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Recreation Vehicle Industry Association

Recreation Vehicle
Electrical Systems

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RV Electrical Systems - 4th edition

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Chapter
4-1 The RV Electrical Systems

4-1.1 Introduction and Overview

Most RV owners have encountered repair technicians who spend long, expensive hours in vain attempting to find a relatively simple problem. They have all had some occasion to lose confidence in ever getting a failure in one of the electrical systems repaired. But then there is the technician who can tell us just what is wrong in a few minutes and repair a defect efficiently and at reasonable cost. What makes the difference between the competent, efficient troubleshooter and the average repair tech? Are successful technicians specially gifted? Do they have an inborn knack, or is it something they have been lucky to acquire? Can anyone learn this knack? The answer is quite simple. Anyone who understands the principles of electricity can learn to troubleshoot and service electrical systems quickly and efficiently.

Comparing successful technicians with average "wrench-turners," it is found that, in addition to understanding the principles of electricity, successful technicians have "reasoning ability." In other words, they have developed a systematic, logical approach to isolating the failed circuit or component and repairing it efficiently, successfully, and profitably.

Troubleshooting techniques are really just an effort to be as efficient as possible when locating a problem. It is possible to locate problems by a meticulous search and analysis of the performance of a particular system. It is also possible to find a problem by testing every component incorporated within a particular system. Still another method would be to check the input and output of each section within a particular system. Which method used will depend largely on the type of problem.

In troubleshooting any system, the old saying "time is money" is absolutely and always true. The cost of troubleshooting depends entirely on the time spent locating the problem. The cost of the replacement part is the same, whether it takes ten minutes or ten hours to find the defective component. Logically enough, as troubleshooting time decreases, profit increases. This text is intended to show how to develop a systematic and logical approach to troubleshooting electrical systems.

To get the most out of this material, the technician should have a good, basic understanding of the fundamentals of electricity, including ohm's law manipulation, electrical diagram interpretation, and the use of basic test equipment. This material will cover RV electrical systems and all related components, wiring, connectors, and support systems. Each section will include a circuit description and a troubleshooting procedure. Even with the assumption that the reader has basic knowledge of electricity, it is recommended that a basic electricity textbook be available for a more detailed explanation of a concept mentioned in a particular procedure.

4-1 Review

1. As troubleshooting time ______________ profits ______________.
2. List things a technician needs to know or to be able to do to become efficient at troubleshooting electrical systems.

   A.

   B.

   C.

   D.

   E.

Chapter

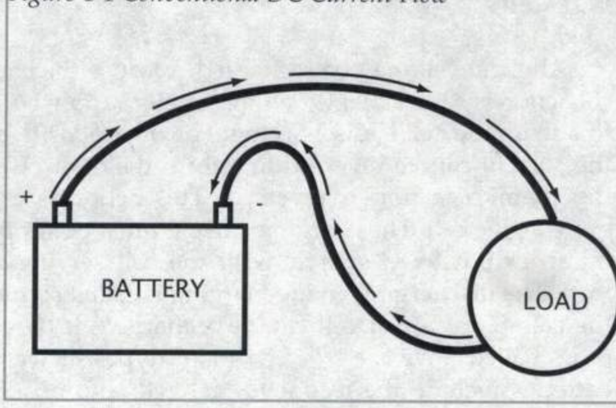
4-2 DC Electrical Systems

- Identify types of batteries.
- Identify charging circuits.
- Test, size, and install solar panel systems.
- Identify the function of an alternator.
- Test alternators.
- Calculate circuit draw.
- Demonstrate proper terminal and connector installations.
- Identify applications of linear and ferroresonant and switch mode converters.
- Add a circuit.
- Describe the purpose of printed circuit boards.
- Describe the RV 12 VDC system.
- Wire maintenance (including soldering, terminal types, crimping, etc.).
- Identify battery-powered equipment.
- Identify converter-powered equipment.
- Check and troubleshoot the 12 VDC fuses or circuit breakers.
- Test, accept/reject, and replace batteries, lamps, switches, resistors, fuses, converters, inverters, and control devices.

4-2.1 DC Electrical Sources

Because RV owners want to use equipment while on the road without 120 VAC shore power or generator power, the 12 VDC power system is the primary power system used in the RV. The source of the 12 VDC power can be batteries, converters, or alternators, and, in some cases, solar. All of these sources connect to the 12 VDC power distribution panel or fuse box. From there the circuits are routed to the individual 12 VDC loads. The following section will be devoted to direct current (DC) sources. The wiring system in the RV that is connected to any DC power source is also commonly called the "low-voltage" system. Before discussing DC sources, a review of direct current fundamentals follows.

Figure 4-1 Conventional DC Current Flow



The current flow illustrated in *Figure 4-1* is a simple DC circuit because it has just one direction of flow – positive to negative. The reason for the unidirectional current is that the battery maintains the same polarity of output voltage across its two terminals. It is the flow of charges in one direction and the fixed polarity of applied voltage that are the characteristics of a DC circuit. The current can be a flow of positive charges, rather than electrons, but the conventional direction does not change the fact that the charges are moving only one way. Furthermore, the DC voltage source can change the level of its output voltage, but if the same polarity is maintained, current will flow in one direction, meeting the requirements of a DC circuit.

Components, devices, and equipment in the RV that utilize low-voltage direct current are often referred to as *DC loads*. Examples of common loads in the low-voltage system are lights, water pumps, fans, detection devices, and entertainment equipment. Devices that utilize electric motors will usually require more current than other low-voltage devices. Examples of higher current-consuming low-voltage devices are electric steps, power jacks, and slideout room motors.

4-2.1.1 Batteries

The first source of DC voltage that will be discussed is the battery. Batteries are a common source of DC voltage. They are a group of cells that generate electrical energy from a chemical reaction. The cell itself consists of two different conducting materials called *electrodes*. When the electrodes are immersed in an electrolyte, the chemical reaction results in a separation of electric charges in the form of ions and free electrons. As a result, the two electrodes have a difference of potential that provides voltage output from the cell. Its function is to provide a source of steady DC voltage of fixed polarity.

4-2.1.1.1 Types of Batteries

The two main types of batteries are the *dry cell* and the *wet cell*.

Dry cell batteries are used in many items, including flashlights, smoke detectors, and wall clocks, and are available in both rechargeable and nonrechargeable types.

