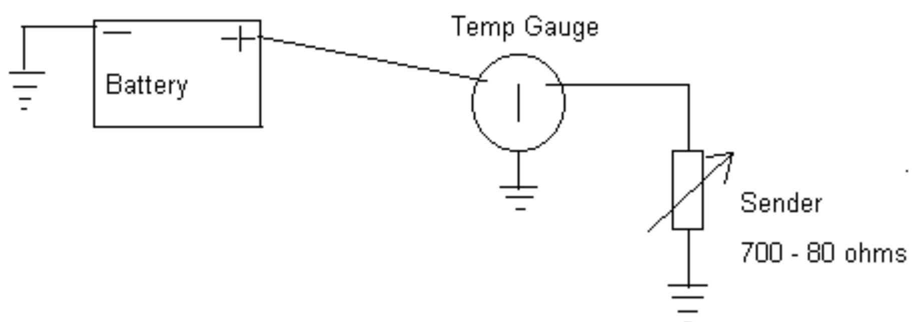
Troubleshooting Corvette gauges

This troubleshooting guide covers Corvettes that have gauge systems similar to the 63-67 cars. This should include most of the earlier cars and some of the cars through the late seventies.

Temperature gauge. This metering circuit consists of a thermistor sending unit installed in the intake manifold, a gauge, and the connecting wiring.

A thermistor is a resistance element that has a large change in resistance over its intended operating range. For Corvette applications, the resistance is high at low temperatures and low at high temperatures. Each sender will vary in its resistance by a certain amount but some of the replacement senders from GM and others may be off significantly.

In general, Corvette gauges will read about 180 degrees F when the resistance of the sender is about 125 ohms. The range of values for a **typica**l sender are:



Temp	Resistance
75	569
80	539
90	477
100	410
110	355
120	300
130	240
140	187
150	171
160	150
170	134
180	123
190	112
200	94
210	83.5
211	83.0

As you can see, there is a large change in resistance at the low temperature end of the table and as the temperature reaches the “normal” range the change in resistance per degree gets less. This means the sender is non-linear and is most accurate in the range from about 160 to 210 degrees.

Anything in the circuit that will add resistance to the circuit will tend to lower the gauge reading. This can be one or more of the following:

1. The body of the sender that is screwed into the manifold serves as the ground for the sender. If the threads are corroded in the manifold or if a sealant is used on the threads, the gauge will read low. If the sealant effectively insulates the threads from the manifold the circuit will be "open" and the gauge will read 100 degrees or less under all circumstances.
2. If any of the connection points are corroded, the increased resistance will cause the gauge to read low. The amount the gauge reads low is a function of the amount of corrosion (resistance) on the terminals. This can appear at the connector to the sender, at the bulkhead connector, or at the plug on the back of the panel gauge.

If the instrument cluster does not have a good ground, the temperature gauge will read high.

Later model cars have a wire wound resistor mounted on the back of the gauge to serve as a shunt.

Meter shunts are typically wire wound resistors since their values are typically on the order of 0.1 ohm or less. These shunts fail by open circuiting and the meter will read as if the ignition is off.

Assuming that the engine temperature is normal and that the gauge is at fault, there are two checks that can be made to determine if the sender is bad or if there is a problem in the wiring or gauge.

Warm the engine up to normal operating temperature. Disconnect the connector at the temperature sender and measure the resistance between the center contact of the sender and the sender body. Compare the resistance reading obtained with the above table to see if the sender is within +/- 10 ohms of the table values. If so, the sender is good.

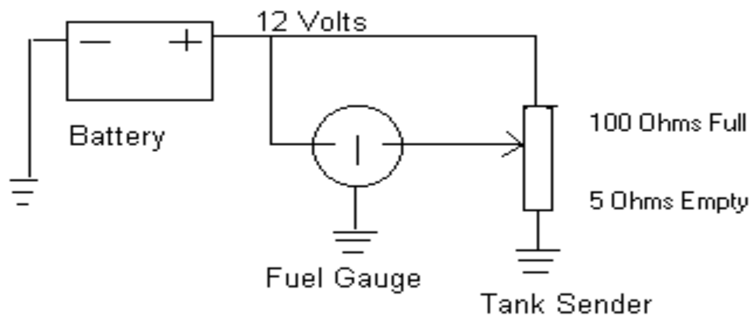
Check the resistance between the center contact and an engine ground. If the threads are making a good ground, the resistance should be the same as previously read within a few ohms.

To check the wiring and the panel gauge, obtain a 1000 ohm potentiometer. Solder two wires on the potentiometer, one to the center lug and one to one of the end lugs. Attach alligator clips to the ends of the wires.

