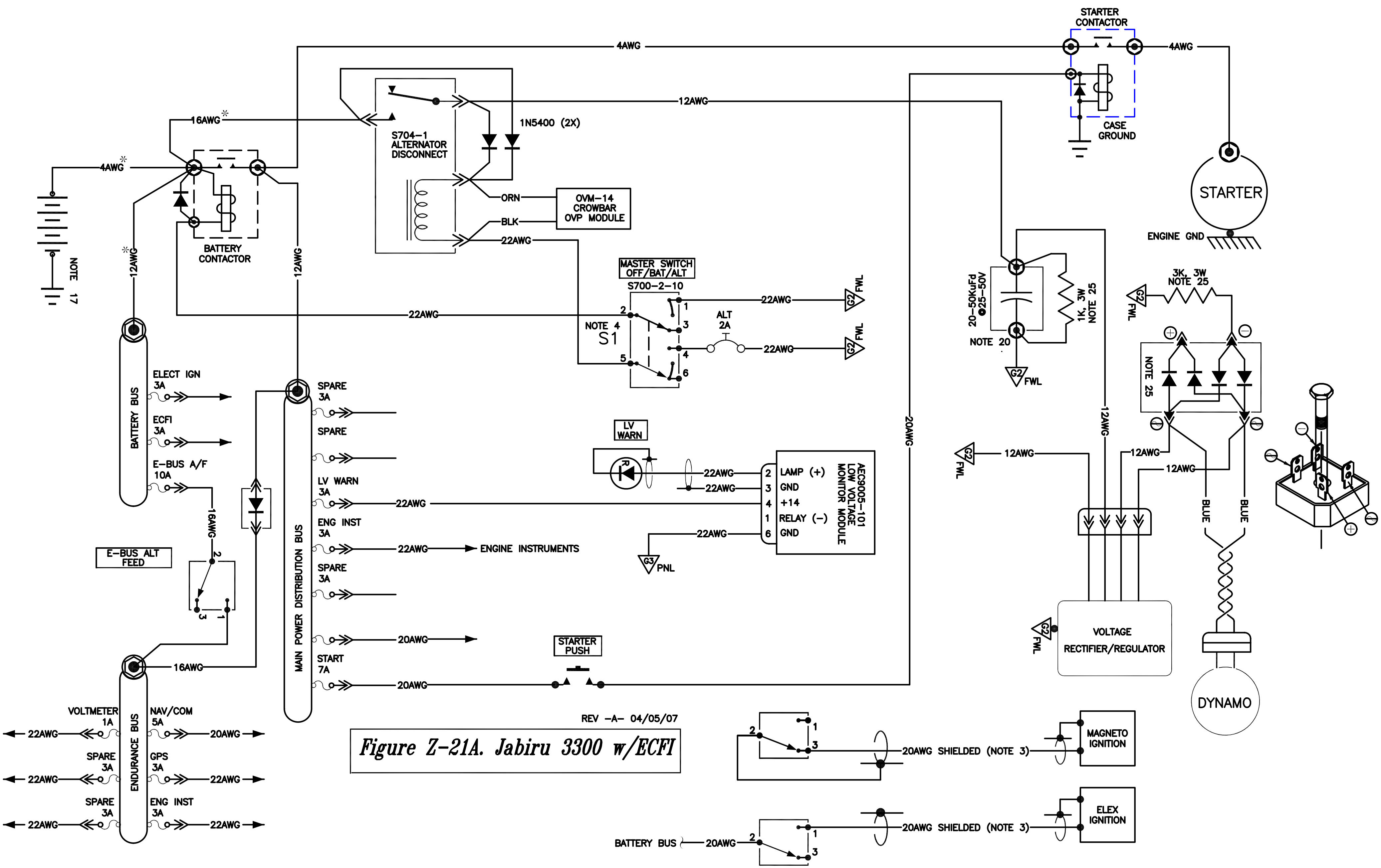

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Figure Z-21A. Jabiru 3300 w/ECFI

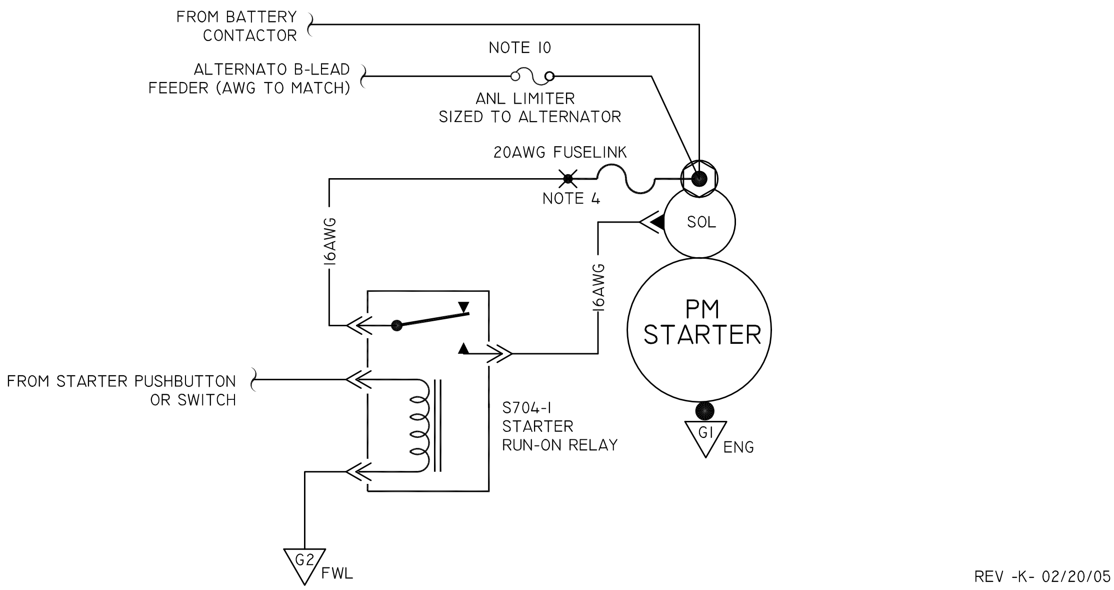


Figure Z-22. Fix for "Run-On" in Starters with Permanent Magnet Motors.

