Power Hour Lessons

Cessna 172S Model Systems - How things work.

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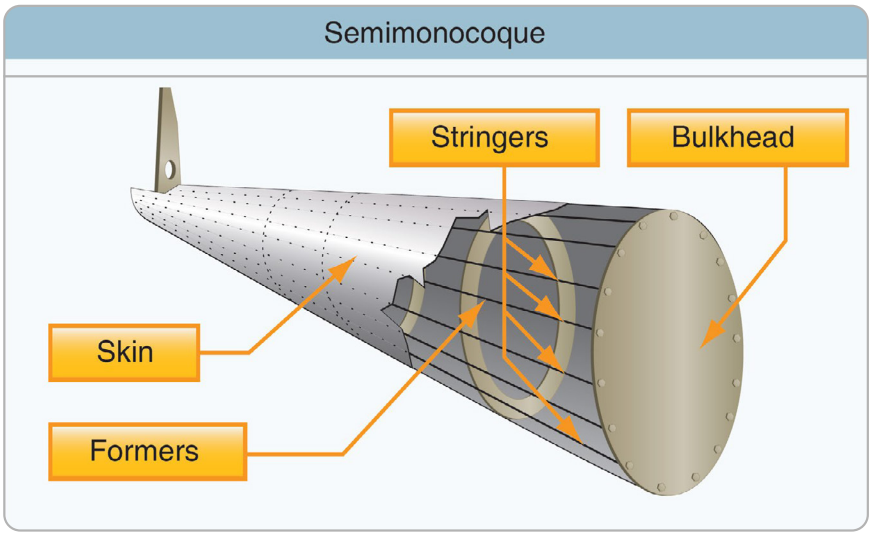
Overview

Airframe

Metal, four-place, high wing, tricycle landing gear. Conventional formed sheet metal bulkhead, stringer design (Semi monocoque).

Cessna 172



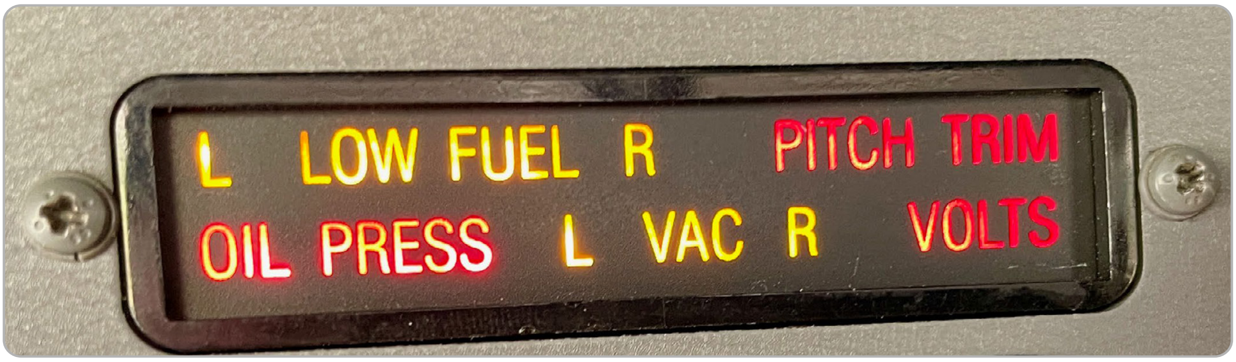
Semimonocoque construction

Instrument Panel

Contains the flight instrument, engine instruments, combined ammeter and vacuum gauge, various navigation instrument and the main circuit breaker panel and avionics circuit breaker panel.

Annunciator Panel

The annunciator panel is located above the altimeter.



CAUTION MESSAGES:

LOW FUEL

Yellow lights - L LOW FUEL if the left tank is low or LOW FUEL R if the right tank is low. If both tanks are low the message is L LOW FUEL R