Wet cell batteries are used as a power source of 12 VDC in RVs and automobiles. This type of battery can be recharged, needs regular maintenance to be sure it has electrolyte, and requires the ability to maintain a fully charged condition. Technology is ever-changing—consult battery manufacturers for other new batteries.

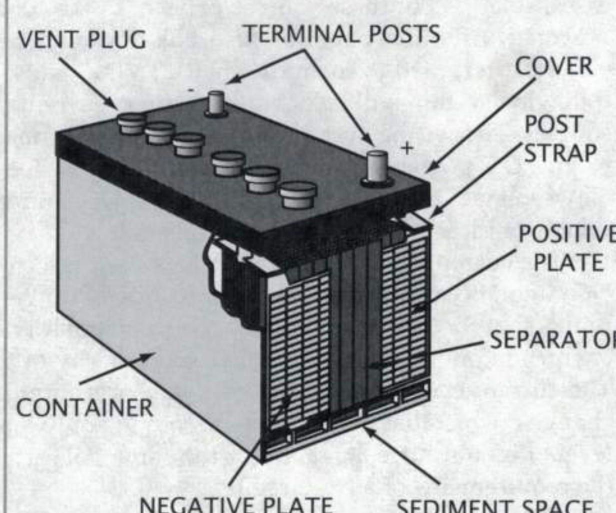
Dry Cells

The dry cell battery is the most common type used in consumer electronic devices. Sizes of dry cell batteries are AAA, AA, 9-volt, C, and D, among others. The dry cell is not actually dry. The electrolyte is not in a liquid state but is a moist paste. If it should become totally dry, it would no longer be able to transform chemical energy to electrical energy. Dry cells are available in both rechargeable and nonrechargeable types. Common examples of dry cell use in RVs would include wall clocks and smoke detectors.

Wet Cells

The wet cell may be recharged, because the chemical action is reversible. When these cells supply current to a load, the cell is discharging. For the opposite case, the current can be reversed to reform the electrodes as the chemical action is reversed. This action is called *charging* the cell. The charging current must be supplied by an external DC source, with the cell serving as a load. The discharging and recharging is called *cycling* of the cell. Since a wet cell can be recharged, it is sometimes called a *storage cell*. The many types of wet cell batteries include the lead-acid, gel cell, and absorbed glass mat batteries.

Figure 4-2 Lead-Acid Battery

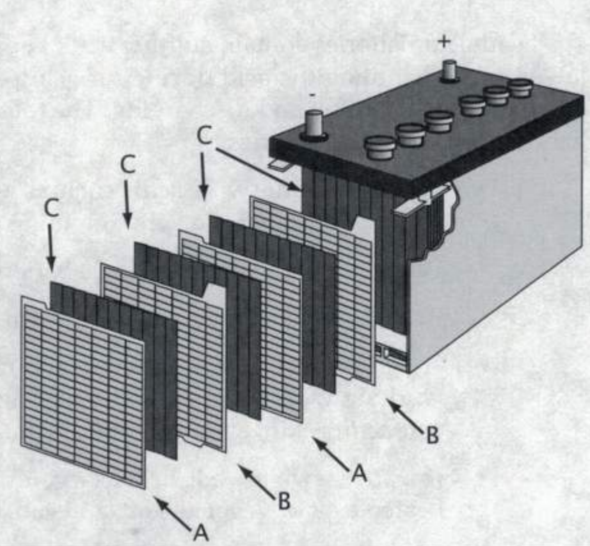


Lead-Acid Cell

The most common type of wet cell battery used in the RV industry is the lead-acid battery. *Figure 4-2* shows the makeup of a lead-acid battery. The container (battery case) houses the separate cells. Most containers are hard rubber, plastic, or some other material that is resistant to the electrolyte and mechanical shocks and will withstand extreme temperatures. The container is vented through vent plugs to allow the escape of gases that form within the cells due to the chemical actions. The cells have two groups of plates. One plate is attached to the positive terminal and the other plate to the negative terminal. The plates are made of lead, lead peroxide, or lead dioxide and fit together as shown in *Figure 4-3*.

Between the plates are sheets of insulating material called *separators* (C in *Figure 4-3*). The separators prevent the plates from touching each other (A is the negative plate, B the positive plate in *Figure 4-3*). If they touch, the cell could be destroyed. One of the sets of plates is treated chemically to form lead dioxide. The two sets of plates with separators between them are then placed in a container filled with a solution of sulfuric acid and water. The voltage in this type of cell is 2.1 volts nominal. Therefore, a 12 VDC battery will have six cells, and a 6-volt battery will have three cells.

Figure 4-3 Battery Cell Plates



Gel Cell Battery

The gel cell battery contains electrolyte that is permanently locked in a *thixotropic* (i.e., becomes a fluid when stirred or agitated) gel instead of conventional liquid acid. Gelled electrolyte batteries offer many significant advantages over conventional liquid acid batteries. Because there is no liquid electrolyte to leak out of the battery, the gel cell can be easily installed in hard-to-reach locations; it can also be installed on its side if needed. Even if it is left discharged for 30 days, it will still come up to 100 percent of capacity when charged. The battery can be stored for two years. Because it has a gelled electrolyte, it cannot sulfate like a liquid acid battery, and since there is no liquid, there is no need to check liquid levels. The battery's gelled construction also minimizes vibration damage to the plates. Under normal use, there is no acid leakage, hence there is no terminal corrosion. However, gel cell batteries are susceptible to overheating during charging. Therefore, closely regulated charging systems must be used to recharge gel cells.

Absorbed Glass Mat (AGM) Battery

Another battery technology is referred to as AGM, which stands for *absorbed glass mat*. AGM battery technology was developed to provide increased safety, efficiency, and durability. Advanced AGM batteries are based on lead-acid battery principles; however, the electrolyte in an AGM battery is absorbed and held in place by microfibrous silica glass mats, which are sandwiched between the plates. The electrolyte is still liquid and remains so for the life of the battery. The mats are over 90 percent saturated with electrolyte, allowing the oxygen produced during charging to readily migrate to the negative plate and recombine into water. Because the plates are kept "moist" instead of "flooded," gas recombination efficiency is very high (typically 95 percent).

The extremely low resistance of AGM batteries permits recharging with no current limits when incorporating voltage-regulated charge sources. This allows for much faster battery recovery from a discharged state. AGM batteries typically provide significantly extended cycle life compared to other battery types.