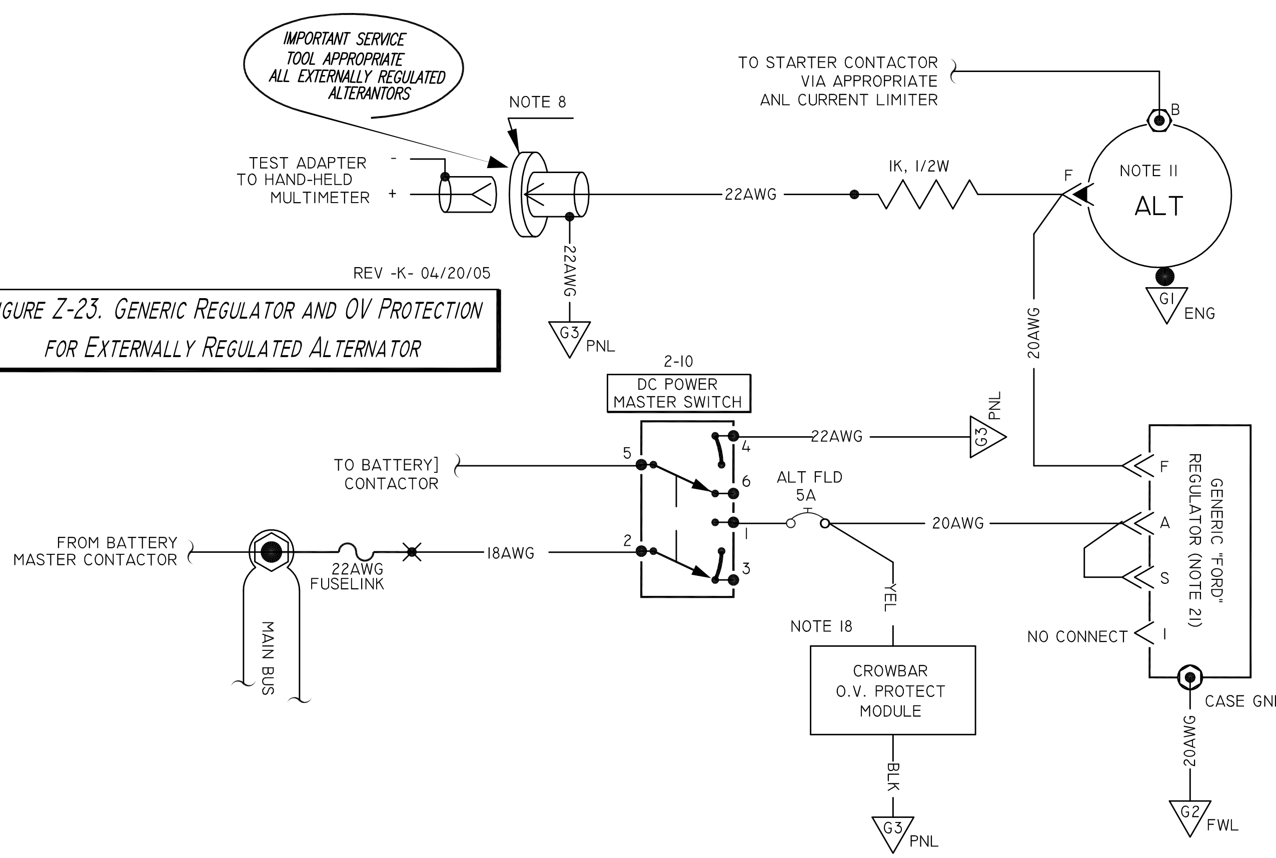
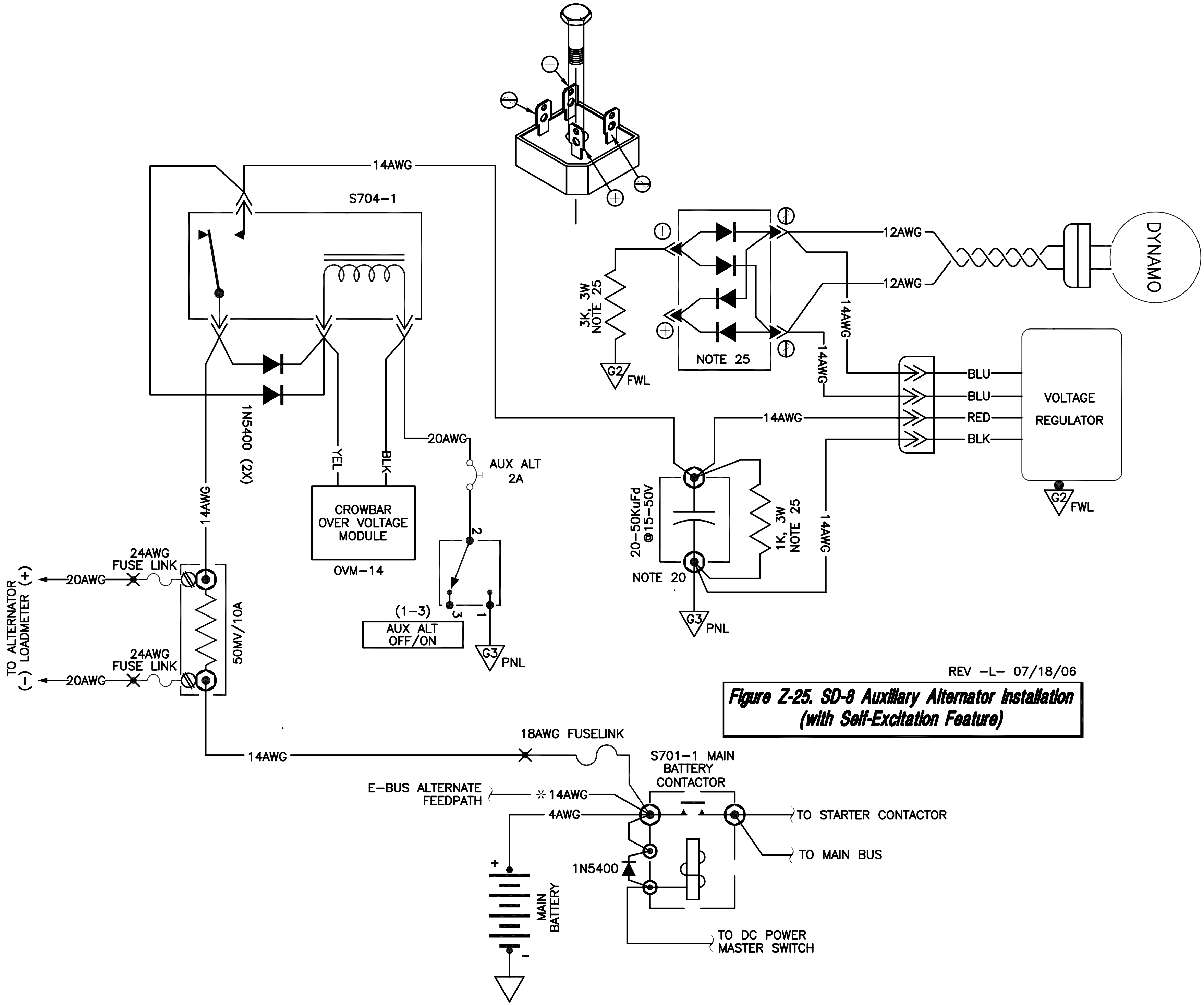