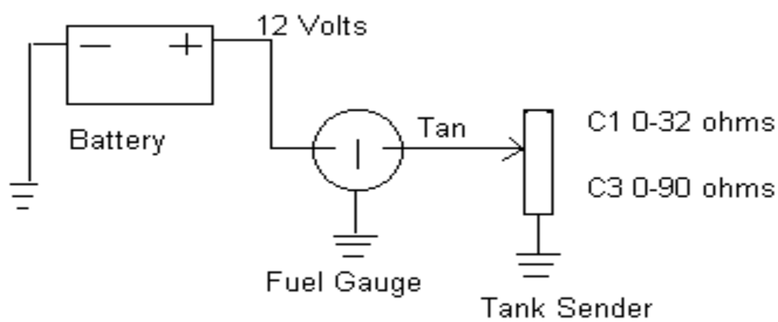
Disconnect the temperature sender connector at the sender. Connect the center lead of the potentiometer to the connector in the wiring harness and the other to a ground. With someone in the car, turn the ignition switch to ON or ACC and adjust the potentiometer until the gauge reads 180 degrees. Turn off the ignition and disconnect the potentiometer from the sender connector and ground without changing the position of the pot. Read the resistance of the pot from one lead to the other and compare it to the above table. If the resistance reading is within the expected range for the sender, the wiring and gauge are working correctly. If it takes less resistance on the pot to make the gauge read 180, then you have a corroded contact somewhere that is adding resistance to the circuit.

If both the sender and the gauge check out within the expected range, there is probably nothing wrong with the metering circuit and the car is actually running hot. This is the time to get an infrared heat gun (Ray Tek) and start checking temperatures at various points in the cooling system.

Fuel Gauges. Simplified circuit diagrams for the fuel gauge are shown below.



63-67 Corvettes only



C1 and C3 Corvettes (the sender is at maximum resistance when the tank is full)

The circuit consists of a sender in the fuel tank and a gauge. The sender resistance element is a wire resistor bent into an arc. A metal slider connected directly to the float arm moves this slider along the sender resistance unit.

The sender resistance is shown in the above diagrams. As with all things, these resistance values will vary somewhat from sender to sender but the values will be much closer than the temperature sender since the physical makeup of the resistance unit can be more closely controlled.

For C2 Corvettes:

At the sending unit, there are three connections, a black wire to ground, a tan wire from the slider and a pink wire that supplies 12 volts to the sender. 63 cars use Green for Pink and Yellow for Tan. The power connection on the sender is smaller than the slider connector.

You will note from the diagram that the top of the sender and one side of the gauge are both hooked to the battery.

A constant current flows through the sender resistance unit. This can be calculated using Ohms Law (I=E/R) or about 0.125 amps. The power consumed by the circuit is given by P=EI giving about 1.56 watts. Kirchoff's Law states that the voltage drops around a circuit must equal the applied voltage. Since the only resistance in the sender circuit is the resistance unit of the sender, the entire 12 volts must be dropped by the sender. The slider picks off the voltage drop of the sending unit as it moves from full to empty. You can use Ohms Law (E=IR) and plug in various values of resistance between 5 and 100 ohms to determine the actual voltage drop as the slider moves.

Referring to the above figure, you have one side of the meter hooked to battery voltage and the other side hooked to the slider. The voltage at the slider terminal will be less than the battery voltage since the sender resistance is dropping some of the voltage. As the fuel level changes, the slider picks off more or less voltage depending on the tank level and the gauge sees a difference in voltage proportional to the position of the slider. The gauge is responding to the difference in voltage between the battery voltage and the voltage picked off by the slider.

To test the sender there are two measurements. Disconnect all leads to the sender. Measure the resistance between the Pink lead terminal of the sender and the ground lug of the sender. This should read about 100 ohms.

Connect the ohmmeter between the Pink terminal and the Tan terminal on the sender and have someone carefully move the float arm through its full range of motion. Do not use a metal rod as this may cause a spark or ground out the sender, use a piece of wooden dowel. The resistance should vary between 100 and about 5 ohms. If these resistance values are correct, the sender is working properly.

Measure the voltage at the pink lead of the wiring harness with a voltmeter and the ignition ON. This should be battery voltage. Turn off the ignition and measure the resistance to ground at the black lead of the wiring harness. This should read zero.

Connect the Pink and black leads to the sender. Connect a voltmeter to the sender terminal for the tan lead and to ground. Turn ON the ignition and move the float arm through its range of motion. As you move the float arm from the full to empty position the voltage should decrease from near battery voltage to near zero. The actual values you get will be dependent on battery voltage and the resistance characteristics of the sender. In general, you should get about 10 volts when full and zero volts when empty.

