A Tale of Two Voltage Regulators

Solid-state automotive replacement units are cheaper, but not better.

by Dan Stogdill

Come on, admit it: When the voltage regulator on your pride-and-joy packs it in, haven't you been tempted to run on down to the nearest NAPA auto parts dealer and purchase an automotive regulator as a replacement? We've all been tempted, I'm sure. Some of us have done it. And in some cases, you can get away with it—but not always. In fact, sometimes the results of such a switch are disastrous.

Recently, I was called upon to troubleshoot a nasty electrical problem in a 1977 Cessna 150. It seemed that shutting the master switch off wouldn't power down the electrical system while the engine was running. Closer examination revealed a host of other symptoms. Every light bulb in the aircraft was burned out; the navcom was fried (to the tune of $535 in repair bills); the lens over the panel-mounted "high voltage" lamp was melted; and the battery box was a seething sluice pit of sulfuric acid. What's even stranger is that when the ALT portion of the master switch was opened, the ammeter showed a charge of 20 amps or more, even though the high voltage light indicated that the charging system was supposedly disabled.

If everything were working according to Hoyle, these last two symptoms should not exist simultaneously. (See accompanying diagram.) The electrical system is set up in such a manner that if the ALT half of the split master is open, or the over-voltage sensor trips (i.e., opens), the +12 volts is removed from the 'S' terminal of the voltage regulator and the regulator's field relay drops out, causing the 'F' terminal to go cold, cutting the alternator's output to zero. At the same time, the regulator's 'I' terminal goes to ground potential, completing the high-voltage indicator circuit.

Attempts to "shotgun" the circuit had proved futile. Replacing the master switch, removing the over-voltage sensor, and replacing the regulator with a similar unit, all made no change. (Tuck that phrase "similar unit" away in the back of your cranium—it will come back to haunt us.)

Voltage measurements taken at the bus indicated 14.4 volts at 1,000 rpm with both halves of the master switch closed. But when the ALT half of the master was opened, instead of getting 13.6 volts DC (i.e., battery voltage), the bus voltage shot up to more than 16 volts. A voltage reading taken at the regulator's 'S' terminal showed zero volts with the ALT half of the master open; thus the switch was doing its job. Moving over to the 'F' terminal of the regulator, however, I got an indication of approximately 14 volts, when there should have been zero volts (if there were no excitation of the alternator's field). At first blush, it would appear that the regulator was defective. But replacing it with a similar unit (there's that term again) made no difference.

I studied the charging system schematic again. It indicated an alternate path for the +12 volts to the regulator with the ALT half of the master open; namely, through the *high-voltage indicator.* When this lamp was disconnected, normal operation of the regulator was restored. With the ALT half of the switch closed, charging rates were normal; with the ALT switch open, the ammeter no longer showed a charge and the 'F' terminal read zero volts when checked with the voltmeter. In addition, system voltage as measured at the bus indicated 13.6