Figure Z-23. Generic Regulator and OV Protection for Externally Regulated Alternator



REV -L- 07/18/06

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

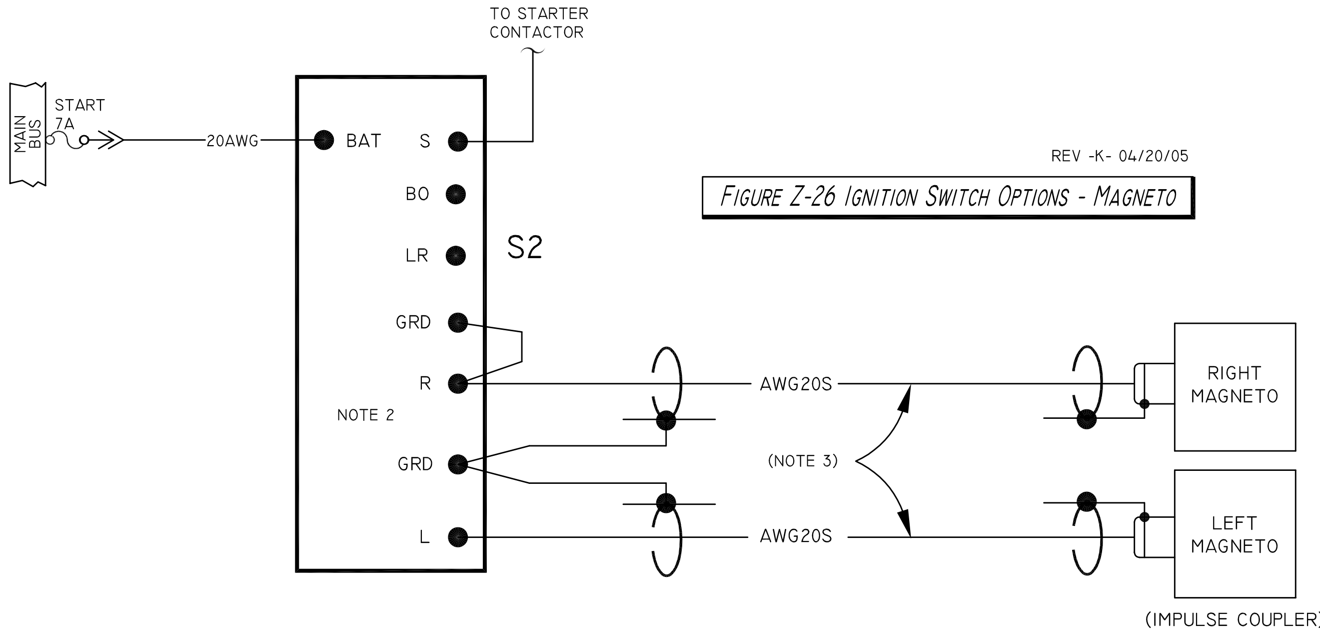
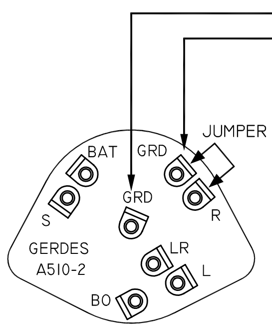


FIGURE Z-26 IGNITION SWITCH OPTIONS - MAGNETO



	TERMINAL							
POSITION	BAT	S	BO	GRD	LR	L	R	GRD
OFF				●		●	●	
RIGHT				●		●		
LEFT				●			●	
BOTH								
START	●	●	●	●	●	●		●