If all these tests are OK, then the problem is in the gauge or wiring. It is not necessary to use a potentiometer to test the gauge or wiring since you have one built in to the sender. If the sender checks out OK then you can move the float arm of the sender and check the gauge.

If you want to substitute a potentiometer in the circuit in place of the sender, obtain a 100 ohm 2-watt potentiometer. Set the pot at 100 ohms and mark the position of the pot shaft. Set the pot to 5 ohms and also mark this position. Set the pot back to 100 ohms. Solder three leads to the pot with alligator clips on each lead. Connect one of the end leads to the pink wire, one of the end leads to ground and the center lead to the tan wire. Adjust the pot to obtain the gauge readings for empty, ¼, ½, ¾ , and full marking the position of the shaft for each gauge reading. Disconnect the pot and read the resistance between the lead you connected to the pink terminal and the center lead of the pot.

The resistance of the sender is fairly linear. If you plot the values you obtained using the pot on a graph, you should get a straight line, more or less.

Unlike the temperature gauge, corroded contacts can cause the fuel gauge to read either high or low depending on which side of the gauge the bad connection is located.

If the gauge continually wants to read high, then the bad contact is on the battery side of the gauge. If the gauge continually wants the read low, then the bad contact is on the sender side of the gauge. Recall that the meter is responding to the difference in voltage across the meter.

A bad ground could also insert some resistance into the circuit. In this case all of the voltage would not be dropped across the sender since the resistance added by the bad ground will also drop some voltage. In this case the gauge will read lower than the tank level.

C1 and C3 Corvettes.

These cars use a two-wire circuit for the sender. Battery voltage is applied through the gauge to the Tan lead, which is connected to the slider. The circuit is completed by grounding one end of the sender through a Black lead. The sender is a variable resistance that controls the current flow through the gauge. For the C1 cars the sender resistance is 0-32 ohms and for the C3 cars the sender is 0-90 ohms. These senders are at maximum resistance when the tank is full.

Since my hands on experience does not include either the C1 or C3 cars, the following references are offered. For the C1 cars refer to an article in the Winter 2001 Restorer by Dan Materazzi. For the C3 cars refer to the following web site – http://members.core.com/~faldritch/fuelgauge.htm.

Oil Pressure Gauge. This is a purely mechanical gauge. The only electrical connection is the dash light.

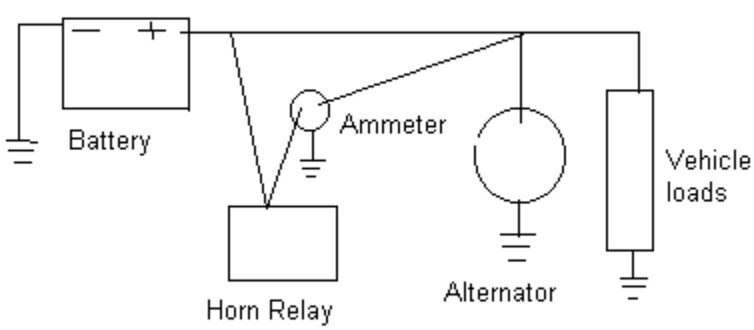
This gauge uses a Bourdon tube sensing unit. A Bourdon tube is a flattened tube closed at one end and bent into an arc.

Pressure is defined as Force per unit area (P=F/A). If we solve this formula for Force we get F=PA. One of the properties of a fluid (either liquid or gas) is that pressure is exerted equally in all directions. This means that the **pressure** inside the Bourdon tube is the same everywhere.

The inside radius of the Bourdon tube is less than the radius of the outside of the Bourdon tube. This equates to the outside radius of the tube having more **surface area** than the inside radius of the tube. Since the force on the tube is F=PA where A is the Area, it follows that the force on the outside radius of the tube is greater than the force on the inside radius of the tube. Since there is an imbalance of forces on the tube, the imbalance tries to straighten out the tube to equalize the forces.

The closed end of the tube is connected to the gauge pointer through a mechanical linkage and the motion of the tube responding to changes in pressure causes the gauge needle to move.

Ammeter. Refer to the below figure.



Troubleshooting the ammeter circuit can be difficult. The following applies to cars equiped with alternators. In the Chassis Service Manual there will be a simplified diagram of the charging system similar in part to that show above.

Possibly the biggest mistake that people make associated with the ammeter circuit is not turning the ignition switch to either ACC or ON when trying to decide if the ammeter is showing proper discharge. You can perform the following test and see if it makes a diference. Start the engine and let it run for a few minutes until the ammeter reads close to zero. Shut off the engine and with the ignition switch OFF, turn on the high beam lights. Make a note of the ammeter reading. Turn off the headlights. Turn the ignition switch to ACC and again turn on the high beams. The amount of discharge shown by the ammeter should be about twice, or more, what it was before.

