Electrical Protection from Pulses

Based on Cessna Service Bulletin SNL 62-8

The Magic Diodes:

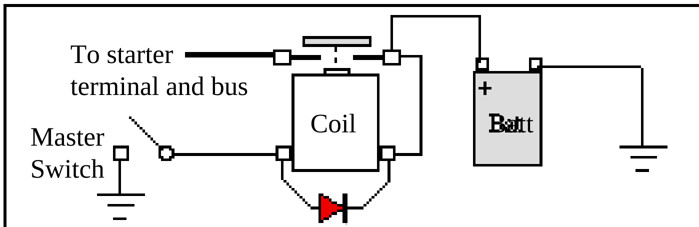
A reverse voltage pulse, measured and found to be on the order of 200 to 400 volts, is induced by the battery relay/solenoid coil when the master switch is turned Off. When current is flowing in a coil, a significant amount of energy is contained in the magnetic field sustained by the current. The magnetic field collapses as the switch is opened and the collapse creates that large reverse voltage pulse which can damage sensitive equipment still attached to the bus. Although with a lesser consequence, some of the pulse energy makes an arc between the switch points, pitting and eventually making it intermittent.

To limit the pulse magnitude, Cessna mandated that a silicon diode be added in parallel with the coil which "clips" the pulse when the master switch is opened. Some call it a snubber, perhaps a better descriptor. For those planes with a starter solenoid as well, Cessna calls out a diode for them, too, for the same purpose.

A diode passes current only one direction. The diode arrowhead symbol shows the direction of easy current flow; no current can flow in the opposite direction up until the reverse voltage across the diode exceeds its breakdown voltage. You might ask why, if Cessna knew the advantage of the diode, they did not include it the circuits when the planes were made. Because silicon diodes did not exist when our planes were manufactured and for many years thereafter.

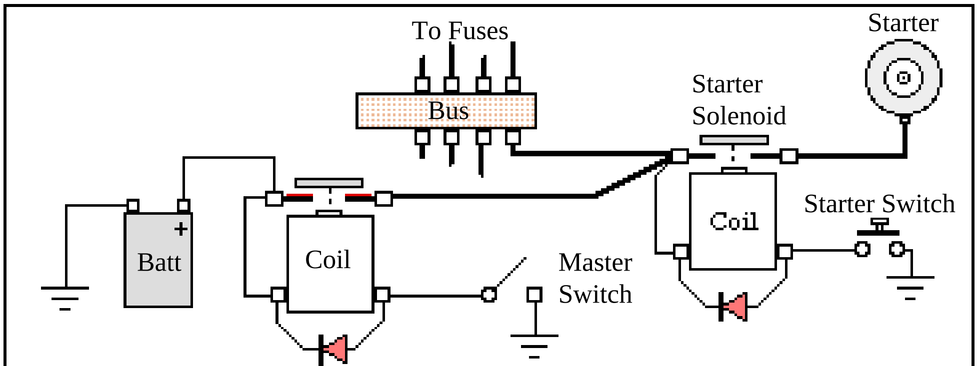
The magic of the diode as shown in the diagram is that it does nothing when the master switch is on and the battery relay is closed, but the instant the master switch is opened and the reverse voltage pulse is created, the diode does pass current and so "clips/snubs" the voltage of the surge such that it never exceeds more than 0.7 (yes, seven tenths) volts above the bus voltage. Consequently, nothing attached to the bus can be hurt by the surge and master switches will last years longer.

The circuit to "clip" the reverse voltage surge is as noted, with a silicon diode attached to the coil terminals of the solenoid/relay as indicated. Note that the current from the battery does not go through the diode because current cannot flow opposite the direction of the arrowhead, known as the anode of the diode.



Diode shunt for clipping the pulse (back electromotive force) created when the Master switch is turned off.

More and more planes are having the pull-style starter replaced by the electrically activated type via a relay. The reverse voltage pulse from the opening of the starter switch and the relay can be higher than for the battery solenoid, so Cessna also has called out for a diode to be in parallel with that coil, shown in the next sketch.