REV -K- 04/20/05

FIGURE Z-27. NON-IMPULSE COUPLED MAGNETO AND ONE ELECRONIC IGNITION

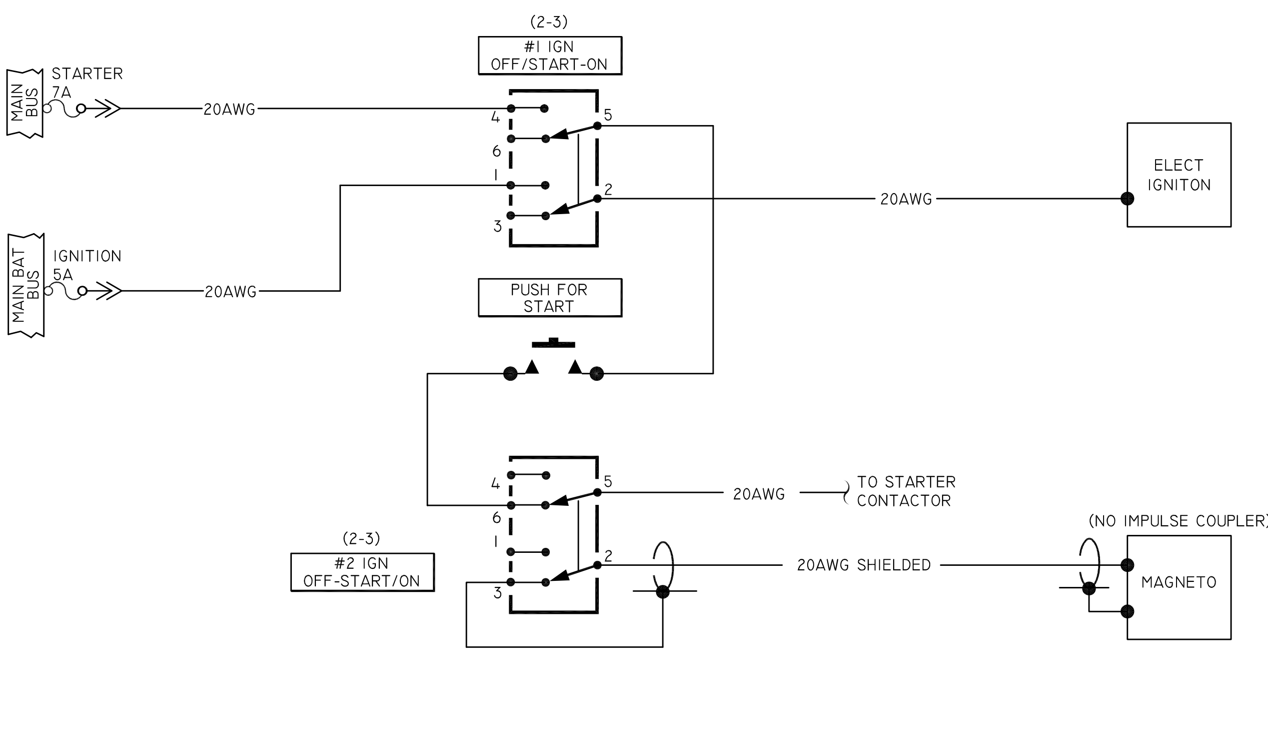


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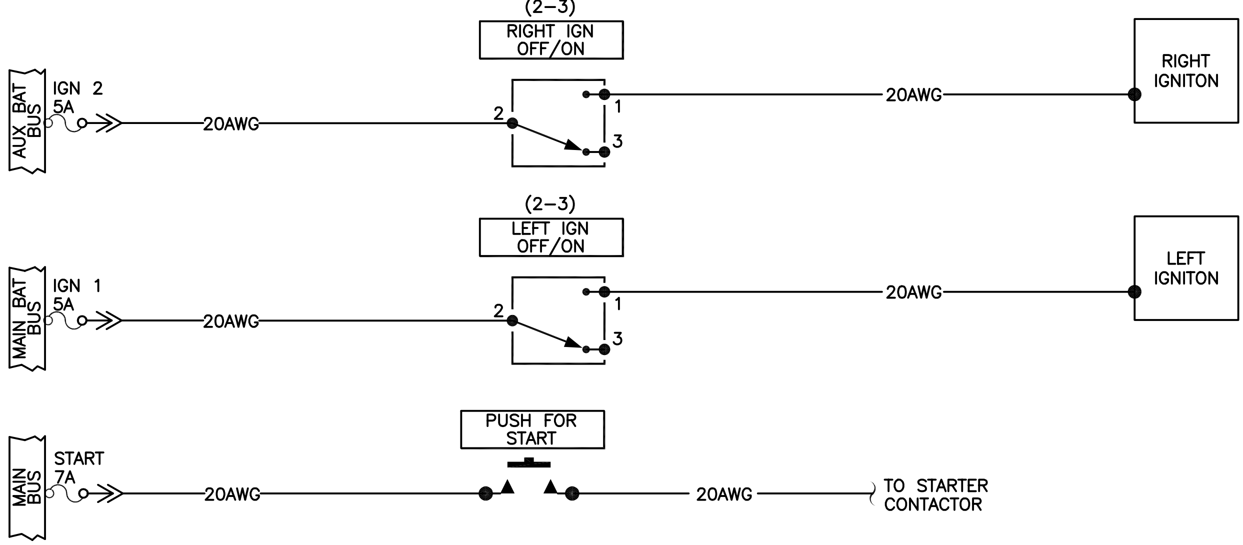
Figure Z-28. Dual Electronic Ignition with One Alternator