OIL PRESSURE

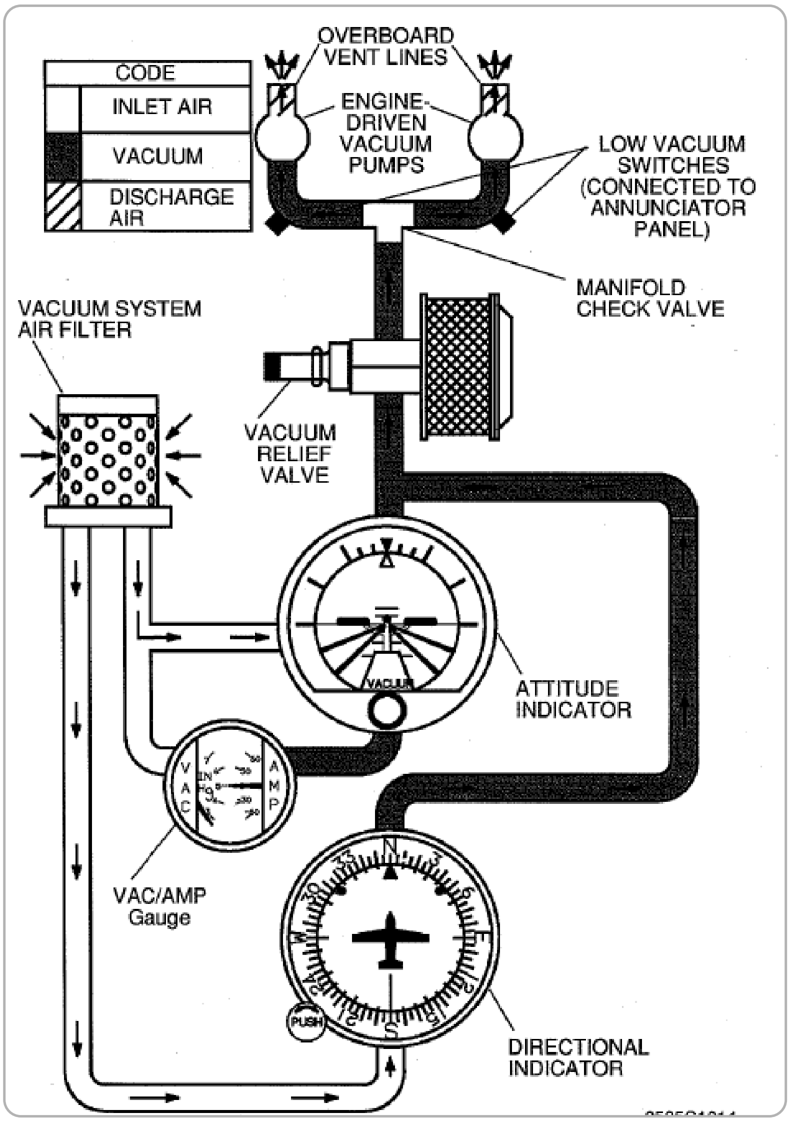
Red Light - OIL PRESS illuminates when the oil pressure is below 20 PSI.

LOW VACUUM

Yellow - L VAC and/or R VAC (left vacuum pump failure, right vacuum pump failure)

LOW VOLTAGE

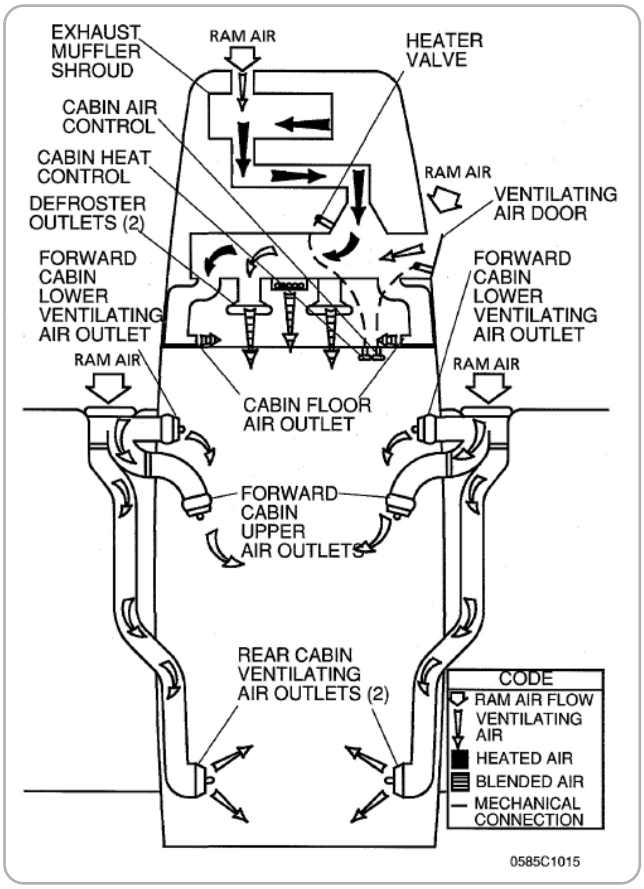
Red Light – VOLTS – If system voltage drops below 24.5 volts



Vacuum System Diagram

Annunciator Panel

Separately adjustable ventilators for additional air are located near each upper corner of the windshield for the pilot and copilot. The other two ventilators are in the rear cabin area to supply air to the rear passengers. There are additional ventilators located at various positions in the cockpit.



Environmental Systems

Fuel System

The fuel system incorporates two vented wing tanks, one in each wing. At the filling point for each tank, there is a fuel filler tab. It sticks down into the tank on the backside of the fuel filling point. If fuel is filled to the bottom edge of this fuel filler tab the fuel in the tank will contain17.5 gallons of usable fuel rather than 26.5 gallons.

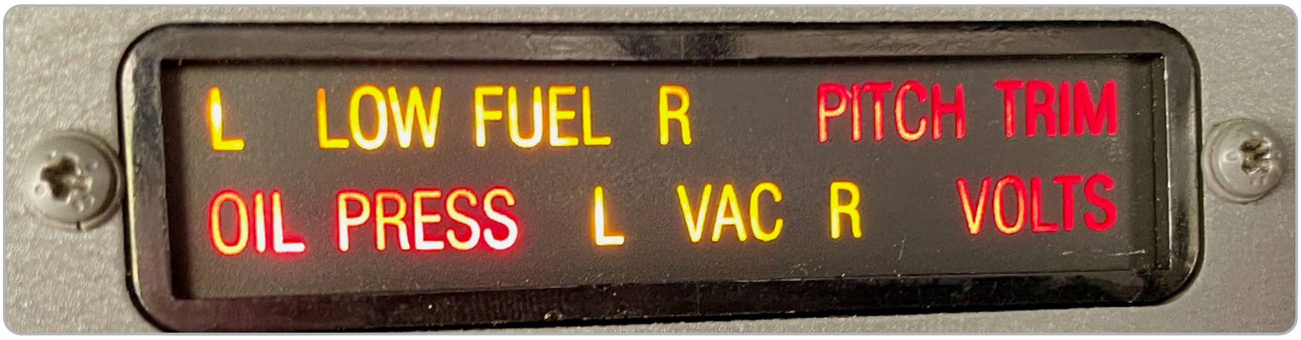
Venting of the tanks is accomplished by an interconnecting line (crossfeed tube) from the top of the right fuel tank to the left tank. The left tank is vented overboard via a vent that is mounted on the left-wing behind the strut. Both fuel filler caps are also vented.