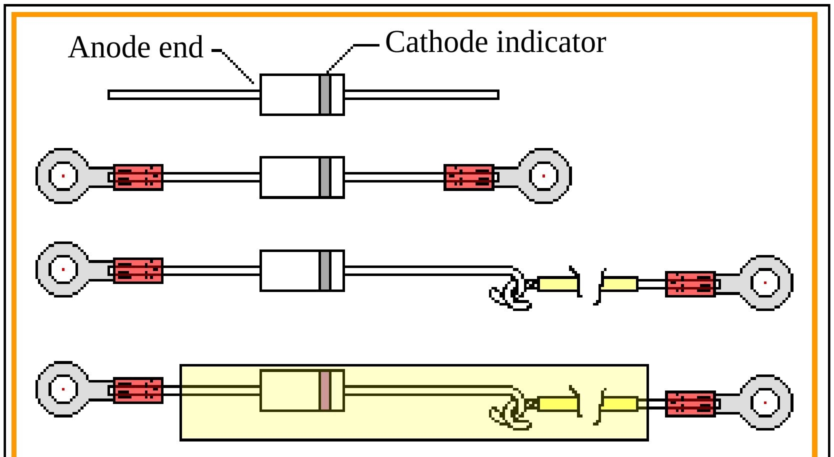


Circuit for planes with electric starting circuits, with shunt diodes on both solenoids.

Diodes

1. Diodes in parallel with relays or solenoid coils are true magic to protect the spike-sensitive transistor and integrated circuit radios.
2. Our planes were built before silicon semiconductors were invented, so their designs did not include protective diodes; besides, the tube radios absorbed the voltage spikes without damage.

What size diode in parallel with the master solenoid and the regulator field relay? A general purpose silicon (important to use silicon, not germanium) diode capable of at least an amp and with a reverse voltage capability of at least 100 volts and a half watt rating. The reason this is enough is that the pulse is so short that the event is over before the diode has a chance to heat up from the energy dissipation. The larger you get in amperage or voltage, the more robust it will be for mounting and the larger leads means an easier time of termination. Makers of silicon diodes find it difficult to make any with less than these attributes, so we are talking about a fifty cent diode at Radio Shack. How to attach? Attach red (for 22 to 18 gauge wire) terminals (lugs) to the ends of the diode; the lead length on the diodes as they come is enough to reach the solenoid terminals on some planes, but for our boxy solenoids on the 120/140's, one lead must be longer to reach. Crimp the diode lead to the lugs/terminals (best) or solder them but use an alligator clip attached to the diode leads to draw off the heat of soldering. Most of the battery solenoid coil terminals I have seen are size 8, but you could use a terminal with a size ten hole as well.



Solder the splice and cover the exposed wire with insulating tubing.

The polarity rule? The cathode (usually denoted by a contrasting color band at the cathode end) of the diode goes to the positive terminal of the coil, and the anode of the diode to the terminal where the wire to the master switch attaches. If you reverse this, the first time you turn on power will cause the diodes to smoke and their souls will depart this world. The acrid odor is unmistakable!

Note that, if you have the newer three terminal solenoid (see the article on solenoids for the new substitute sanctioned by Cessna), the cathode end must be attached to the “BAT” terminal because the normally external coil lead is now internally connected to the Bat terminal.

The diode can be a one amp, 100 volt type, or larger in either parameter. The size depicted here is about that of a three amp, 400 volt unit, just because that is what the electronics store had the most of with the original lead length. For the size of diode called out by Cessna, you would have to splice the leads to make the leads usable in a terminal, but with the 3 amp size, the leads are large enough in diameter to crimp nicely in the red terminals. The covering tubing, if heat shrink is used, serves no better if the covering is shrunk. If you cover the diode and leads with non-transparent tubing, make sure you know which end is which for connecting.

Page 2400-02 and 03 of the International Club maintenance big book (“silicone” in that service letter should be “silicon”, a common error).

A lot of our brethren seem to confuse bus with buss; “bus” means “common carrier’, whereas buss means....to kiss. Wires get connected to a bus, not a buss/kiss.

Are You Sure It is Needed?

So many things are recommended but not necessary and so many tales are out there. The following is part of an actual series of observations made to answer just that question for the pulses to be found.

Credit: The content following was determined by actual measurements and the results deserve to be acknowledged. The tests were made by: Mike Mladejovsky, PhD EE Mechanical Engineering Dept., Univ of Utah WA7ARK From: MikeM mladejov@my-deja.com

I have taken a sampling digital Oscilloscope out to the ramp and attached it across the main power bus of my Cessna 182. I recorded the voltage transients which occur when the Master switch is turned on/off, when the starter starts/stops cranking, and when other high current loads, like landing lights and the flap motor are turned on/off.