REV -K- 04/20/05

Figure Z-29. Always-Hot Battery Bus

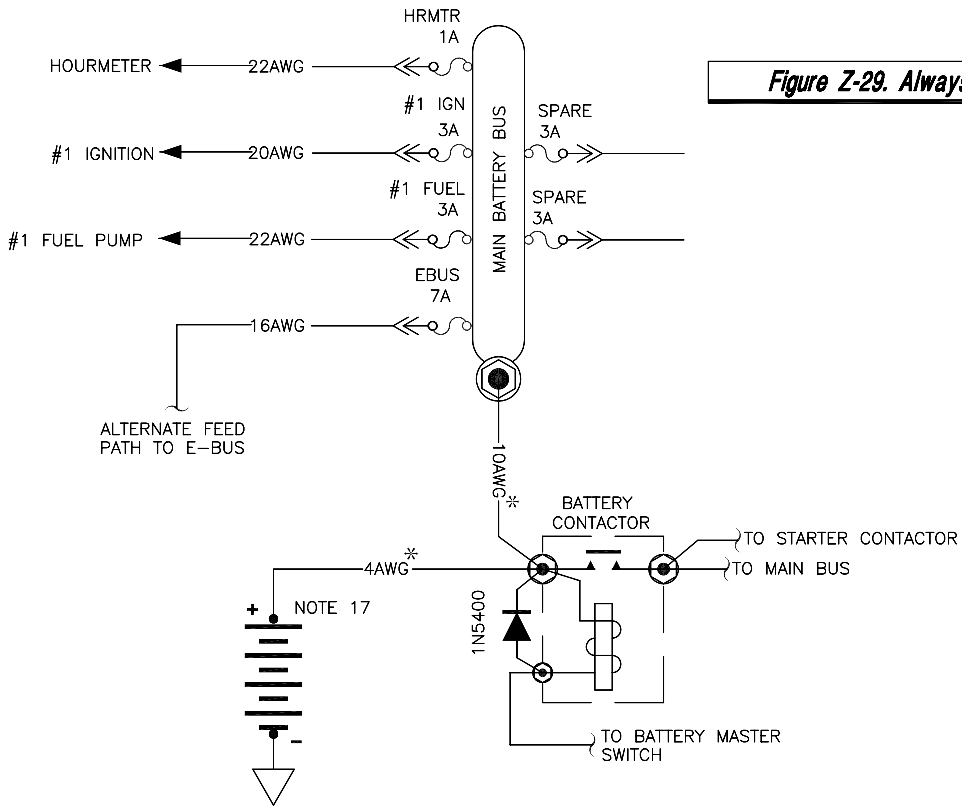


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