Fuel flows by gravity from the wing tanks to the fuel selector valve, to the reservoir tank to the auxiliary fuel pump, the fuel shutoff valve through the fuel strainer to the engine-driven pump.

The engine-driven pump delivers fuel to the fuel/air control unit. Fuel is metered and then sent to a fuel distribution valve or manifold which distributes fuel to each cylinder. The flow rate is determined by the amount of air that passes through the fuel/air control unit.

From serial number 172S9491 and up and on airplanes incorporating MS172-28-01 a fuel system return system was added. This system carries a metered amount of fuel from the fuel/air control unit back to the reservoir tank. This increases the fuel flow at the engine inlet and results in a lower fuel temperature that reduces the amount of fuel vapor in the engine lines at high-temperature operations.

For selecting which fuel tank, the engine will use, there is a three-position fuel selector valve that has LEFT, RIGHT, and BOTH positions. The BOTH position must be used for takeoff, climb, landing and anytime there will be prolonged slips or skids of more than 30 seconds.



Annunciator Panel will Show L Low Fuel or Low Fuel R when 5 Gal left in the corresponding tank.

Fuel quantity is determined by a float-type transmitter in each tank. This unit provides the fuel quantity to an electrically operated fuel quantity gauge on the instrument panel. The system has warning circuits to detect low fuel conditions and erroneous fuel transmitter messages.

If the fuel in the tank reaches below approximately 5 gallons and remains at this quantity for more than 60 seconds, the amber L LOW FUEL, or R LOW FUEL (depending upon which tank is affected) message flashes on the annunciator panel for approximately 10 seconds after which it will turn steady on.

If there is a failure of the transmitter the fuel level indicator needle will go to the OFF position (Below the 0 mark on the fuel gauge) and the amber annunciator for either L LOW FUEL or R LOW FUEL will turn on.

A transducer is located in the fuel manifold and produces an electrical signal in proportion to the amount of pressure exerted on it. It converts this pressure to an electrical signal that is used to display fuel pressure in gallons per hour.
Fuel sampling points are located below each wing and under the airplane. There are 5 drain valves under each wing. Under the airplane, there are three drain valves, one each for the fuel selector, fuel reservoir, and fuel strainer. Fuel samples must be drained enough to be clear any contamination.

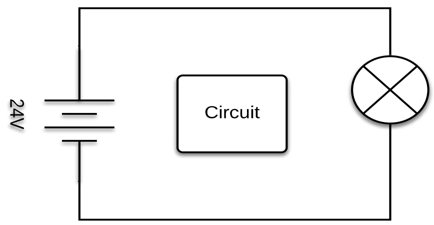
Approved Fuel Grades 100LL Aviation Fuel (Blue) and 100 Aviation Fuel (Green).

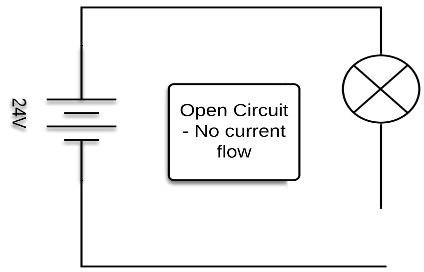
FUEL CAPACITY

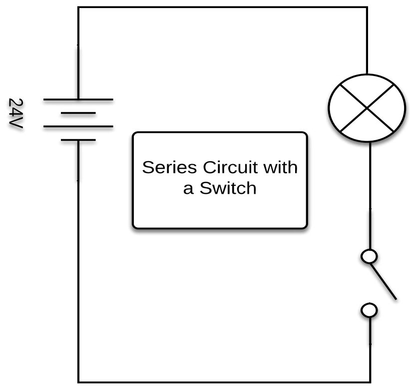
56 US Gallons Total: 28 US Gallons per tank.

Usable Fuel: 53 Gallons: 26.6 Gallons per tank.

Annunciator Panel Showing Low Fuel for Both Left and Right Tanks.