Charging profiles for AGM batteries are typically 14.4 VDC bulk @ 70°F (21°C) and 13.4 VDC float @ 70°F (21°C). AGM construction and technology significantly reduce the possibility of battery damage due to sulfation (buildup of lead sulfate on the plates) over time. However, like all lead-acid batteries, some sulfation can occur over time. Additionally, normal battery cycling tends to develop slightly different voltages internally within each cell. To correct both these conditions, an "equalizing" or "conditioning" charge is often recommended. The equalization charge process involves charging the battery beyond its gassing state for a specific period of time on a scheduled basis. "Equalization" of AGM batteries is generally recommended annually at 15.5 volts for three hours. Consult the individual battery manufacturer for specific instructions before equalizing.

4-2.1.1.2 Battery Safety

Lead-acid batteries contain sulfuric acid. For this reason, there are numerous safety precautions to be followed when handling the acid during servicing operations. The other principal hazard with batteries occurs when they are charging and discharging. The following is a list of the safety rules that must be observed when handling or servicing batteries:

- When working with acid, such as when filling batteries, splash-proof safety goggles must be worn. Additional protective clothing may be advisable, particularly if many batteries are handled.
- When adding water or filling a battery with electrolyte, use nonmetallic containers and funnels.
- Do not store acid in excessively warm locations or in direct sunlight.
- Avoid contact with skin, eyes, and clothing. Use goggles or safety glasses to protect eyes when working with batteries to prevent against possible splashing of acid in eyes. In the case of acid contacting skin, eyes, or clothing, flush immediately with water for a minimum of 15 minutes.
- If acid is swallowed, drink large quantities of milk or water followed by milk of magnesia, a beaten egg, or vegetable oil, and call a physician immediately.
- Hydrogen and oxygen gases are produced during normal battery operation. This gas mixture can explode if flames or sparks are brought near the battery.
- When charging or using a battery in an enclosed space, always provide ventilation, and shield the eyes.
- Be careful to avoid letting tools or other metallic objects fall across the battery terminals.
- Never break a live circuit at the battery terminals. An arc could occur whenever charger leads or booster cable leads are disconnected. Any arc could ignite the accumulated hydrogen gas.
- Always disconnect the ground cable first, at a point away from the battery terminals. Disconnecting the ground first will eliminate the potential of the wrench grounding out on a live circuit and causing a spark.
- When removing cell caps to test or inspect a battery, reinstall them before charging or using jumper cables. This will prevent electrolyte from spilling and prevent explosion by ensuring that the spark arresters are in place. The battery caps contain spark arresters.
- Use fender covers to protect the equipment finish from any possibility of acid spillage.

The following special precaution, in addition to those listed above, applies to batteries with thin-wall polypropylene containers:

- The electrolyte level is critical when handling a polypropylene-cased battery because of the flexibility of the container. Excessive pressure placed on the end walls could cause acid to spew through the cap vents in conventional batteries. To lift this type of battery, use a battery carrier, or carry it with hands at diagonally opposite corners.

4-2.1.1.3 Automotive Battery/Cranking Battery

The automotive wet cell battery is a rechargable storage battery. It is used to support the automotive requirements of a motorized RV and is a reservoir of electrochemical energy. Electrical current is drawn from the battery to turn over (crank) the starter and start the engine. When the engine is running at normal speed, the alternator creates enough electricity to operate the ignition system, lights, and electrical accessories and also supplies some additional electrical energy that is put back into the battery and stored for future demand. An automotive or cranking battery is called upon to give short bursts of high current before the engine-driven alternator on the vehicle takes over. The automotive or cranking battery is never discharged by more than a few percent of its voltage under normal conditions. The automotive or cranking battery is commonly referred to as the *chassis battery*.

4-2.1.1.4 Deep-Cycle Battery

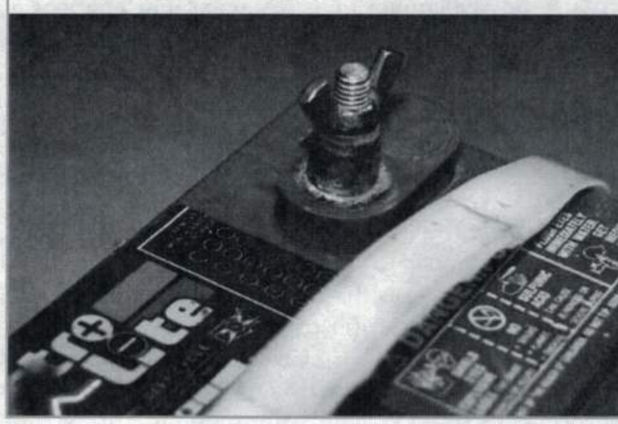
When comparing an automotive to a deep-cycle battery, their external differences may go unnoticed. With the exception of the deep-cycle battery being a little larger in size and, in most cases, having threaded posts, they appear almost identical. It is important to understand, however, that there are a number of internal differences that separate them and account for the slightly larger size and higher price tag.

Deep-cycle battery plates are fabricated of high-density active materials that allow the plates to withstand repetitive cycling without loss of composition. Their grid alloy has greater adhesion and is heavier due to the separators and plates that are bonded with a special "hot-metal" process. This adds to the battery's ability to withstand frequent motion and vibration from the RV chassis.

There are definite reasons for these internal design differences between automotive or cranking batteries and deep-cycle batteries. As the name implies, a deep-cycle battery is subjected to many various depths of discharge. In some cases, a deep-cycle battery can be drained to 0V before it is recharged. Even the best automotive or cranking battery would not last more than 50 deep-cycle discharges, and of these 50, only the first 15 or so would recharge to a full 100 percent state of charge. The major advantage of deep-cycle batteries is that they will supply continuous DC power for long durations. This is because the deep-cycle battery has fewer plates with more material on each plate. This enables it to provide current over a longer period of time. Because of their ability to repeatedly be recharged, deep-cycle batteries are used as the DC power source for the appliances and devices in the living area of the RV. As such, this battery is often referred to as the *house* or *coach* battery.