By referring to the above diagram, it can be seen that the ammeter reads the difference in voltage between the battery and the alternator. The wire that goes directly from the battery to the alternator and appears to short out the ammeter is a meter shunt. What the ammeter actually reads is the voltage drop across this wire. The resistance of this wire is about 0.1 ohm. There is no physical resistor in the circuit, the resistance is due to the length of the wire required to get from the starter solenoid to the horn relay around the engine bay.

The horn relay is not in the ammeter circuit but is a convenient connection point for the alternator output and the voltage regulator.

When the output voltage of the alternator is greater than battery voltage, the ammeter shows a charge proportional to the difference in voltage. When the battery comes up to full charge, the ammeter drops to near zero. If the output of the alternator is less than the battery voltage, as under a heavy load, the ammeter will show a discharge proportional to the difference in voltage.

The voltage regulator is set to have a voltage slightly higher than the fully charged voltage of the battery so that the alternator will carry most of the vehicle loads and maintain a slight trickle charge on the battery at all times the engine is running. Under normal conditions, the ammeter will show a slight charge when the engine has been running for a few minutes and the system is working correctly.

Charging System 101

Introduction.

In order to maintain a proper charge on the battery and carry the other vehicle loads, the alternator produces an output voltage and current to the electrical system. To prevent overcharging the battery, the output of the alternator is regulated by the voltage regulator. The purpose of this paper is to describe how the charging system works without too much technical electrical detail. Troubleshooting the charging system is not included since the steps for checking out this system are covered in the CSM.

Most service manuals talk all around this subject but seldom get in to how this system actually works. With the introduction of transistorized voltage regulators and later integrated regulators built into the alternator itself, the knowledge of these types of circuits is being lost.

While the earlier cars use a DC generator, the principles of operation of the voltage regulator and charging system are basically the same.

The drawing for the following discussion is Figure 4c in Section 6Y of the 1966 GM Chassis Service Manual. Similar simplified schematic drawings appear in other CSM's.

CHARGING SYSTEM 6Y-6

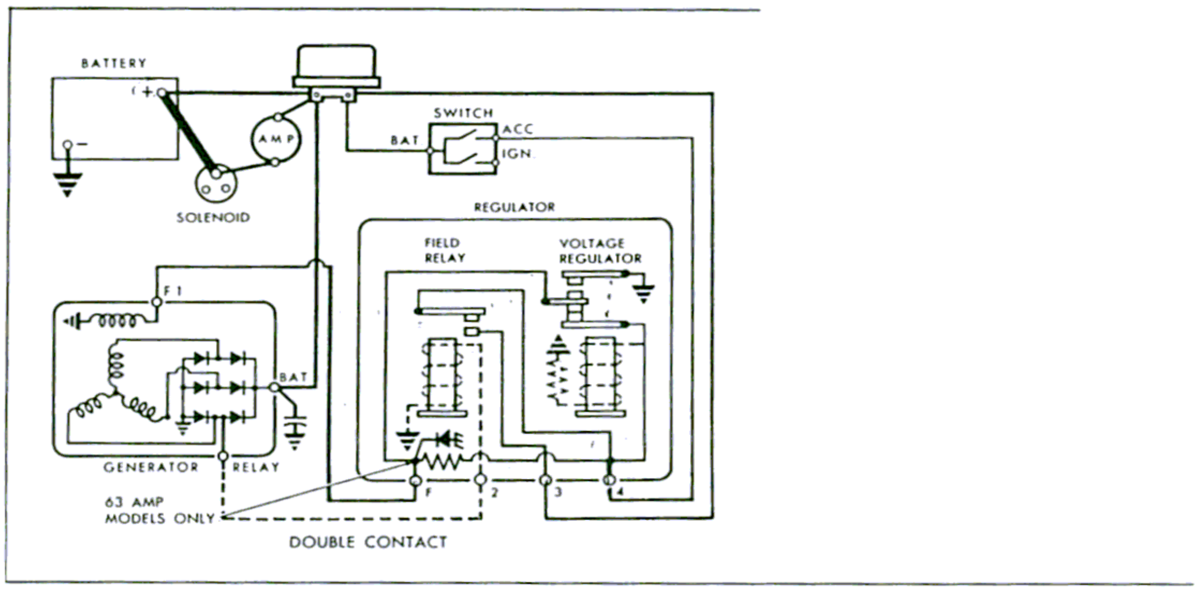


Fig. 4c—Circuitry - Voltage Regulator Assemblies (Corvette)

1. **Basics, Terms, and Definitions.**

Load Sharing. When two or more DC sources are connected in parallel, as is the case with the Battery and the Alternator, the source with the higher voltage will take the load away from the other source. The source with the higher voltage will also try to bring the voltage of the other source up to its value.