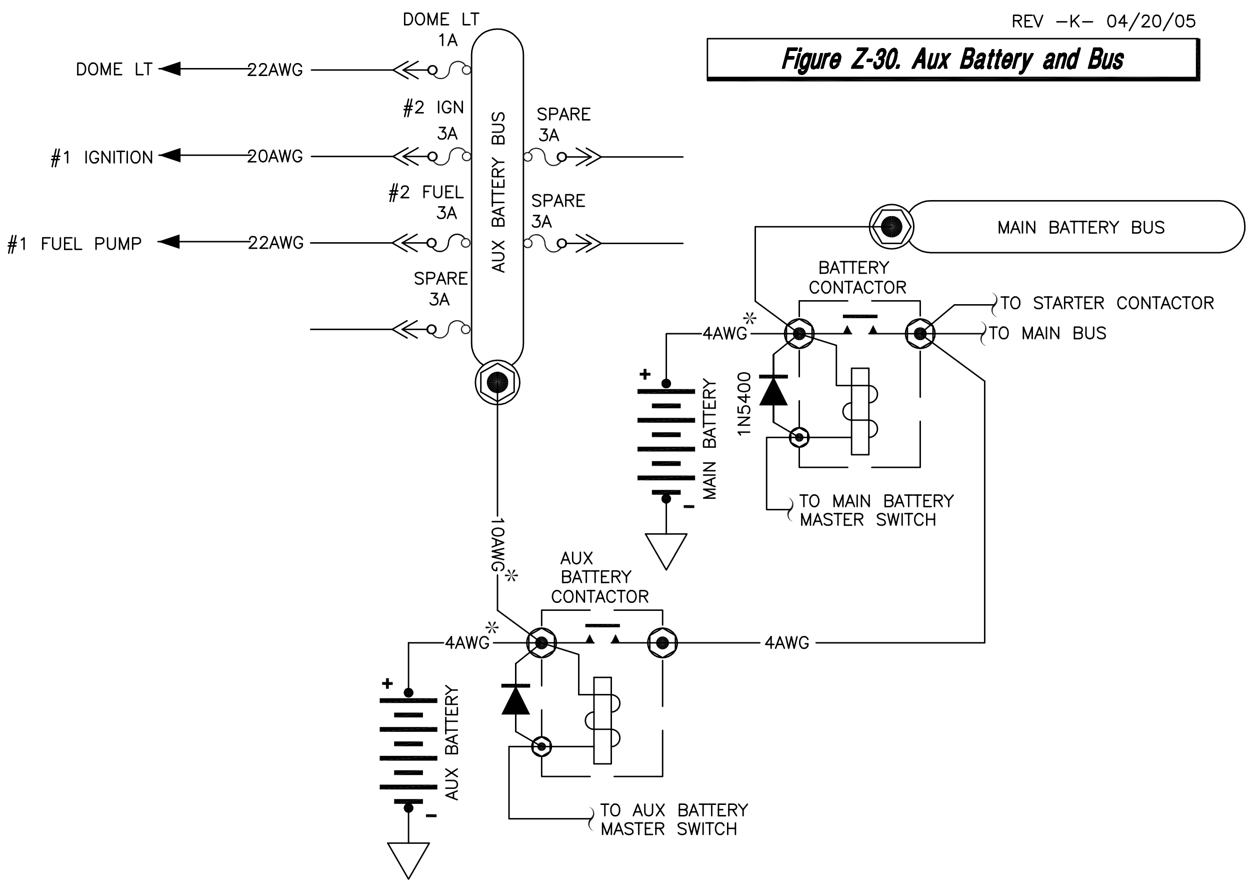
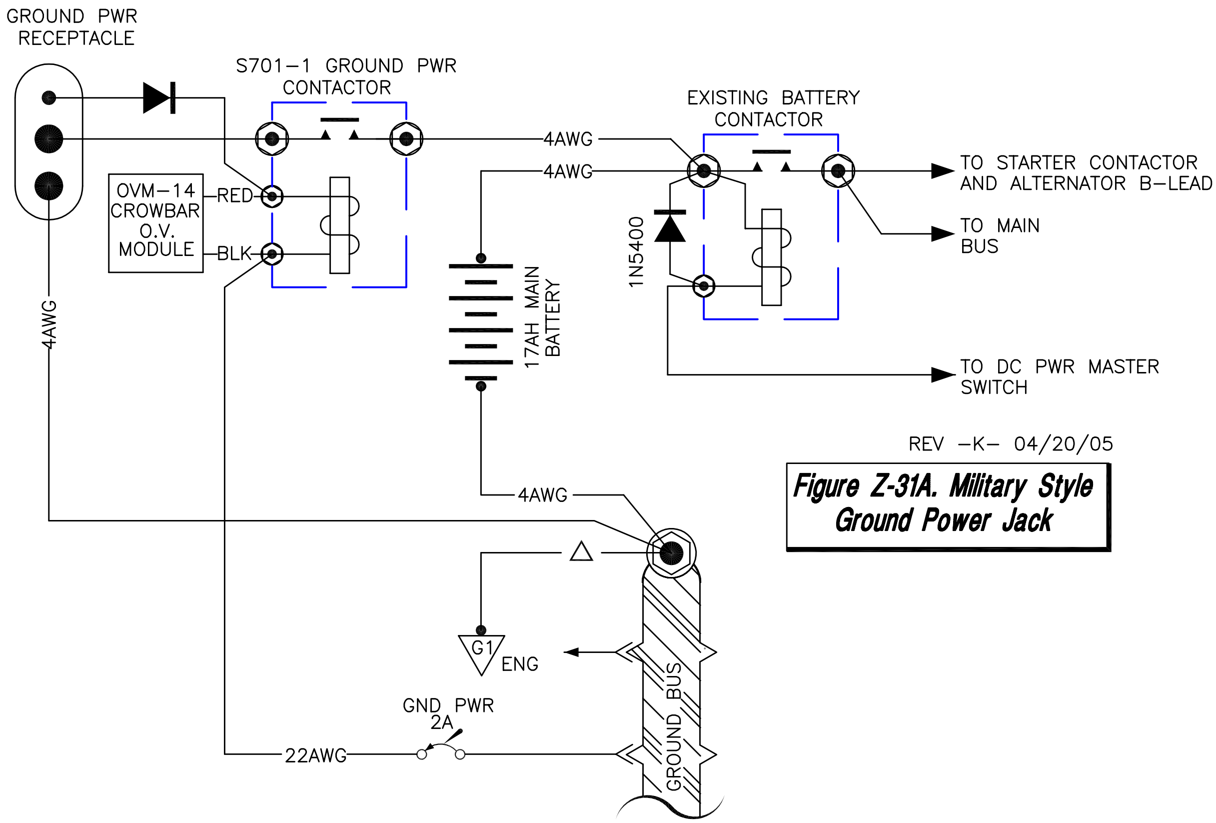
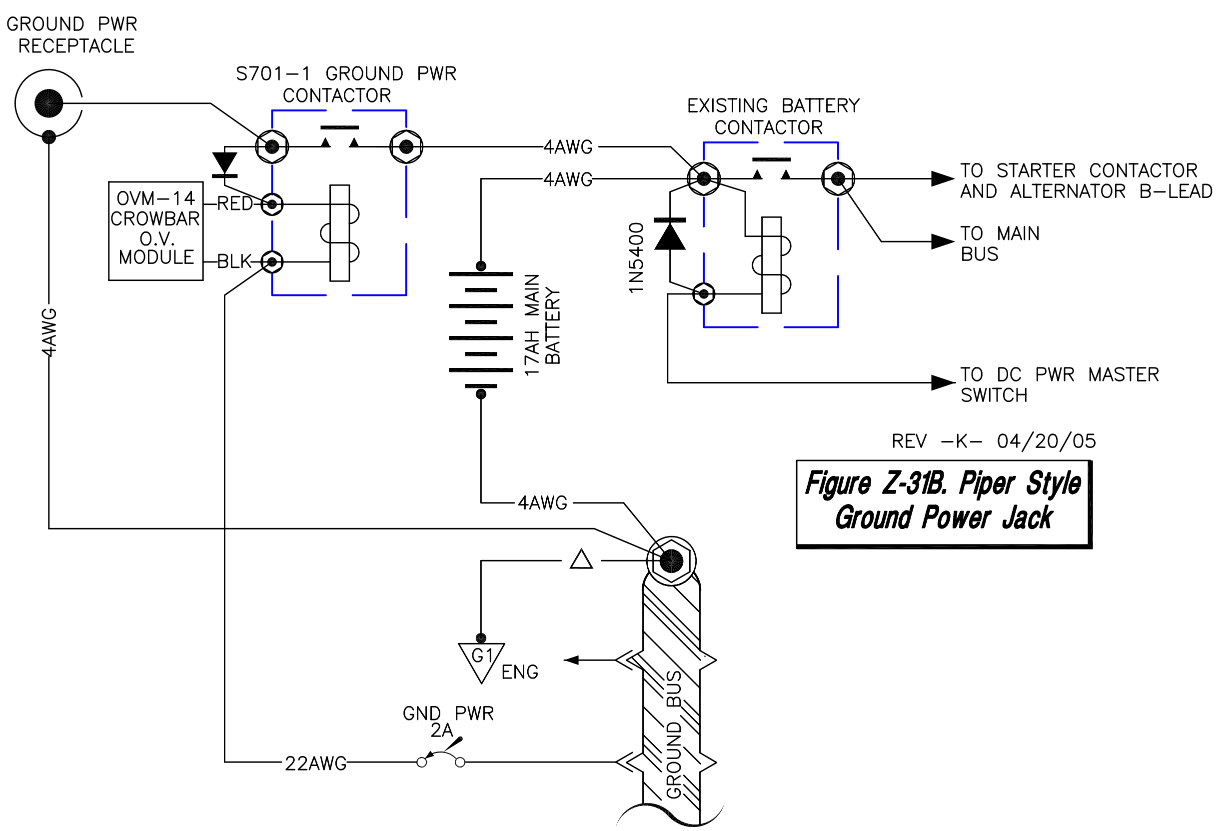
Figure Z-30. Aux Battery and Bus