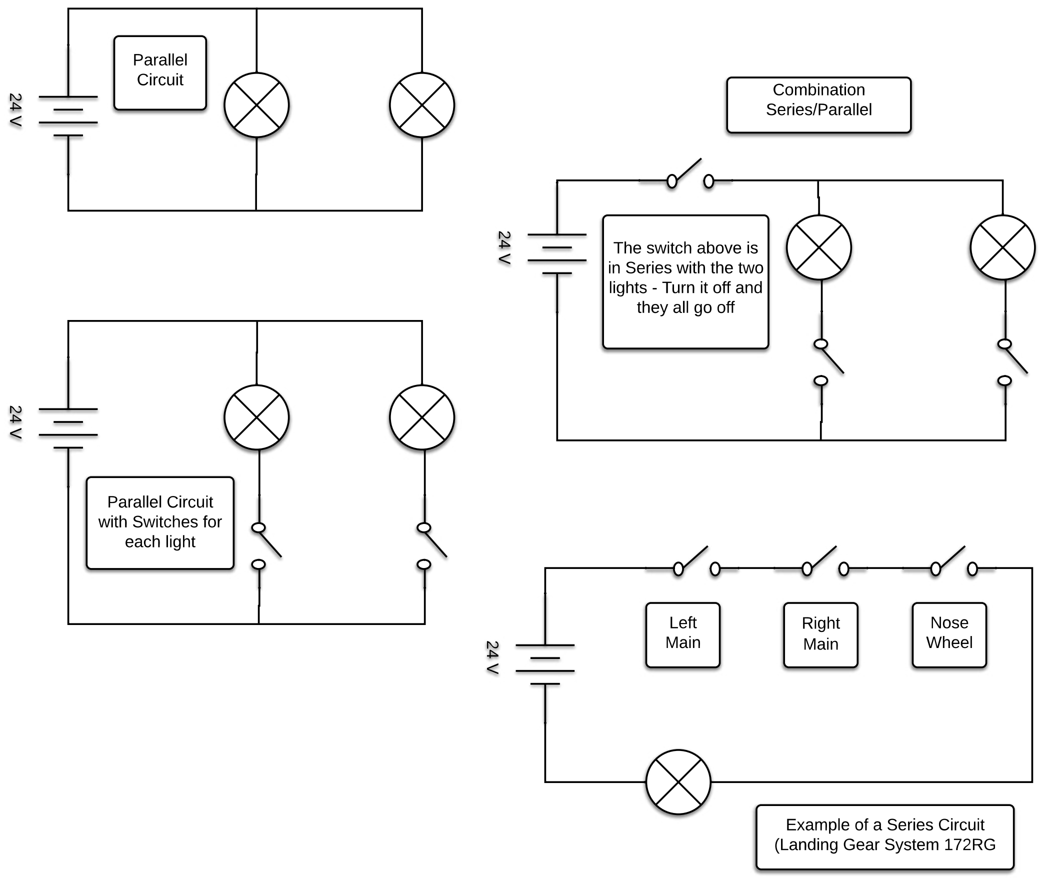




If I wanted to add additional light bulbs to this kind of circuit, it would be possible. I just need to connect them end to end like the diagram named series circuit. All devices are connected end to end, thus in series with each other. The issue here is two-fold. First, if one light bulb fails, then the return path for the current to return to the battery is interrupted and so the entire circuit fails (All lights go dark). The second problem is that when I only had one light bulb like in the first diagram then the battery was connected to both sides of the light bulb. So, if the battery were a 12 Volt battery, then I would need a 12 Volt light bulb. When I connect multiple light bulbs in series then the 12 volts are not connected to each one. It's divided between the light bulbs, so I need different voltage light bulbs for that to work. Not practical at all for an airplane. Airplanes have either 12 Volt or 24 Volt electrical systems. There is no way to have that kind of system and have a bunch of radios, lights, etc., that work on different voltages.

So, we need an answer to this problem. And…the answer is something called a Parallel circuit.

Look at the diagram for the parallel circuit and you can see that all of the light bulbs are connected directly to both sides of the battery. This way if one fails then there the others can work because their circuit (path from one side of the battery to the other) is not interrupted. The other advantage is that all of the light bulbs can be 24 Volts. We don't need different voltage light bulbs.



Parallel, Series and Combination Circuits

Now just to finish on this point, there are practical applications for the series circuit. Look at the landing gear diagram for a Cessna 172RG. This airplane has one green light that turns on when all three gears are down (nosewheel, left main, and right main). If all three don't come down the green light doesn't come on. This is a perfect application of the series circuit. In the diagram, when a gear comes down it touches a switch. The switch connects (closes) and if all three closes, then the light comes on. If any don't come down, then the green light doesn't turn on.

Another place for a switch like that is one wired in SERIES with the entire electrical system. An example would be the master switch in an airplane. Look at the diagram where I have the master switch wired in series with the rest of the electrical system. All of the other devices are connected from one side of the battery to the other, so they are in parallel with the battery.....but only if the master switch is on (closed). If that switch is off (open) then everything else can't work.

Ok, now a few more things I need to go over so you can understand the schematic diagram in the POH. The first is what a relay is. Like the master relay, starter relay, etc. Other diagrams call them contactors or solenoids. They are all the same things.

Concept – The diameter of a wire determines how much current it can move through it.
The bigger the wire the more current it can move. Take the battery wire for example. It's about the diameter of your thumb. It's a pretty big wire. The battery sources all of the current for the airplane so it will have the largest wire size of anything in the plane. The wire for the radios, lights, etc., however, are around 10 to 20 times smaller.