Open Circuit Voltage. When a battery is put under a load the output voltage of the battery will drop by an amount proportional to the load applied. This is due to the internal resistance of the battery itself, which is typically about 0.5 ohms for a lead-acid battery used in automotive applications. The Open Circuit voltage is the voltage produced by the battery when no load is applied.

Lead-Acid Batteries.

The active materials in a lead-acid battery are Lead Peroxide for the positive plate and sponge Lead for the negative plate. The plates are immersed in a dilute solution of sulphuric acid and water. On discharge, the active material of both plates is converted into Lead Sulfate and the electrolyte into water. The amount of lead sulfate formed and the amount of electrolyte lost is in direct proportion to the ampere-hour discharge of the battery.

When a battery is charged the exact opposite occurs except that the process is not totally reversible in that some active material is lost from each plate.

At the positive plate: Lead Peroxide + Sulphuric Acid <> Lead Sulfate +Water+Oxygen

At the negative plate: Lead+Sulphuric Acid<>Lead Sulfate+2 Hydrogen

The combined reaction is: Lead Peroxide+Lead+Sulphuric Acid<>2 Lead Sulfate+2 Water

The <> symbol means that the chemical reaction can proceed in either direction.

Lead Peroxide and Sponge Lead are initially formed after the battery is first assembled and a "Forming Charge" is put on the battery. Both of these materials are crystalline in structure with the crystals being composed of interlocking tendrils (dendrites) created when the forming charge is applied.

This structure is very porous and electrolyte seeps in to the structure to fill the interstitial voids in the structure. This is a crucial point in the later discussion.

Neither active material has much mechanical strength so that a form or grid structure is used to provide mechanical support to the active material. To keep the active material apart physically, a separator material is interleaved between the plates. This material can be wood, porous rubber or, in the newer batteries, and vitreous material that is also porous to the flow of the electrolyte.

In order for the chemical reaction to proceed in either direction, the active material of the plates must be in physical contact with the electrolyte.

Within the body of the electrolyte there are three somewhat distinct groups. The electrolyte that is in contact with the surface of the plates, the electrolyte that has diffused within the structure of the plate, and the bulk of the electrolyte that fills the case.

When a charge (or discharge) event occurs, the chemical reaction first occurs at the most accessible part of the plates, this being the surface. Let's use a discharge as an example.

The chemical reaction forms Lead Sulfate at the surface of the plates and the electrolyte is converted into water thereby diluting the electrolyte immediately at the surface of the plate. If the discharge is slow, the diluted electrolyte has time to mix with the bulk of the electrolyte and sustain the chemical reaction at about the same rate. In addition, as the electrolyte at the surface is being diluted, the chemical reaction moves into the region **within** the crystal structure where the electrolyte is more dense. This process maintains battery voltage for a relatively long time.

If, on the other hand, the discharge rate is very rapid, the time required to allow mixing of the diluted surface electrolyte and the diffusion of the reaction into the structure is insufficient to maintain the battery voltage and the voltage drops very quickly.

When a battery is discharged at a high rate, surface depletion occurs very rapidly. If the battery is left alone for a while, the electrolyte can diffuse throughout the plate structure and the battery will recover somewhat. This surface effect also accounts for the fact that the voltage of the battery under charge will remain at about 12.5 volts until near the end of the charge when it will rise quite rapidly to match the voltage of the charger. This **surface charge** allows the voltage regulator to be set high enough to carry the vehicle loads and maintain a trickle charge on the battery. If the charging current is not reduced near the end of the charge, excessive gassing and heat will be produced. The point at which this occurs is called the TVG point for temperature-voltage-gassing . At the TVG point, the charging current must be reduced to prevent the above. Depending on temperature, this can be as high as 2.65 volts per cell.

When a battery is discharged below about 1.75 volts per cell, the active material of the plates is sometimes irreversibly damaged.

When a battery is discharged and not immediately charged, the soluble lead sulfate that forms as a part of the reaction converts to an insoluble form and this is eventually terminal for the battery.

In addition, stratification of the electrolyte can occur with the more dense electrolyte (e.g. higher specific gravity) at the bottom. This can cause what is referred to as local action which damages the plates since the chemical reaction is not uniform throughout the battery.

Not all the lead sulfate is returned to the base material when a battery is charged. Some of the lead sulfate that is not recombined sloughs off the plates and settles to the bottom of the case. In extreme situations this sediment can build up to the point where it shorts out the plates.