Turning on the Master is benign (tiny, so not of consequence). Turning off the Master is benign if there is a correctly polarized diode wired across the coil in the Master relay (as per the Cessna Service Letter). Without the diode, I recorded transients directly across the main bus up to 250V lasting up to 2 mS (milliseconds) as the magnetic field in the Master Relay coil collapses after the Master switch is opened.

The onset of cranking is benign, unless the START position the key switch is dirty, and makes and breaks several times before it settles into full contact. As the key is released after the engine fires, there was a huge 400V+ transient, lasting 2 mS. Putting a diode across the coil of the Starter Relay per Cessna's Service Bulletin snubbed the Starter Relay coil transient to 0.7 volts above the bus voltage!

I was curious how well the alternator regulator would do at holding the bus voltage constant when the landing light was turned on/off. With the engine running, and the alternator on line, the bus voltage would sag about 1V below its nominal 14.2V for about 200 mS when the landing light is first turned on. In other words, it takes about 1/5 of a sec for the regulator to detect the drop, & crank up the alternator field current to bring the bus voltage back to 14.2V. Turning off the landing light causes an initial overshoot up to about 14.5V, with several oscillations over/under (like a phugoid?) dying out in about a 1/2 second.

The flap motor wasn't so kind. As it shuts off, it puts out a huge 400V spike, also lasting 2 mS. This happens any time the flap motor is actuated. To counter the non-suppressed flap motor which operates when the avionics are on line, I did something else to my airplane. I put a 500 uF, 50V electrolytic capacitor, and a 0.01 uF 1000V disc ceramic capacitor between the "avionics bus" and ground.

The reasoning is this: There is a finite amount of energy (Joules) in the transient (s). It takes a nearly infinite amount of energy to suddenly change the voltage across a large capacitor in a very short time. Conversely, a sufficiently large capacitor will gobble up the transient, keeping the voltage excursion at a volt or two. Since electrolytic capacitors are slightly inductive, the ceramic disc capacitor gobbles the leading edge of the transient, where the electrolytic would not be effective. I confirmed this with the O'Scope. (The ceramic cap absorbs the fast transient and the large electrolytic absorbs the slower energy.)

MikeM

Relief from the $358 for the original battery solenoid:

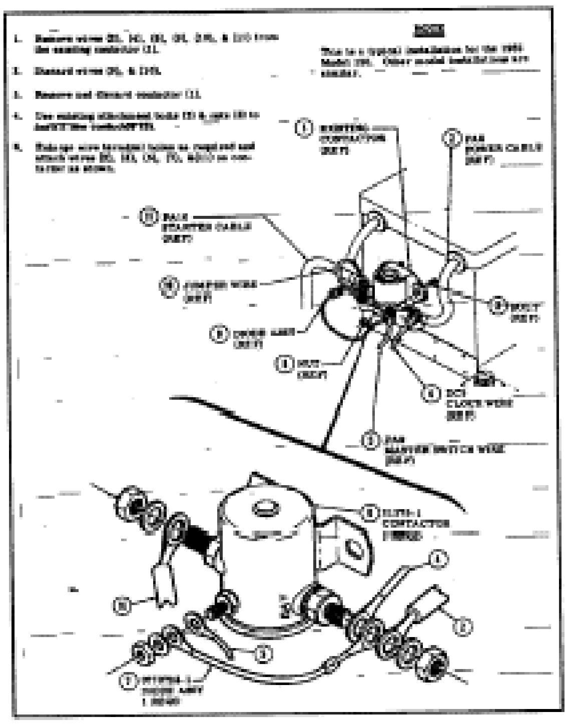
Service Bulletin 65-89 Allows Inexpensive Contactor Replacement For Pre-1966 Singles