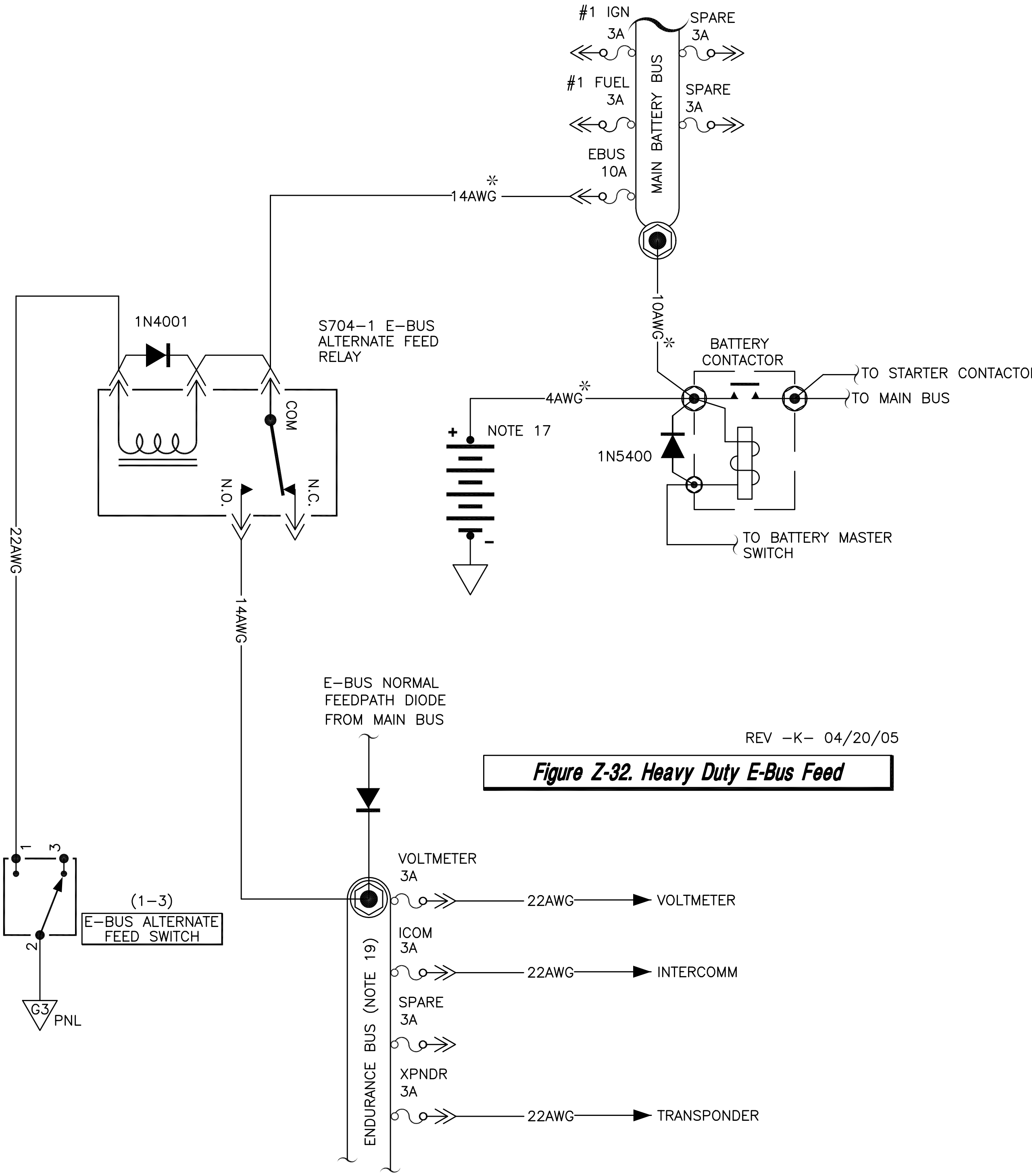
REV -K- 04/20/05

Figure Z-31A. Military Style Ground Power Jack



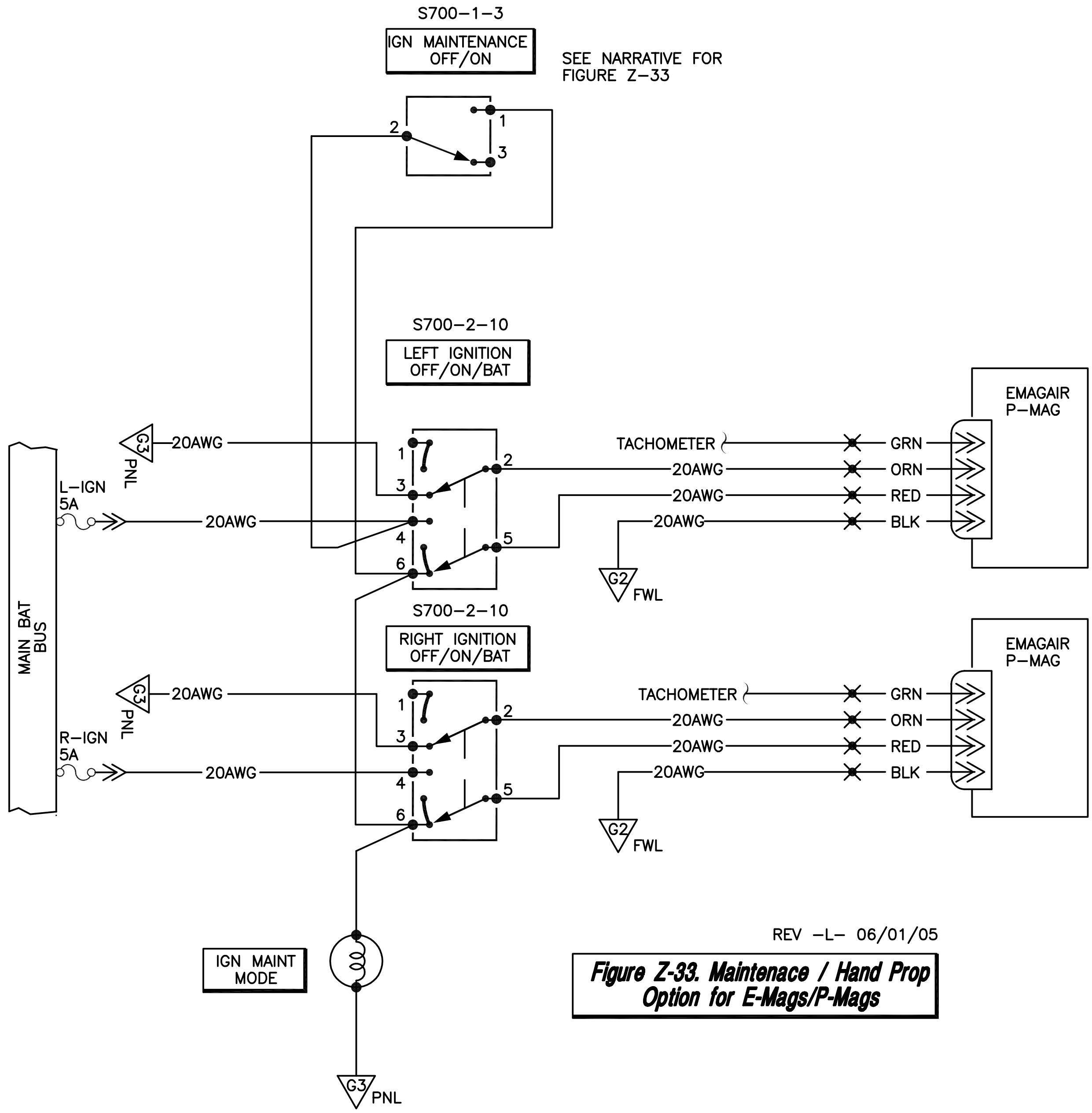
REV -K- 04/20/05

Figure Z-31B. Piper Style Ground Power Jack