Figure 4-4 Deep-Cycle Battery with Threaded Posts

Figure 4-5 Deep-Cycle Battery with Screw Post



4-2.1.1.5 Maintenance-Free Batteries

Maintenance-free batteries are available in both regular automotive/cranking and deep-cycle types. There is seldom any need to check the electrolyte level on maintenance-free batteries. In fact, there are no vent caps to allow access to the electrolyte in the cells. With the exception of two extremely small vent orifices, this type of battery is completely sealed. However, terminals and connection still require periodic maintenance and inspection. As long as the electrical system is operating normally, the water decomposition of the battery is minimal. Furthermore, there is a "built-in" electrolyte reserve within the battery that will keep the electrolyte level above the plates of a properly working battery for its entire life. The level of electrolyte can often be determined by looking through the translucent sidewall of the battery. Should this battery be overcharged, or other conditions occur that cause the electrolyte to be reduced below the top of the plates, the battery would need to be replaced.

An advantage of the maintenance-free battery is that, if it is properly charged before storage, it can be safely stored for several months.

NOTE: Attempting to charge a maintenance-free battery that is low in electrolyte can cause an explosion.

4-2.1.1.6 Storage of Battery

- Disconnect from potential loads when being stored or left inactive for any time period longer than a couple of weeks.
- Always leave in a fully charged state when being stored.
- Acid-filled batteries have less potential for loss of charge when stored in a cool area.
- Always store away from any potential for spark, flame, or source of heat.
- A battery left in a storage condition should be recharged at least every two months.
- Always clean the surface area of the battery between the terminals to prevent any loss of charge. Moisture, accumulated dirt, and so forth will help cause a battery to discharge.
- A battery's state of charge will remain higher when stored in a cool area. But do not store a discharged battery in an area that may be subjected to freezing, as the electrolyte becomes very close to water in specific gravity and will freeze and damage the plates and the case.

4-2.1.2 Power Converters

A power converter is a device that changes 120 VAC current to 12 VDC current. In this way, 12 VDC devices in the RV are supplied by the converter when the RV is plugged into a 120 VAC source or if the generator is running.

Most power converters are equipped with a battery charger to keep the RV's battery or batteries charged when connected to 120 VAC power. These chargers are called *trickle* chargers, as their charge rate is usually limited to less than 10 A. Some chargers are equipped with a sensing switch that allows a charge to go to the battery only when needed.

Because the converter must be connected to a 120 VAC system while taking voltage and current measurements, extreme caution must be exercised. Remember that there is potential for lethal shock to occur. Be certain the converter is disconnected from shore power while doing any other work on the converter.

Listing is a specific process by which a device is evaluated for safety by a third-party agency such as Underwriters Labs (UL), CSA (Canadian Standards Association), or other acceptable agencies. Listing for RV use means that additional factors specific to the RV environment (such as vibration) were part of the listing process. In the RV, many components are required to be "listed" or "listed for RV use." It is important to ensure that devices or equipment meet this requirement where applicable. In the case of a converter, look for a listing agency mark on the device that states "listed for RV use" or similar language.

There are three different types of converters currently in use: linear, ferroresonant, and electronic switch-mode.

4-2.1.2.1 Linear Converters

The linear converter has been around the longest. This type of converter uses "linear" circuitry, which means that any change in AC input voltage will result in a change in DC output voltage. This linear characteristic means that low AC input voltage coming into the converter will cause low DC output voltage from the converter, causing lights to dim and motors to operate at speeds slower than intended on the 12 VDC side of the converter. This linear characteristic means that high AC input voltage also causes high DC output voltage, resulting in burned out light bulbs, vents, and motors.

Because the output from the linear converter is pulsating, the linear converter output is generally referred to as *unfiltered*. This means that sometimes the actual output can be as high as 19.5 volts but, when measured, will show an average voltage of 13.8 volts. Twelve-volt loads operate on this power by averaging the content of the positive pulses and the spaces between them. Because of this pulsating output, the load must turn on and off 120 times per second. This builds up additional heat in pumps and fan motors and can cause greater wear and premature failure to many 12 VDC devices. It also causes "humming" in audio systems.

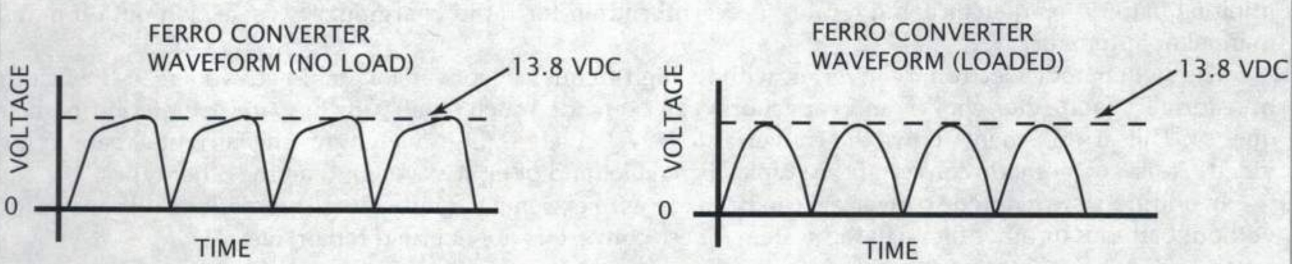
However, batteries float at peak voltage and cannot survive at these elevated levels of voltage. Therefore, to protect the battery, linear converters are designed to isolate the battery from converter output when the converter turns on. In an effort to provide a measure of battery charging, the linear converter may have an optional charge module built in that will slow charge (trickle charge) the battery from a small portion of the converter output. This module can also provide one or more "filtered" circuits for radios, monitoring panels, TVs, VCRs, and gas detectors that cannot operate from the pulsating DC voltage. Overloading the filtered circuits will nullify any battery charging capabilities of the linear converter's charging module.

The linear converter is the least expensive type of converter. However, it is also one of the heaviest, can produce heat as a by-product (making installation clearances very important), and often has an audible hum that is produced by its transformer. The linear converter can be field repaired, but the types of repairs are limited due to labor costs and time involved. Typically, replacement of relays, diodes, and fan motors are the extent of field work performed.

4-2.1.2.2 Ferroresonant Converters

The main difference between ferroresonant converters (FRs) and linear converters is that the ferroresonant converter DC output voltage will not change when the AC input voltage changes. While the ferroresonant converter has a pulsating output like the linear converter, because of an innovative three-stage transformer, the pulses are limited to a maximum voltage, causing the pulses to be shortened and widened (see *Figure 4-6*). The output pulse resembles a squared AC sine wave at no load and, as the load increases, the wave rounds downward to a smaller sine wave. This means the ferroresonant converter output voltage will remain essentially constant over a wide range of input voltages. Typically, ferroresonant converters will provide a constant output voltage of approximately 13.5 VDC even though the input voltage varies from 95 to 130 VAC. Output voltage will vary based on output current/load.