The open circuit voltage of a battery is a function of the specific gravity of the electrolyte corrected for temperature. A check of the battery voltage does not indicate its capacity to deliver current to a load. The ability of the battery to deliver the required current is a function of the amount of plate area available for the chemical reaction. This, as can be seen from the above discussions, is dependent on a number of factors which include the specific gravity of the electrolyte, the surface area of the plates, the rate at which the reaction can diffuse into the plate structure, the rate at which mixing of the electrolyte occurs and the internal resistance of the battery due in part to the amount of sulfate built up on the plates in insoluble form.

Assuming all is right with the battery, most of the charging current goes toward forcing the chemical reactions from right to left. The remaining current not involved in the reaction goes to heat in the battery.

If the battery is badly sulfated, the active material is isolated from the electrolyte and the chemical reaction cannot occur at a rate equal to the charging current and excessive heating occurs. In addition to the excessive heating, the generation of hydrogen gas is accelerated and dangerous levels of hydrogen can result.

The point of this discussion is that even though the alternator is pumping current into the battery, it may be only generating heat and gassing of the cells. At the end of the charge, you still have a dead battery.

Now what does this tell us. With a voltmeter, you can tell if the charging system is operating at the point for a trickle charge. With an ammeter, you can tell the alternator is delivering current to the battery. What you can’t tell is whether the current is charging the battery or just making gas and heat. The only way to really tell the condition of a battery is with a load discharge after the electrolyte has been equalized by topping up the cells, mixing thoroughly, and applying an equalizing charge to the battery to bring all cells up to the desired specific gravity.

During a load test the battery voltage is monitored during the discharge to determine the capacity of the battery. If an amp-hour meter is connected during the test discharge and the subsequent charge cycle, the efficiency of the battery can be determined by a ratio the two values. This should be above 90 percent for a good battery.

Battery Charging. When a battery is partially discharged, the charging current can be high. As the battery comes up to charge, the charging current must be reduced to prevent excessive heating of the battery and gassing (Hydrogen) from the cells. There are several ways to do this but typical automotive charging systems use the constant potential method. If the battery charger (in this case the alternator) is held at a constant voltage, the difference in voltage between the alternator and the battery will become less as the battery reaches full charge. As this difference in potential decreases, the current delivered to the battery also decreases. To prevent the formation of insoluble lead sulfate on the plates of the battery, it is preferred to have a slight trickle charge or discharge on the battery at all times. For a battery that is going to be inactive for a period of time, the most important thing is that it is fully charged prior to being inactivated and that it receives a periodic charge either with a battery maintainer or with a charger .

<u>Alternator Excitation</u>. The rotor of the alternator is called the field coil. Current is supplied to this coil through a set of carbon brushes and slip rings from the voltage regulator. This current produces a magnetic field in the rotor which, when rotated, induces a voltage in the stator coils of the alternator producing an output current. The function of the voltage regulator is to control the field current delivered to the rotor thus controlling the output of the alternator. The current supplied to the rotor (field) is called the **field excitation current.**

<u>Relays and Solenoids</u>. A relay and/or a solenoid are electrical devices where a small current controls contacts that control a much larger current. A relay/solenoid consists of a coil of fine wire wound on a cylindrical form. Inside this form is a core of magnetic material (usually sintered iron) that offers an easy path for the magnetic field produced by the coil.

A relay has a fixed core and the magnetic field moves an armature containing the contacts for the circuit being controlled. A solenoid has a movable core that is mechanically linked to the contacts through some form of mechanical linkage. An example of a solenoid is on the starter. When the key is turned to start your Corvette, the coil is energized which causes the core to move a disk into a fixed contact providing the 300-400 amps required to run the starter motor. The devices in the voltage regulator are relays.

<u>Alternator Basics</u>. Refer to figure 4c. The alternator is a wye connected, three phase AC generator with a full-wave rectifier and a filtering capacitor to remove ripple from the rectified output.

The wye connection refers to the way the three stator coils are connected together to form a “Y” or star. Each of the coils react to the magnetic field produced by the field coil of the rotor and independently produce an output voltage. The stator coils are physically and electrically 120 degrees from each other. The output from each coil is called a phase, thus a three phase generator.

Each phase produces a sine wave voltage. The amplitude of the voltage produced is a function of the strength of the magnetic field of the rotor, which is in turn a function of the excitation current delivered to the field coil (rotor) by the voltage regulator. The frequency of the AC voltage produced is a function of the rotational speed of the rotor. Draw a horizontal axis and on this axis draw a sine wave. This sine wave represents a complete cycle of 360 degrees. Move over one-third of the length of the sine wave you drew (120 degrees) and draw another sine wave identical to the first and then do it again moving over another 120 degrees. This is what the output of the alternator would look like with out the rectifier (diodes).