Now consider the size of the master switch on the panel. It's two switches in one. One is for the alternator and the other is for the battery. How small is that switch? It's pretty small really, considering it's only using one side of the switch for the battery. Now imagine how big the battery wire is from the battery. It's huge. The switch, to work, would need to be about 10 times bigger than it is to allow that much current to flow through it. Remember its connection points are really small.

So, what gives. How does turning on the master switch in the cockpit allow for all of that current from the battery to get past it and do some work like powering radios, running flap motors, starting the engine with the starter motor, etc.?

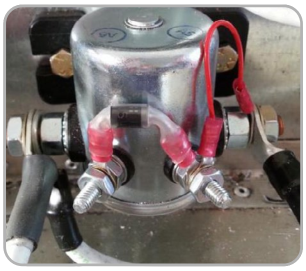
The master switch controls another big switch that is located on the firewall of the airplane. This big switch is called a Relay, Contactor, or Solenoid. The words all mean the same thing and different airplane manufacturers call them one of those three words.

You can see by the picture that it's a can with two big connections. One side of the battery is connected to one of those bolts and the rest of the electrical system is connected to the other bolt. With the master switch turned off the two bolts are not connected electrically.

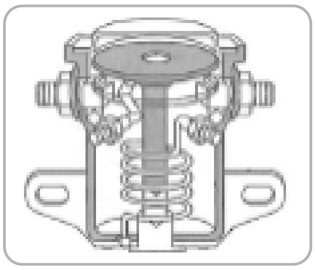
There is a gap between them, so no power is available to anything. The two smaller connections on this device are where the master switch connects. By turning on the master switch, a small amount of battery power is applied to this device which allows the connections between the two big bolts to connect.

The cut-away diagram of this shows its internal workings. You can see the two big bolts and you can also see a circular plate that is not touching the bolts. This is the normal condition of the relay. You can also see a coil of wire and a piece of metal running vertically through the coil of wire that attaches to the big plate at the top. The master switch is connected to this coil. When the coil is energized, from the master switch being turned on, the coil takes on the property of a bar magnet. It will have a north and a south pole, all electrically created. The metal piece that runs through the middle of the coil that attaches to the big plate can move up and down like a piston or plunger. When the master is turned on the coil energizes, and the top part of the coil becomes one of the poles of a magnet. That pulls down the big plate as it is attracted to the magnet. This causes the plate to touch both of the big bolts which allows power to go from one side of the relay to the other. So, the little master switch in the cockpit controls this way bigger switch on the firewall. The device is big enough to allow a lot of current to pass through it.
The relays are used for the master relay, connecting the battery to the rest of the electrical sys-

tem, the starter relay, used to momentarily connect the battery to the starter motor, the alternator relay which connects the alternator to the electrical system, and the external power relay which allows an outside source of power to be connected to the electrical system.



An Actual Contactor, Relay, Solenoid - Mounts to the Firewall

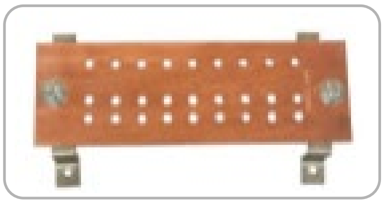


Inner workings of a Contactor, Relay, Solenoid

Ok, now we are almost done with what things do in the diagram. The last item is what is a bus? What is it for?

A bus is just a common connection point. It allows lots of wires to be connected with a sound mechanical connection. Imagine if you had to twist the radio wires, nav lights, strobe lights, the flap motor, the inside lights, etc. together. It would turn into a big ball of wire, and it wouldn't have a very good mechanical connection.

The busbar takes care of that. It's a solid piece of copper or aluminum that has threaded holes for all the wires that need to make contact with it. The wires have an eye hook, and this is screwed into the hole which makes a great mechanical connection.



Busbar Example – Not the Actual Busbar Used in the 172

The last item we need to understand is the alternator. It's simply a device that when it spins it produces electricity. Of course, it's more complicated but that's almost all we need to know about it. A belt that is connected via a pulley in the front of the airplane turns the alternator anytime the engine is running. If the engine stops so will the alternator. The alternator is not a battery. It doesn't lose a charge or discharge. It can produce 60 amperes of current at 28 volts as long as it's spinning. It is a higher voltage than the battery, which is 24 volts so there is a difference of potential (voltage/pressure) so the alternator can charge the battery.