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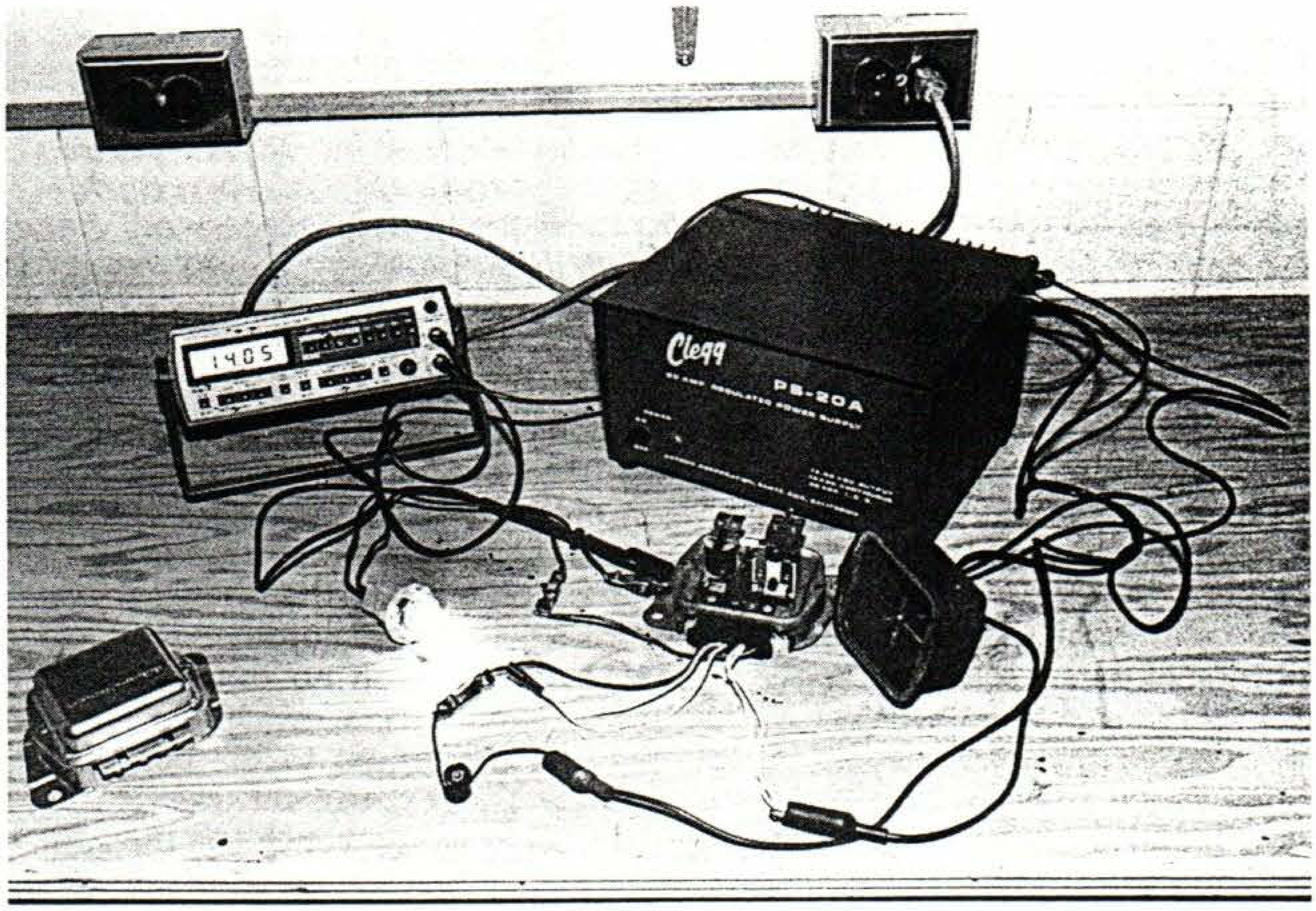
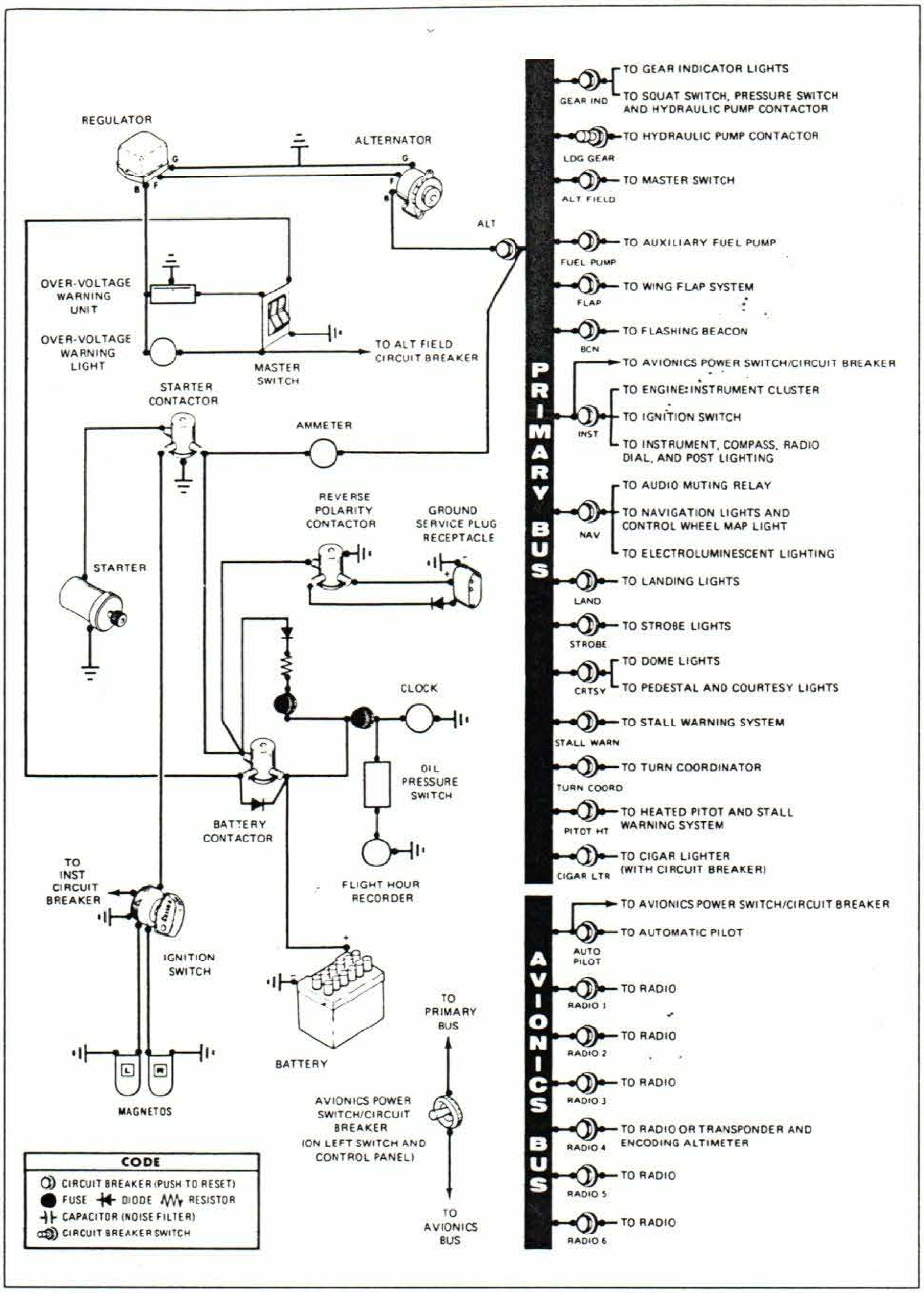