Figure 4-6 Ferroresonant Waveform



Because of this voltage regulation that comes from the three-stage transformer (sometimes referred to as a *ferroresonant transformer*), the entire output range of the ferroresonant converter is compatible with the battery. Therefore, it can be connected in parallel with the batteries and functions as a real battery charger while also providing power to operate the 12 VDC load. A separate battery charging unit is not needed, as this function is provided by the design. The ferroresonant converter must be wired to a battery in order to operate. Because the battery remains part of the system during converter operation, the converter and battery act as partners in providing 12 VDC power to the load. When additional power is needed for a limited time and the converter cannot provide it, the required power is drawn from the battery. As the load is later reduced, the battery is recharged by output from the converter that is not needed to supply the load. The battery acts as a large filter for the squared-off pulsating DC output of the ferro transformer, reducing the 60-cycle noise that would otherwise be unacceptable on the radio. This does not happen with the linear converter.

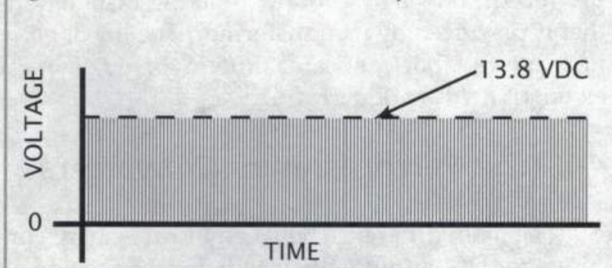
The main benefits of ferroresonant converters in RV applications are their very smooth DC output and the fact that the output is inherently short circuit protected. However, this converter costs a little more than the linear converter, is bigger than the linear, and weighs more due to the ferroresonant transformer. It has improved battery charging capabilities but generates even more heat, and it, too, has an audible hum when operating. Field repairs for this type converter are limited to replacing the diodes or the 600 VAC resonator capacitor. Also, ferroresonant converters are frequency sensitive. Variations in AC frequency cause variations in DC voltage. This most often happens while operating a generator that is off specifications. If there is no battery in the RV, a capacitor across the converter output is required to properly filter the output.

NOTE: When servicing the 600-VAC capacitor, a potential danger is that it can cause bodily harm. To discharge the capacitor, set the analog voltmeter to the highest AC scale, and touch the leads across the terminals of the capacitor. Another method is shorting across the terminals with a 15-k¾, 2W resistor.

4-2.1.2.3 Switchmode Electronic Converters

This type of converter utilizes a significant amount of electronic circuitry to convert 120 VAC to 12 VDC. This converter increases the standard frequency of 60 Hz to a much higher frequency before stepping down the voltage. This low voltage is then electronically regulated so that it remains constant even if the input voltage and DC load varies. Due to its high frequency operation, its 12 VDC output is so fast and dense that, to the connected load, it seems solid, performing the same as battery DC (see *Figure 4-7*). The switchmode electronic converter output is completely battery compatible.

Figure 4-7 Electronic Converter Waveform



The switchmode electronic converter provides the most powerful converter type battery charging available. However, battery characteristics dictate certain charging rules. A 12 VDC battery stands at 12.65V, but in order to overcome an internal resistance to change, it requires approximately 14 volts to fully charge. However, with the presence of this converter's charging ability, the same 14 volt level that the battery needs to charge may now cause additional battery maintenance when left on too long. There are two different electrical needs: rapid charging and long-term battery maintenance. A single output voltage level may compromise these needs. Sometimes switchmode electronic converters offer a dual output voltage choice—one selection for minimal battery maintenance and a more powerful setting for rapid charging. This selection option may be manual or automatic.

The switchmode electronic converter, with its high-frequency conversion, takes advantage of the fact that transformers (and filter chokes and capacitors) can be made much smaller if they are operated at high frequency. This arrangement allows the converter to be relatively light in weight for the current capability provided. Thus, switchmode converters are typically smaller and of lighter weight than the other types.

In addition, switchmode converters can be made with extremely good voltage regulation and can function without batteries or other filters in the system. These converters are not field repairable.

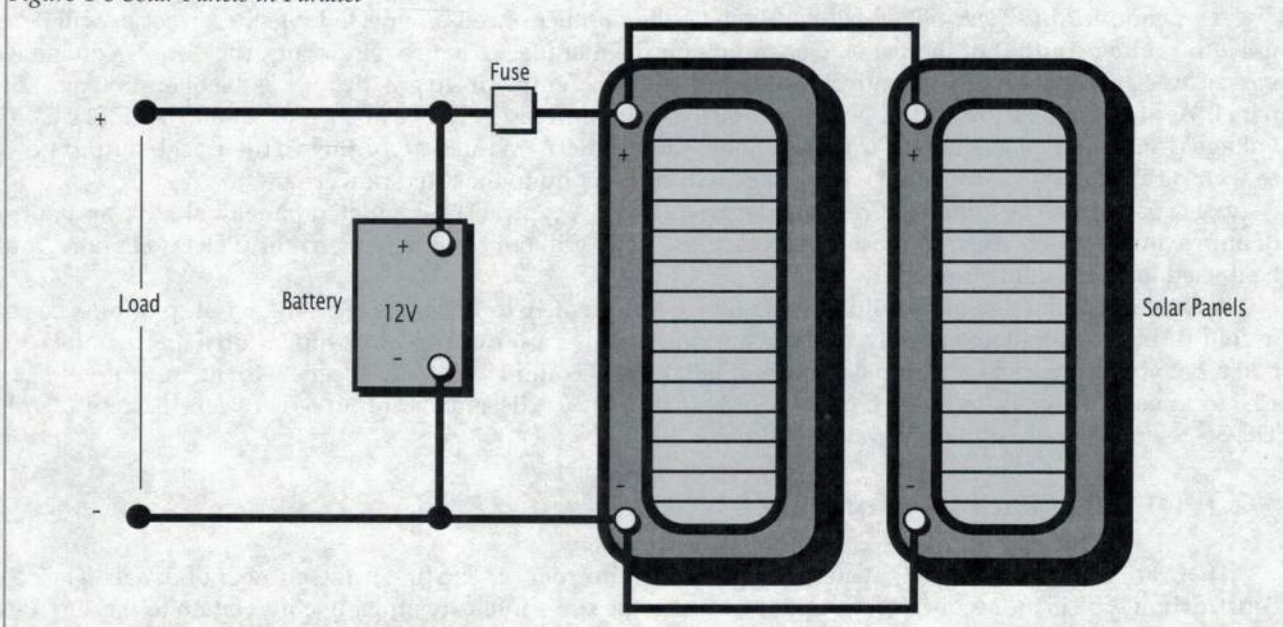
4-2.1.3 Solar Panels

4-2.1.3.1 Types of Panels

Solar panels are another potential source of power for RVs. Solar power is the production of electricity when sunlight strikes a photovoltaic module. A photovoltaic module is made up of two or more solar cells that are designed to react to sunlight by creating an electrical current. The amount of current is affected by both the surface area of the panel and the intensity of sunlight. Solar panels are installed to provide battery charging. Electrical devices use the battery power to function, and the solar panels replace the energy used by recharging the battery.