$350 Battery Contactor is legally replaced by $21.90 unit

By Steve Ells

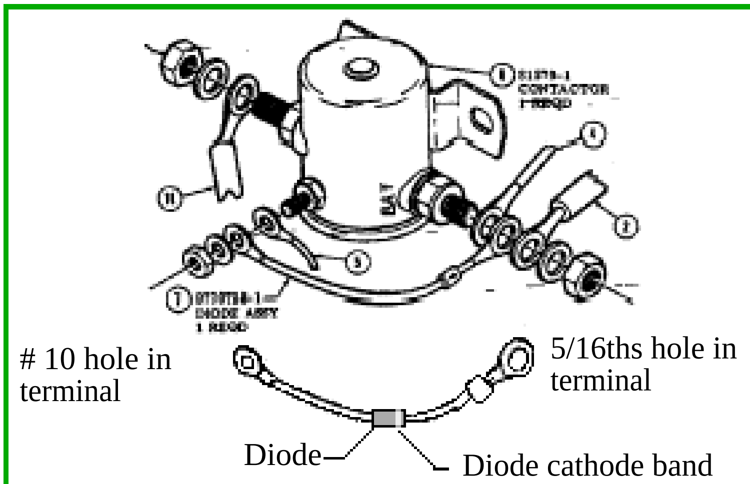
Battery contactors are seldom thought about, rarely tested, and seldom fail. In an article titled, Solenoids, Contactors, Relays: What Do They Do and When Should They Be Replaced? that appeared in the April 1996 issue of the Cessna Pilots Association magazine, CPA suggested that the starter contactor be changed at 2,000 hours time-in-service due to the relative low cost of the contactor and the potential for expensive component damage if the contactor "welded" shut during a start.

Recently CPA received a phone call from Joe Rothrock, Cessna Pilots Association member number 8673, saying that he was looking for a battery contactor for his 1958 172. I checked the parts manual and found that the part number for this contactor was 0712603-2. List price from Cessna is $358. Mr. Rothrock said he knew the list price and wondered if there was any alternative. I didn't know but said I'd try to find out. After a few hours of studying drawings it was obvious that Cessna switched from the $358 contactor to a $21.90 contactor (part number S1579-1; superceded by S1579-A2) beginning in 1966 for 150s, 172s, 180s, 182s, 185s, 205s, P206s, U206s, and 210s. The parts books for all these single engine Cessnas still specifies the high cost contactor.

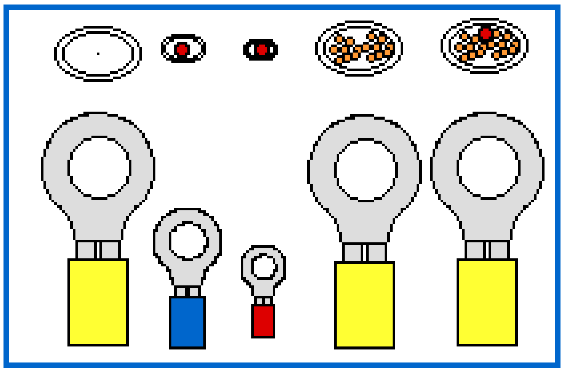


Cessna SB 65-89

Cessna Service Bulletin 65-89 announced, "An approved design heavy duty battery contactor..." had been installed on the single engine models during the 1966 model year. The bulletin goes on to say that the new contactor can be added to earlier model Cessnas and provided the information on how to do this by providing a drawing to aid in installation of the new contactor. This drawing has been reproduced for the benefit of our members that own pre-1966 Cessnas.



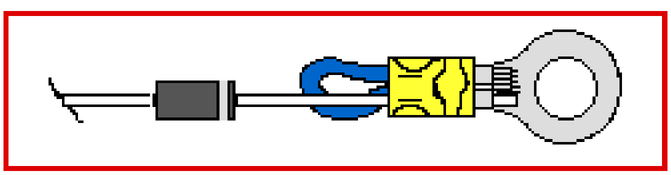
The representation of the diode was poor so this is more as it would look. Usually, the length of the diode leads as new will be enough to reach the studs without splicing a wire to it.



We found that Red or Blue terminals with the necessary 5/16ths hole are rare but even Radio Shack has yellow with 5/16ths hole as part of a package of various sizes. What is not well known is that you can use terminals which are grossly oversize for holding just the diode lead, shown as the red circle, if you fill up the excess opening in the yellow with more wire.

Starting from the left, the upper row of figures are to depict the crimpable cross section of the various sized terminals. Note that the size diode we used, for 3 amps, would crimp well in the red if you could get one with the 5/16ths hole but the blue would be too large to crimp on only the diode lead.

However, with a yellow terminal having a 5/16ths hole, we can successfully crimp the diode lead as long as we add two size 16 wire stubs to make up the necessary size for the yellow. The blue wire is the filler, formed as a loop to allow confirmation of a correct crimp and for a pull check.



Filed as Diode and Pulse data (see diode snubber test data file, and the battery solenoid, too)
25 April 2003
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