Draw another horizontal line and on it draw a sine wave that has gone through two complete cycles (720 degrees). Cover up the bottom half. Even though the top half waveform goes from zero to a maximum and back to zero, it never goes below the line and thus never reverses direction. What you have done is make AC into DC. This is called half-wave rectification since you are only using half of the waveform. As you can see the average voltage delivered to the load is only a fraction of the peak voltage and comes in widely spaced pulses. Now fold the paper along the horizontal line so that the bottom halves lie between the top halves. This is called **full-wave rectification** and provides a much higher voltage to the load with fewer variations. The variations produced by a rectified AC voltage are called **ripple.**

The rotational speed of the alternator does not change the output voltage, this is controlled by the field excitation. What does change with speed is the frequency of the AC produced by each phase. Since the number of complete cycles is greater over a given period of time, the number of bumps in the output of the rectifier is greater (the ripple is less) and the effective voltage delivered to the load increases.

In the alternator, there are six diodes, two for each phase. A diode is like a check valve. It passes current in one direction and blocks current in the other direction. During the positive half of the cycle, one of the diodes conducts and on the negative half cycle the other diode conducts.

Figure 4c shows a capacitor at the Bat terminal of the alternator. This capacitor protects the diodes from high voltages and aids in radio noise suppression. The spike of voltage produced by the field coil collapse contains a significant portion of frequencies that can interfere with the radio. In addition, the capacitor reduces the ripple in the output of the alternator.

Initial Field Excitation. While there may be some residual magnetism left in the rotor after use, there is not enough to produce an output from the alternator immediately after starting the engine. In order for the alternator to be able to produce an output immediately, an initial excitation current must be applied to the alternator just before the starter is engaged. This is one of the functions of the voltage regulator.

Electrical Behavior of Coils. Among other characteristics, a coil (inductor) tries to resist a CHANGE in the current of the circuit. This means that when voltage is first applied to the field coil there is a lag in the current (and magnetic field) that the coil produces. To compensate for this a higher "kicker" voltage is applied to the coil for a brief period to get things going more quickly. When the current through a coil is broken, the coil tries to maintain this current by the collapse of the magnetic field produced by the coil. The reverse voltage produced by a collapsing magnetic field is a function of the field strength and the speed at which the field is collapsing. When a coil is grounded, the field collapses very rapidly giving rise to a very high voltage spike (inductive kick) initially upon grounding the coil.

Schematic Conventions. In the drawing, shown in Figure 4c, the two relays are shown de-energized and the contacts for those relays in the de-energized position. The center contact of the voltage regulator relay is fixed and the upper and lower contacts move downward together when the relay is energized. There is a resistor shown in series with the coil for the voltage regulator relay and for our purposes we will call this R1. The other resistor between terminals 4 and F we will call R2. These are wire wound resistors physically located on the back of the voltage regulator base. There is a diode shown attached to terminal F and to ground. This diode is only in the regulator for the 63 amp alternator used for the A/C cars.

Current Flow Conventions. The current carriers in a circuit are electrons. When a circuit is hooked to a battery, the battery supplies electrons at the negative terminal and since like charges repel, these electrons are forced through the circuit to the positive terminal of the battery, which removes the electron from the circuit. Current flow through a circuit from **negative to positive** is called "electron flow". Military texts use electron flow.

Most commercial texts and technical manuals use "conventional" current flow in which the current flows from **positive to negative**.

The simplest way to visualize this is to consider a clear tube filled solid with ping pong balls. The ping pong balls represent electrons in a wire. If we insert another ball in the left end of the tube, a ball must be pushed out the right end of the tube. In this case, the left end is the negative terminal of the battery and the right end is the positive terminal of the battery. This represents "electron flow".

If, on the other hand, we remove a ball from the right end of the tube a "space" is created. As the balls move from left to right to fill this space, the "space" appears to move from right to left eventually ending up at the left end of the tube, leaving room to insert another ball. This space or "hole" electrically appears as a positive charge and the apparent current flow is from positive to negative. This is called "conventional" current flow.

Where the convention used makes a difference is in the direction current flows through a diode. In conventional current flow, the diode conducts when the arrow side is positive and current flows with the arrow. In electron flow, the current flows against the arrow.

2. **Operation of the Voltage Regulator.**

Voltage from the battery is supplied through the IGN/ACC switch to terminal 4 of the voltage regulator. This voltage is applied through resistor R2 to terminal F of the regulator and out to the field coil of the alternator to provide initial excitation current to the field. R2 is a current limiting resistor and has a value of about 0.1 ohm.

The voltage at terminal 4 is also applied to the voltage regulator relay coil and then to ground through R1, also a current limiting resistor.

Just prior to the relay coil pulling in, battery voltage is applied to the field coil through the lower contact to kick the field coil. This voltage is slightly higher than that coming from terminal 4 since it doesn't pass through R1.