Solar panels are made up of multiple photovoltalic cells. A single photovoltaic cell has the capacity to produce approximately 0.5 volts. This is a constant and does not change with the size or area of the cell. Panels are sized by voltage. Several panels can be installed in parallel to maintain the total voltage output, as shown in *Figure 4-8*.

Figure 4-8 Solar Panels in Parallel



Connecting panels together can alter the voltage and/or the amperage, depending on the method of connection. When panels are connected in series, voltage output is increased. The proper number of series and parallel connections is important to achieve the desired output for each application.

4-2.1.3.2 Silicon Crystals

Solar panels typically use a substrate of glass or stainless steel and a core of silicon crystals. The stainless steel models are more expensive but are less susceptible to breakage in RV use. Silicon crystals are used as the material that generates electricity from sunlight. Silicon crystals can be produced in different forms: crystalline, polycrystalline, and amorphous.

The crystalline cells have the highest efficiency—approximately 12 to 16 percent. The manufacturing process is very time consuming and therefore expensive. Polycrystalline cells are less expensive to manufacture, but there is a loss of efficiency. These are capable of 11 to 12 percent efficiency. The crystalline and polycrystalline modules require a rigid framework for mounting.

The amorphous cell panels are less expensive, but they are only about half as efficient, or approximately 6 percent (note that efficiencies are being increased with new technology almost constantly). The efficiency of photovoltaic units at 6 to 16 percent may seem low and impractical, but a typical engine-driven generator is only about 12 to 14 percent efficient. For a very simple and extremely reliable piece of equipment with no moving parts, the actual efficiency is very good.

Amorphous cell panels are very common in RV and marine applications, as they are flexible and can follow the contours of the vehicles and boats. They can even be walked on without damaging the structure. They are not indestructible, though. If the top surface becomes scratched, their output will be decreased. Because of their inefficiency, amorphous cell panels would require the use of more panels for large-load applications.

4-2.1.3.3 Solar Panel Output Ranges

If a customer wants to add solar panels to a unit, it is necessary to first know what the customer wants to operate with the panels. To determine this, find the wattage of each device intended to be connected to the solar panels, and convert the wattage to amperes. Then determine how many hours per day the device(s) will operate. This will give the total ampere-hours per day. In the information that comes with the solar panel, there should be a chart that provides the average output of the module being installed for the area of the country where the RV is to be used. This information will help determine how many panels are needed to meet the customer's needs.

As mentioned in *"Types of Panels" on page 4-10*, the number of cells connected together in series will determine the voltage output of the panel. Depending on the manufacturing requirements, the output voltage will vary. There are other factors that affect the output voltage. Temperature greatly affects the operation of a solar panel. As the temperature increases, the output voltage decreases. Between 32°F (0°C) and 76°F (24°C), the voltage drop could be as much as 2 volts. Photovoltaic panels are rated according to their peak output power in watts at 76°F (24°C). Amperage and voltage will correspond to the rated power.

Solar panels can be either self-regulated or regulated. A typical self-regulated panel will have and output of approximately 14.5 volts. In most instances, these units will not overcharge a battery. The exception would be if used in a very cold climate.

A typical regulated panel would have a voltage output of 16 to 18.5 volts. This higher output must be connected through a regulator to prevent overcharging of batteries. Even in hot temperatures, these units could boil a battery, if unchecked. A typical self-regulated panel could have 27 to 30 cells with an output voltage of 13.5 to 15 volts. A typical regulated panel could have 33 to 36 cells and an output of between 16.5 and 18 volts. The 36-cell units are best used in warmer climates.

4-2.1.3.4 Solar Panel Performance

There are three main items that affect output and performance. The first is the number of panels. The cell's construction type is the second factor, and the third is the sun's intensity and angle in relation to the surface of the panel.

The amorphous type of panel is less efficient than the others when all panels are receiving full sun. If part of the panel is shaded, then the cells that are in the shade create the equivalent of an open circuit, and the output is reduced. Amorphous units have diodes between the cells and, as a result, will not have as large a differential in output with partial shade.

Solar panels are most effective when they are perpendicular to the sun rays and not shaded. Panel performance will fall off as the sun rays tilt away from the perpendicular and/or when the unit becomes shaded. Most solar panels can start producing when the sun is at 5 to 10 percent of midday potential. The period of full potential, or almost full potential, on a clear day will be between 6 and 10 hr.

4-2.1.3.5 Sizing Solar Panels

When considering the size and number of solar panels required, there are several things to consider. The number of batteries is probably the first item. The number of batteries should relate to the load requirements of the system. Since photovoltaic panels do not store energy, batteries are an integral part of the solar system. A typical one-panel system will require one battery of at least 105 ampere-hour (A·h) rating, a fuse or circuit breaker, and a length of copper wire. The panel is wired by connecting the wire from the positive and negative terminals of the panel to the corresponding terminals of the battery. These in turn are connected to a device or load. The fuse or circuit breaker should be installed in the positive line, fairly close to the battery (within 18 in.). The fuse or circuit breaker should be sized according to the wire size used. Wires should be at least 10 ga. Additional panels can be added in parallel.

Solar panels come in a variety of sizes. Common nominal sizes for panels are 5 to 100 W. While they can be installed in series to produce 24 or 36 volts, they are usually wired for 12 VDC for RV applications.

Another consideration is where the unit will be used, i.e., the intensity of the sun, the ambient temperature, and the hours of direct sunlight available.