The author's bench-test setup included a Micronta meter and Clegg power supply. Automotive regulator can be seen at lower left.



Cessna electrical systems differ in subtle ways from model to model, but the above schematic (from the 1978 Cardinal RG) replicates the author's setup.

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VDC (i.e., battery voltage). There was obviously some type of backfeed through the high-voltage lamp which allowed the regulator to excite the alternator field even with the ALT portion of the master switch open.

I should mention that three weeks prior to all the excitement, fluctuations in the charging rate had been noted; and in anticipation of an impending failure of the voltage regulator, I replaced it with a new—albeit unapproved—solid-state automotive regulator. No more fluctuations were observed in the ammeter, so I assumed everything was satisfactory. Could the new, solid-state automotive regulator be the cause of all the trouble? I knew that some aircraft were using older automotive regulator designs with no trouble. Still, I wondered.

In order to get to the bottom of matters, an experiment was set up. I decided I would bench-test three different types of voltage regulators. The abilities of the different regulators to control field excitation was carefully studied using a power supply with variable output voltage to simulate an alternator's output at various rpms. A discovery was made that sent a chill up my spine. The approved Cessna regulator as well as an old-style Ford electromechanical regulator performed flawlessly. With both halves of the master switch closed, the 'F' terminal of the regulator continued to supply excitation until a line voltage of 14.4 VDC was reached. At that point, the 'F' output dropped to zero volts, as would be expected, thereby removing excitation from the alternator's field. On a full-blown system this would prevent the line voltage from ever exceeding 14.4 VDC. In addition, I observed that any time the ALT half of the master switch was opened, with either of these regulators, the 'F' terminal indicated zero voltage, as expected, and the high-voltage light lit up.