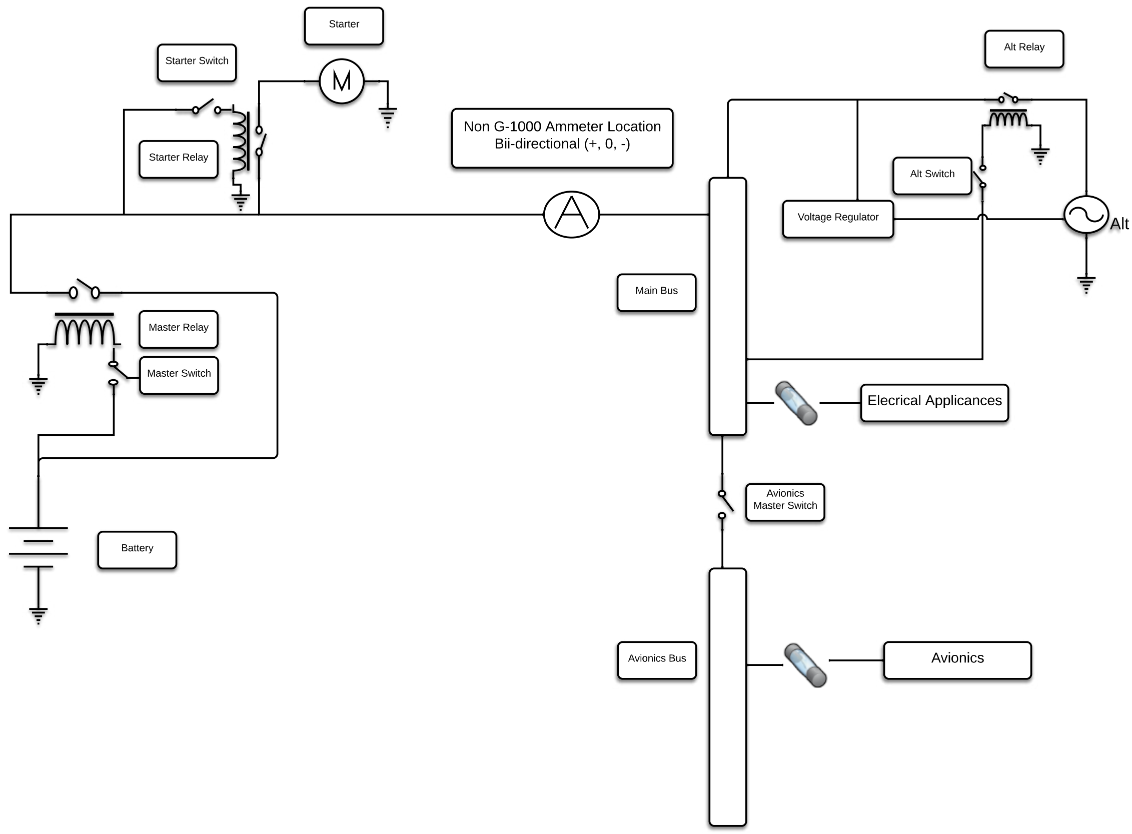
When you first turn on the airplane electrical system the system voltage would be 24 volts, or less, as the battery is supplying all of the power. When the engine is turned on and the alternator is working the system voltage will be above that, and as high as 28 volts.

The alternator has an alternator control unit (ACU) which senses the output of the alternator and varies its output to maintain a consistent voltage with changes in RPM. At very low RPM, at idle and below, the alternator control unit may not control the alternator output very well. The system voltage will fall below 28 Volts. Simply increasing the RPM will allow the system to function again normally.

Alternator mounting with Belt and Pulley

Cessna 172S Model Systems - How things work.

Ok, now let's use the simplified electrical system diagram to see if you can understand how the system works.



Simplified Electrical System Diagram

On the left side of the diagram, there is the battery. It is connected to the master relay. When the master switch is turned on the relay closes (the switch works) and power can go directly to the main bus. The power is also available to the starter relay. At this point, everything connected to the main bus can work. A separate avionics switch is located between the main bus and the avionics bus. If the switch is not turned on, there will be no power on the avionics bus. If the switch is turned on, then items on the avionics bus will have power available to them.

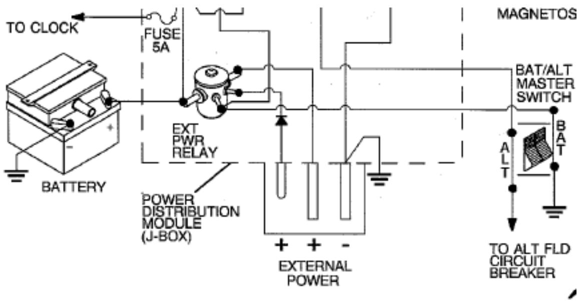
From the master relay, there is a wire that connects the battery to the starter relay. If the pilot turns the key switch to the start position, the starter relay will close, and battery power will be delivered to the starter motor which will cause it to turn.

Once the engine is running, the pilot releases the key-switch, and it goes to the both setting of the switch. This allows both engine-driven magnetos to provide high voltage to the spark plugs which run the engine. No electrical connection is required from the battery or alternator for the magnetos to work.

When the alternator switch is turned on, the alternator relay will close, and the alternator will be connected to the main bus. It can also charge the battery. The ammeter is connected between the battery and alternator. It shows the rate of charge of the alternator in the + direction. For example, once the engine starts the battery has been depleted of a lot of charge, so the alternator will provide power to the entire electrical system and begin charging the battery. This is indicated on the ammeter by a large positive deflection of the ammeter needle. As the battery charges the needle shows less and less until it rests at or near 0. If the alternator fails, the battery will supply power to the electrical system and the ammeter will show the rate of discharge in the negative direction.

The diagram in the POH shows the external power relay. When the engine is not running the battery will discharge over time. It may not be possible to start the engine or use any electrically powered device. In this case, an external power source may be required.

Once the external power source is connected to the external receptacle (Plug) it is stopped from going anywhere by the external power relay. If the master switch is turned on, the external power relay closes and power from the external source can power the entire electrical system and recharge the battery.