To perform a solar panel sizing exercise, see *"Solar Panel Sizing Exercise" on page 4-30.*

4-2.1.3.6 Installation

The crystalline and polycrystalline units should be mounted with at least 1 in. of clearance under the unit. This will allow the air to circulate and keep the panel cooler. Keeping the panel cooler will prevent output loss. The amorphous-type units can be mounted directly on the surface. Installing the unit flat on the roof will give approximately 5 percent loss of output because of temperature. Installing the unit angled toward the sun will provide better efficiency, but only when it is directly facing the sun.

The amorphous-type units can be glued directly to the coach surface. A good method of doing this is with a double-sided adhesive tape. (Note: this is not recommended for rubber-roofed units.) A 3M® product (VHB #4950) works quite well for this application. The surface must be very clean. If the panels need to be removed at any time (e.g., the owner changing coaches), a very thin wire can be pulled between the panel and the coach surface. This will slice through the tape. The residue can be removed with the proper cleaner or solvent as recommended by the roof material manufacturer.

When wiring the units to the coach system, it is better to use a heavier gauge of wire than the minimum required to avoid low output caused by increased resistance in the conductor itself. Any wiring that will be exposed on the exterior of the unit must be ultraviolet resistant. Most RV owners will find that, at some point, they will require more power and thus more panels. If the wiring was marginal to start with, it may have to be redone to allow for the increased output.

Wire should be routed using the shortest path direct to the batteries. If a regulator is required, it needs to be installed between the battery and the solar panels. Connecting the panel and/or regulator into the refrigerator circuit is not recommended, as it could cause circuit overload and refrigerator operation issues.

4-2.1.4 Alternators

Recreation vehicles have become increasingly dependent on 12 VDC power to operate RV equipment while on the road. An alternator is a device that creates 12 VDC current from the mechanical energy provided by the primary mover engine. The engine alternator to keeps the batteries adequately charged to provide the necessary 12 VDC power. Alternators will be present only in motorized RVs. Alternators will function better in relation to power usage if the charging system has had proper care and maintenance. Many times, a charging system failure is blamed on the alternator or regulator when the problem is actually a defective battery or a poor connection. Make sure the battery is undamaged and capable of holding a charge, all cable connections are clean and tight, and the top of the battery is clean.

The charging system includes the alternator, either an internal or external voltage regulator, a charge indicator or warning light, a fusible link to protect the system from overloads, and the wiring between all the components. A battery isolator is also common. The battery isolator is used to separate the alternator's output between the starting/cranking battery and the RV battery. In some instances, a three-battery isolator may be used to include a dedicated generator battery. The charging system supplies power to the battery group, the ignition system, the lights, the radio, and so on. The alternator is engine driven. The purpose of the voltage regulator is to limit the alternator voltage to a preset value. On external regulator systems, the regulator is mounted somewhere in the engine compartment. On internal regulator systems, the solid-state regulator is housed inside a plastic module in or on the alternator housing itself. The fusible link is a short length of special insulated wire incorporated within the engine compartment wiring harness to protect the system from overloading. The link serves as an in-line fuse, sized to be about four gauges smaller than the circuit it protects. It is a specific safety component that can be obtained from the chassis manufacturer's parts distribution network. Fusible links are not items that can be designed and made up from general wiring.

Some vehicles will have an ammeter located on the instrument panel, indicating charge or discharge of the battery's current passing into or out of the battery. With the electrical equipment switched on and the engine idling, the gauge may show a discharge condition. At fast idle or normal driving speeds, the needle should stay on the charge side of the gauge, with the charge state of the battery determining just how far the needle moves. The lower the battery state of charge, the farther the needle should swing toward the charge side. Other systems use a voltmeter located on the instrument panel of the vehicle, indicating two functions: (1) battery voltage with the key on and engine off, and (2) alternator output when the engine is running. A third system in use, and not as informative, is a light on the instrument panel that illuminates with the key on and the engine not running. This light should go out when the engine is running, indicating the battery is charging.

An alternator is much more efficient and reliable than the old-style DC generator. The alternator will deliver a higher current at a lower rpm than a generator. The disadvantage of the alternator is that, because of rectification, the output is not perfectly "clean" DC. This is not too much of a problem in a situation where the battery is receiving the alternator's output, because the battery serves as a filter and will clean up the DC before it goes to the DC distribution panel.

4-2.1.5 Power Source Review and Additional Notes

Four different 12 VDC power sources have been discussed. These are:

1. Batteries
2. Converters
3. Solar panels
4. Alternators

4-2.1.5.1 Exterior Running Light Circuits

The running light circuits of RVs are powered by batteries, but typically by the "cranking/chassis" battery and not the RV's "house/coach" battery system. Running light circuits include the headlights, tail lights, clearance and identification lights, turn signals, stop lights, and backup lights. In RVs, the power source for these circuits is the chassis battery, which is also used to start the motorhome. On towable RVs, the power source is the tow vehicle's batteries. In most cases, these circuits are isolated from the RV circuits. These circuits are typically protected by fuses in the tow vehicle's system or motorhome chassis, as the RV running light circuits are extensions of the chassis or tow vehicle's running light circuits.

4-2.1.5.2 Charge Lines

In many installations, a charging circuit is run from the tow vehicle battery to the RV, usually through a solenoid or an isolator. This charging circuit will supply power to the RV if the converter is not connected to a 120 VAC source (the DC source discussed in *"DC Electrical Sources" on page 4-3*) or the RV has no house battery. It can also serve as a charge line from the converter to the chassis or tow vehicle battery to keep it charged while parked and when the RV is in the camping mode.

4-2.1.5.3 Converter-Only Circuits

Depending on the type of converter installed in the RV, it is recommended that a battery be installed in the 12 VDC system. Remember from earlier discussions that the battery can serve as a filter and can "smooth out" or "clean" pulsating DC current to keep transilient voltage input to the converter from damaging 12 VDC devices.

4-2.1.5.4 Use of Battery Charger as Converter

Never install or even recommend that a battery charger be used as a power source for the RV. The battery charger may put out excessive voltage that could damage components and devices. In addition, a battery charger is not listed as a converter and may generate excessive heat during operation. Converters listed for RV use have built-in over-temperature protection.