When the solid-state automotive regulator was tested, it too functioned normally when both halves of the split master were closed; more importantly, field excitation disappeared at 14.4 volts. But when the ALT half of the master was opened, the 'F' terminal of the regulator remained hot: It continued to supply excitation, even though the illumination of the high-voltage lamp indicated (or seemed to) that the charging circuitry was not functioning. What's more, when the voltage was cranked up (to simulate increasing alternator output at higher engine rpms), this regulator continued to provide field excitation. At 17.9 volts, the 12-volt lamp I was using to monitor the field output glowed its last glow. Cranking the voltage back down and removing the high-voltage indicator eliminated the backfeed (as it did on the aircraft) and caused the 'F' terminal's output to drop to zero, as it should with the ALT half of the master open.

To ensure that I didn't have one "flaky" regulator that was not representative of the whole batch, two more identical solid-state automotive regulators were purchased from different outlets and tested. All three behaved similarly. The units in question (in case you're wondering) carry no name, although their packaging indicates offshore manufacture. They are approximately half the height of the older electromechanical and Cessna regulators and are a shiny aluminum color.

That the new regulator's idiosyncracies went unnoticed for three weeks—until circumstances were ripe for the over-voltage situation—is understandable. (What those circumstances were, we shall speculate on shortly.) When checking the filament of the high-voltage lamp by opening the ALT half of the split rocker, how many of us simultaneously notice whether the ammeter is is showing a charge or discharge condition? Since most shutdown checks involve shutting the engine off first, before turning the master switch off, the inability of the master switch to control the electrical system while the engine was running (i.e., with the system at normal line voltage instead of battery voltage) would probably go unnoticed in ordinary day-to-day operations.

Although the exact event precipitating the fireworks is forever lost, some speculation can be made. The melting of the lens of the high-voltage indicator, coupled with the apparent boiling-over of the battery, would seem to indicate that an over-voltage condition existed for some period of time. This could have been caused by inadvertently leaving the ALT half of the master switch open while the engine was run up (which is no big deal with a properly functioning regulator, but was disastrous in the present instance). Alternatively, a transient voltage spike could have triggered the over-voltage sensor to open up (which is exactly what it is supposed to do in such instances). Either way, since the sensor and ALT switch are in series with each other, with this particular regulator (and a backfeed path through the high voltage lamp circuit) the results would be the same: a sustained over-voltage condition and some very expensive repairs.

Is there a moral in all this? I think so. If your aircraft has a Cessna-type charging system with an over-voltage light on the panel, be very careful if you decide to try a non-approved voltage regulator. At idle rpm, if the high-voltage light comes on *and* the ammeter shows a charge with the ALT half of the master-switch rocker *open*, you're in trouble. Shut both halves of the master off immediately and investigate further as soon as possible. *Don't* just turn the ALT switch back on and promise yourself that you'll only fly with it in the on (closed) position, because a stray voltage transient could cause the over-voltage sensor (if you have one, and most high-wing Cessnas do) to trip, which is functionally the same thing as turning the ALT switch off. Presto! Scorched avionics.

Those of us who fly older Cessna (and other) aircraft without the over-voltage lamp and spike sensor are somewhat more fortunate. Both the bench tests and the on-aircraft tests described earlier indicated normal functioning (removal of field excitation) when the ALT switch was opened, because of the absence of any path through the high-voltage indicator. Don't get me wrong, however. I am not advocating the use of unapproved parts—after all, there may be other anomalies associated with their use that we have yet to discover. (He or she who discovers them gets to write the next article.) The economy that comes from using unapproved parts—I can tell you from experience—is often false.

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