REV -K- 04/20/05

Figure Z-32. Heavy Duty E-Bus Feed



REV –L– 06/01/05

Figure Z-33. Maintenace / Hand Prop Option for E-Mags/P-Mags

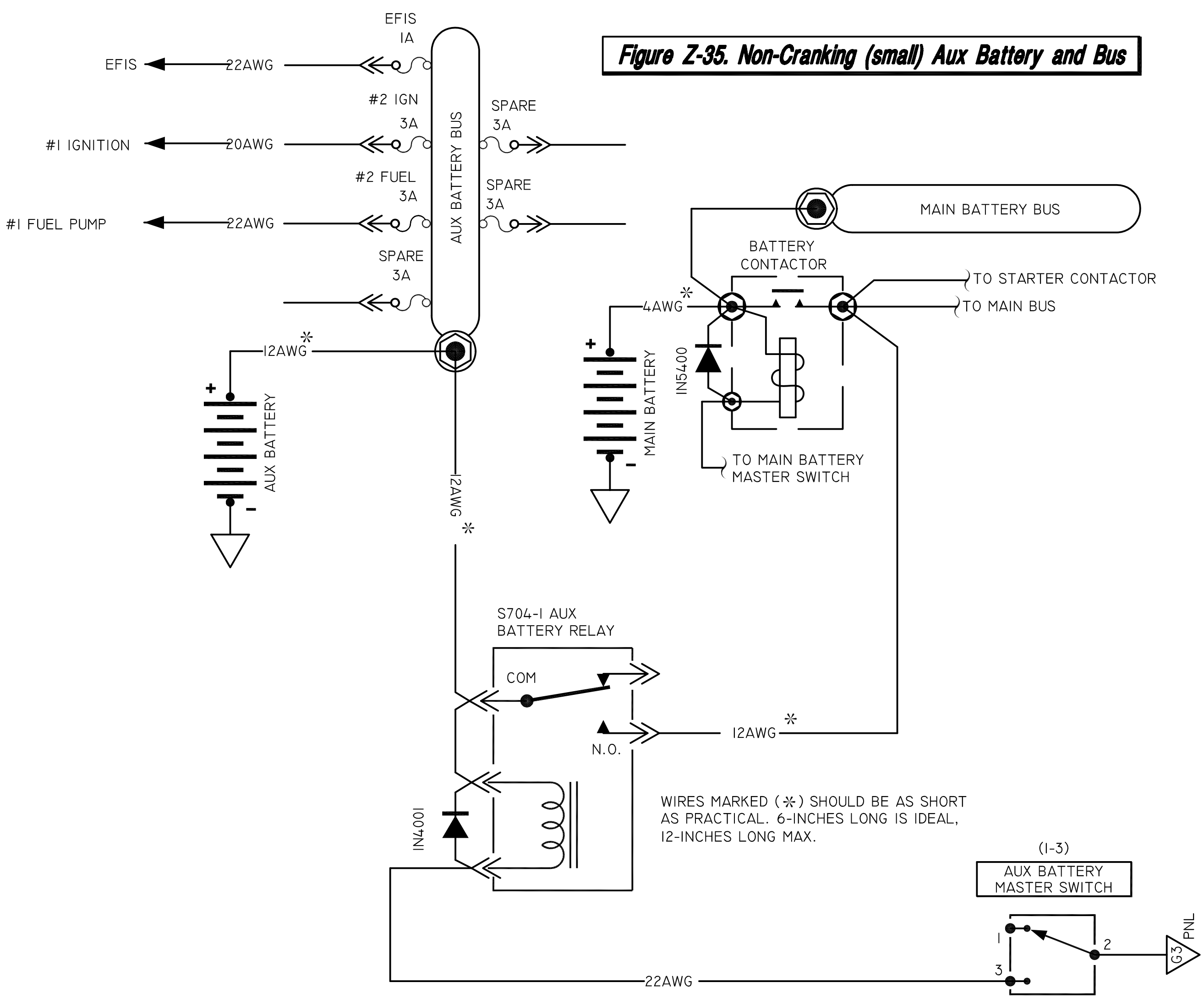


Figure Z-35. Non-Cranking (small) Aux Battery and Bus