External Power Connector and External Power Relay with Diode

The final device to understand is called a diode. It's located on one of the positive terminals of the receptacle for the external power plug. Its purpose is that it won't allow current to flow to the external relay if the positive and negative leads are reversed in the external power unit. A diode only conducts current in one direction if there the positive side of the battery is connected to the large triangle and the negative side is connected to the vertical line.

Diode

Ok. I hope that this sheds some light on the electrical system in piston aircraft and in particular the Cessna 172S model.

Electrical System

The airplane is equipped with a 28-volt DC electrical system. There is a 24-volt battery located on the firewall, and a belt-driven 28-volt, 60-amp alternator. The system uses a bus system for power distribution. A bus is simply a common connection point that provides a solid electrical connection for all devices connected to it. Busses can also be separated, in some airplanes, to provide a means of isolation between them if something goes wrong.

On the diagram labeled Bus structure for serial numbers 172S8407 and on. Both the alternator output and the battery output are tied to both of these feeder circuit breakers.
Connected between Electrical Bus #1 and Electrical Bus #2 is the Essential bus. The Essential bus provides power for the Master Switch, Annunciator Circuits, and the Interior Lighting.
There are diodes connected between Electrical Bus #1 and the Essential Bus and from Electrical Bus #2 and the Essential Bus. The purpose of a Diode is to allow current flow in only one direction based upon the polarity. For example, the large triangle portion of the diode is the anode, and the other side is called the cathode. If the Anode is connected to the positive side of the battery or is receiving output positive voltage from the alternator, the diode will conduct and let power energize the essential bus. If something causes a short circuit on Electrical Bus #1 or Electrical Bus #2 the feeder circuit breaker should disconnect. In this case, power from the good Electrical Bus will still be able to energize the Essential Bus but not be able to get to the other Electrical Bus because the power would be coming from the good Electrical Bus to the Essential Bus but the Diode to the faulty bus would have positive voltage on the cathode side and therefore would not allow power to energize the bad Electrical Bus.

Master Switch

The master switch is a split-rocker type switch with one side of the switch controlling the battery power to the airplane and the left half controlling the alternator. The purpose of the left half of the switch, labeled ALT is to remove the alternator from the electrical system. It is possible to use just the right side, labeled BAT, to connect the battery to the electrical system bus #1, electrical system bus #2, and the essential bus to perform checks. If the Avionics Master Switch or switches (depending upon the serial number) is turned on as well, then those items connected to the avionics busses can also be used while using battery power. Continued operation of just the BAT side of the switch will reduce the battery power to a point where the battery relay will not be able to stay closed, which will cause power to be removed from all of the Electrical, Essential, and Avionics busses. It will also remove power to the alternator field coil which will prevent the alternator from starting or restarting.

Avionics Busses

The aircraft has two avionics busses, Avionics Bus #1 and Avionics Bus #2. Each bus is powered by an Electrical Bus and is circuit breaker protected and is connected via a switch. In serial numbers 172S8001 through 172S8703, a single-section rocker type Avionics Master switch controls power to both Avionics busses through this single switch. In serial numbers 172S8704 and on, a two-section or split rocker-type Avionics Master switch controls power to each Avionics Bus independently. Avionics Master Switches should always be switched off before engine starting or shut down to avoid harmful transient voltage from damaging the avionics.

Cessna 172S NAV II - Electrical System Serial numbers 172S8704 and On)

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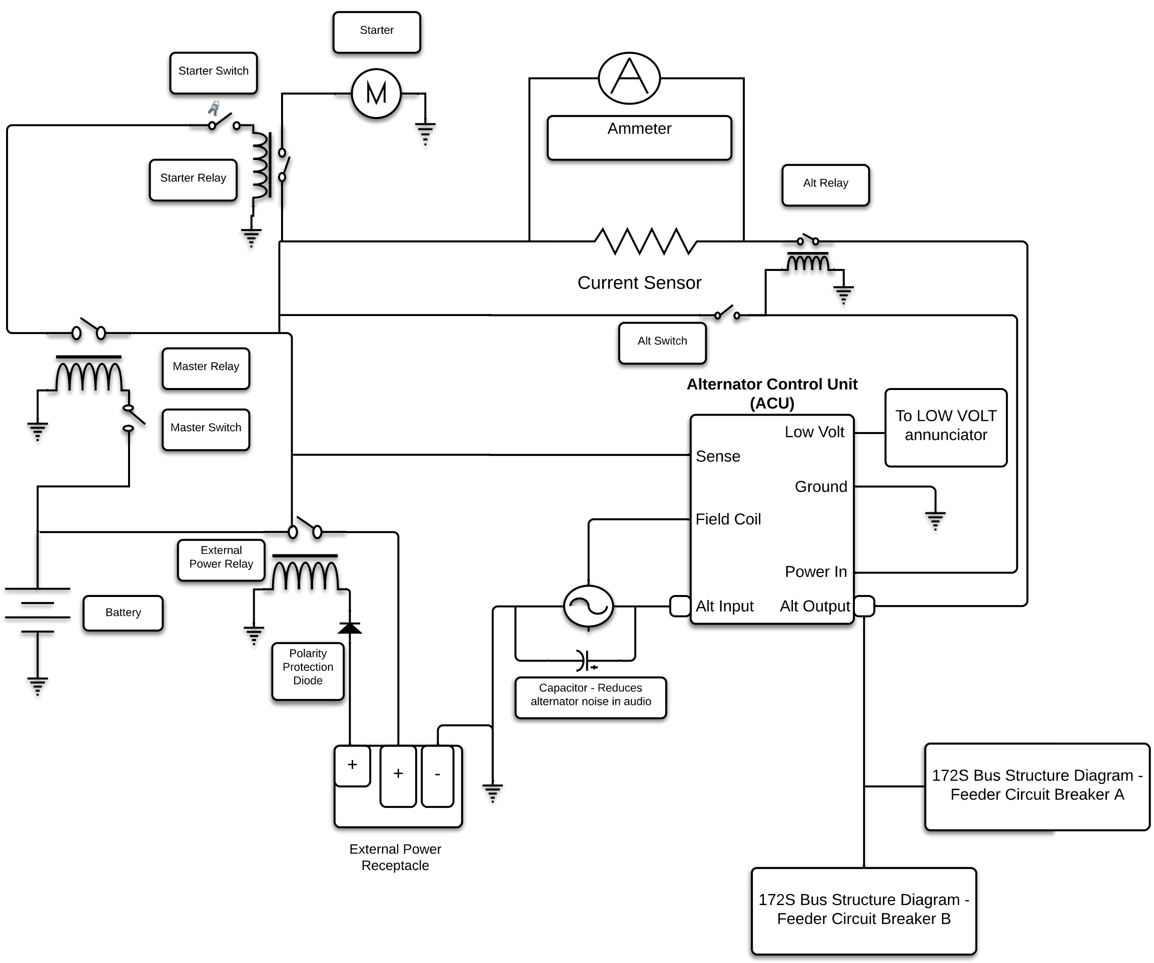