When the voltage regulator coil pulls in, the lower contact is disconnected from the circuit and both the field coil and the voltage regulator relay coil are grounded through the upper contact. When the voltage regulator coil is grounded, the coil is de-energized and the spring attached to the armature pulls the relay contacts back in the de-energized position. When this occurs, the circuit starts all over again. This action causes the voltage regulator relay to vibrate between one position and the other repeatedly, giving rise to the technical name of a double contact vibrating voltage regulator.

What the alternator field coil sees are pulses of voltage supplied by the voltage regulator as the regulator relay vibrates.

The voltage required to pull in the regulator relay is controlled by an adjustable tension spring inside the regulator (see figure 6c of the CSM).

When the engine starts, the output of the alternator is applied to terminal 2 through the dotted line from the bottom pair of diodes. Since this voltage is only taken from one phase of the alternator and is not filtered for ripple, its value is less than one-third of the total output voltage of the alternator. This voltage is applied to the field coil of the voltage regulator. The pull in voltage of this relay is between 1.5 and 3.2 volts and is adjusted by changing the distance the armature of the relay is away from the relay coil. Setting the air gap (Figure 13c) controls this pull in voltage.

Energizing the field relay closes the relay contacts and applies the output voltage of the alternator, via the connection at the horn relay junction point, through terminal 3 to the junction at terminal 4 of the voltage regulator. The only function of the field relay is to turn out the indicator light for cars not equipped with ammeters. For Corvettes, this relay serves no function.

3. **Voltage Regulation**.

The alternator voltage is controlled by adjusting the spring tension on the voltage regulator relay. The higher the tension of the spring, the higher the voltage that is required to pull in the relay. Recall that in the de-energized position, current is being supplied to the field coil of the alternator and the alternator is putting out voltage. When the output of the alternator is enough to overcome the spring tension, the relay is pulled in and the field is shorted to ground, limiting the voltage output of the alternator. This process is repeated many times per second and the voltage of the alternator is regulated.

There are three conditions under which the alternator must operate:

The load on the system is less than the output of the alternator. This is the **normal** condition. Under this condition, the contacts of the voltage regulator will cycle as described above and the voltage output of the alternator will be held constant by the voltage regulator.

The load on the system is equal to the alternator output. Under this condition, the voltage regulator relay contacts are supplying current to the field coils through resistor R2 and the current supplied is constant. The amount of current supplied is controlled by the resistance vs. temperature characteristics of R2 combined with the resistance of the field coil of the rotor.

The load on the system is greater than the output of the alternator. Under this condition, the regulator supplies a continuous current to the field of the alternator. This current causes the amount of heat produced in R1 and R2 and in the internals of the regulator to exceed the rate at which the heat can be eliminated by normal cooling. When this occurs, the resistance of both R1 and R2 increase to the point that the voltage regulator relay will begin to cycle to protect the voltage regulator and the alternator field coil. At this point, the output of the alternator will be reduced to a voltage lower than what the system load is demanding and the battery will supply the extra load current until discharged.

4. **<u>63 Amp Alternator Diode</u>**.

In order to carry the additional loads imposed by the A/C system, these cars are equipped with a high output alternator. In order to produce the current required to support these accessories, the field coil must produce a much larger magnetic field. This requires a much larger field current. The resistance of the field coil is about 4 ohms for this alternator whereas for the 37 amp alternator the field coil resistance is in the 7-20 ohm range. When the regulator cycles to short out the field current to regulate voltage, the **inductive kick** generated by the stronger field coil current is shorted to ground through the installed diode thus lengthening contact point life.

5. **<u>Ammeter Operation</u>**.

The ammeter responds to differences in voltage between the output of the alternator and the battery voltage. When the engine is running and the battery is full charged, the capacitor connected to the output of the alternator is charged to full system voltage with the top of the capacitor being positive. When the engine is shut off, the charge on this capacitor has no bleed off path and system voltage will remain on this capacitor for some period of time. When a load is put on the battery without the dash switch being either ON or ACC the ammeter will not respond or respond only slightly depending on how much charge has leaked from the capacitor. As the charge on this capacitor bleeds off internally, the ammeter will respond more and more.

When the switch is placed in the ACC position to operate a load, the capacitor charge bleeds off through the switch and through terminal 4 of the voltage regulator. This causes a difference in voltage across the ammeter and the ammeter will respond showing a discharge.

When the engine starts, the output of the alternator will be higher than battery voltage due to the discharge from starting current draw. The ammeter will show a charge proportional to the difference in voltages until the battery comes up to full charge. Under normal operation, the output voltage setting of the voltage regulator is set slightly higher (14.2 to 14.6 volts) than the fully charged voltage of the battery. This is done so that the alternator will carry the loads of the car and keep a slight trickle charge on the battery.