Electrical System – Serial Numbers 172S8704 and On

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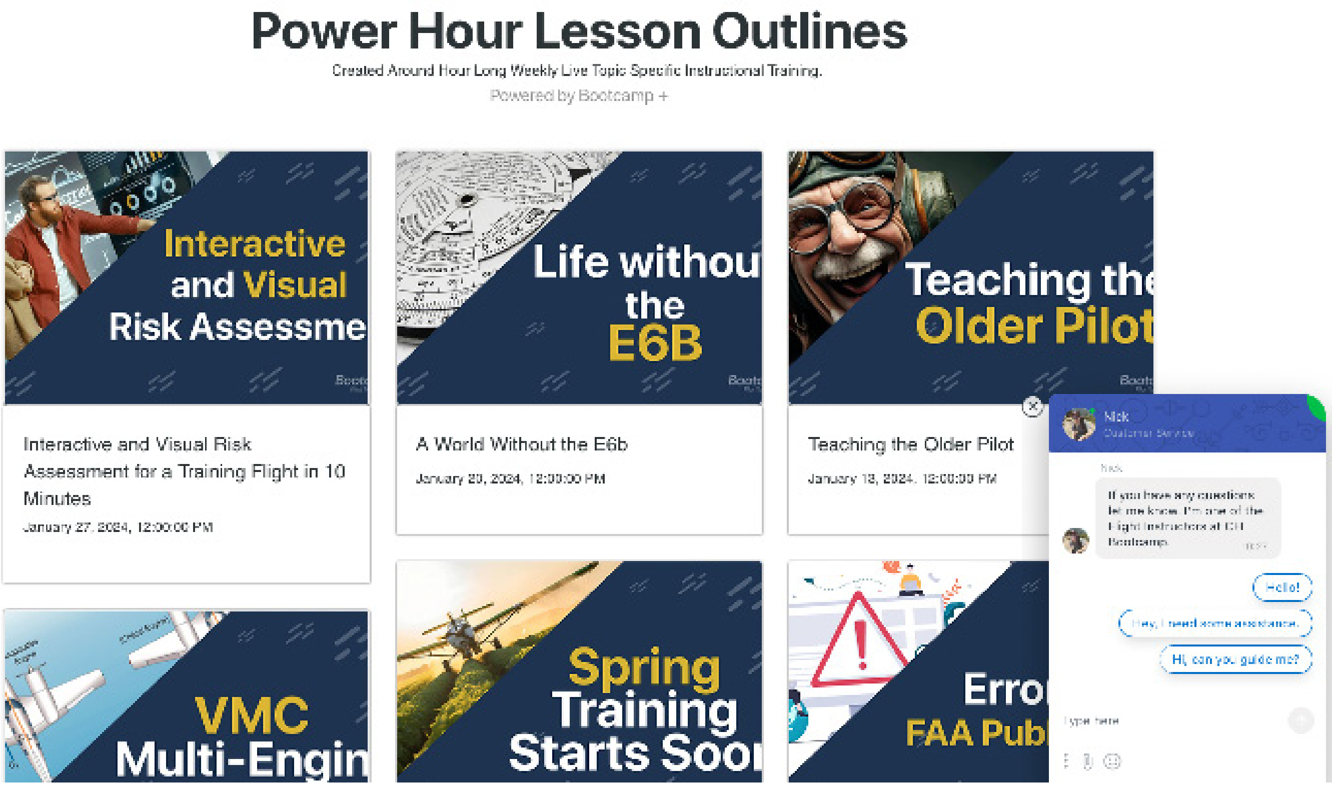

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