4-2.1.5.5 Battery-Only Circuits

Some RVs may only have a battery installed but no converter. Also, some RVs may only have the 12 VDC supply conductor installed from the chassis or tow vehicle battery. This arrangement will work fine for limited uses, but the consumer needs to be aware that the chassis or tow vehicle's battery can be discharged by the RV's use if the tow vehicle is not operated periodically to allow the vehicle alternator to recharge the battery. Isolators or solenoids may be used to prevent discharge of the tow vehicle's battery.

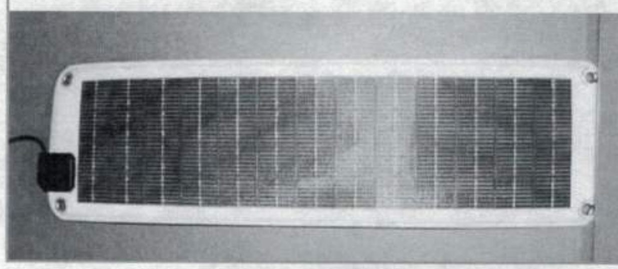
4-2.1.5.6 Combination Battery/Converter Circuits

Combination battery/converter circuits are the most typical and versatile low-voltage circuits in RVs. When 120 VAC power is not available to power the converter, the battery becomes the source of power. If the converter is activated by 120 VAC, the converter will power the DC circuits and replenish battery power via the charging circuit. Together, the combination battery/converter circuits provide the maximum flexibility for the RV's low-voltage DC system.

4-2.1.5.7 Solar Panels

The amount of power available to operate 12 VDC devices from solar panels, as shown in *Figure 4-9*, depends on the size and number of panels installed, the location and environment due to sunlight availability, and the size of the battery connected to the system. Solar panels are used to provide battery charging capabilities only.

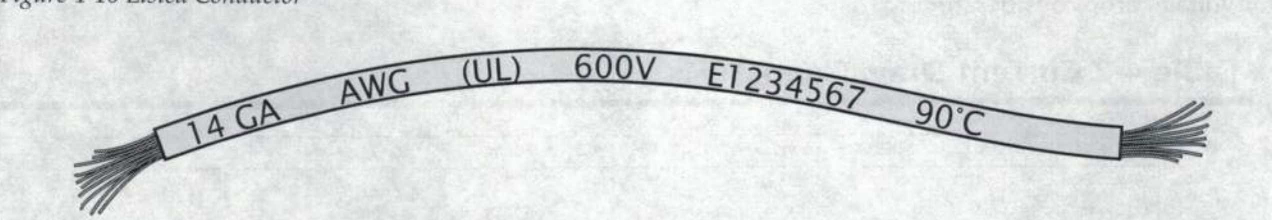
Figure 4-9 Solar Panel



4-2.1.6 Conductors

Current-carrying conductors used in the low-voltage wiring system of an RV are required to be of the stranded copper type. Conductors of sizes 6 through 18 AWG or SAE need to be evaluated by a third-party listing agency such as UL or CSA. An example of a listed conductor is shown in *Figure 4-10*.

Figure 4-10 Listed Conductor



In determining wire size by gauge, the smaller the gauge number, the larger the wire. After the gauge size reaches number 2, the system works the other way. The larger the number, the larger the wire. The marking for larger sizes shows the number size followed by "/0" to distinguish it from the smaller-gauge wires. Battery cables are the most common use for these large-diameter wires. Ring terminal connectors also are designed to fit screw or stud sizes from a small number 0 stud to 3/8 in. dia.

The identification mark of the listing agency needs to be printed on the wire. Any conductor used needs to be sized according to the load and overcurrent protection provided. *Table 4-1* shows wire size versus overcurrent protection. Remember, it is always acceptable to use an overcurrent protection device sized smaller than the conductor specified, but never use an overcurrent protection device larger than specified.

Table 4-1 Low-Voltage Overcurrent Protection

Wire Size	Ampacity	Wire Type
18	6	Stranded
16	8	Stranded
14	15	Stranded
12	20	Stranded
10	30	Stranded
8	40	Stranded
6	50	Stranded
4	70	Stranded
2	95	Stranded
0 (1/0)	125	Stranded
00 (2/0)	145	Stranded
000 (3/0)	165	Stranded
0000 (4/0)	195	Stranded

In addition to sizing the conductor in relation to the overcurrent protection, the length of the circuit is important as well. As the length of the conductor increases, the resistance increases, causing a drop in voltage. In some cases, the size of the conductor may need to increase greater than *Table 4-1* shows. Refer to *Table 4-2* for voltage drop considerations.

Table 4-2 Current Draw (Amps)

	1	2	3	4	5	6	7	8	9	10	15	20	25	30	40	50	60	70	80	100
Gauge	MAXIMUM LENGTH OF SAE CONDUCTOR (in feet) FROM SOURCE TO DEVICE																			
20	107	53	36	27	21	18	15	13	12	11	7									
18	172	86	57	43	34	29	25	21	19	17	11	9								
16	261	130	87	65	52	43	37	33	29	26	17	13	10							
14	413	207	138	103	83	69	59	52	46	41	28	21	17	14						
12	651	326	217	163	130	109	91	81	72	65	43	33	26	22	16					
10	1043	521	348	261	208	174	149	130	116	104	70	52	42	35	26	21	17			
8	1653	827	551	413	331	276	236	207	184	165	110	83	66	55	41	33	28	24	21	
6	2892	1446	954	723	578	482	413	362	321	289	193	145	116	96	72	58	48	41	36	29
4	4170	2085	1390	1043	834	695	596	521	463	417	278	209	167	139	104	83	70	60	52	42
	MAXIMUM LENGTH OF AWG CONDUCTOR (in feet) FROM SOURCE TO DEVICE																			
20	115	57	38	29	23	19	16	14	13	11	8									
18	182	91	61	45	36	30	26	23	20	18	12	9								
16	288	144	96	72	58	48	41	36	32	29	19	14	12							
14	458	229	153	115	92	76	65	57	51	46	31	23	18	15						
12	729	364	243	182	146	121	104	91	81	73	49	36	29	24	18					

Table 4-2 Current Draw (Amps)

10	1159	579	386	290	232	193	166	145	129	116	77	58	46	39	29	23	19			
8	1738	869	579	435	348	290	248	217	193	174	116	87	70	58	43	35	29	25	22	
6	2930	1465	977	733	586	488	419	366	326	293	195	147	117	98	73	59	49	42	37	29
4	4659	2330	1553	1165	932	777	666	582	518	466	311	233	186	155	116	93	78	67	58	47

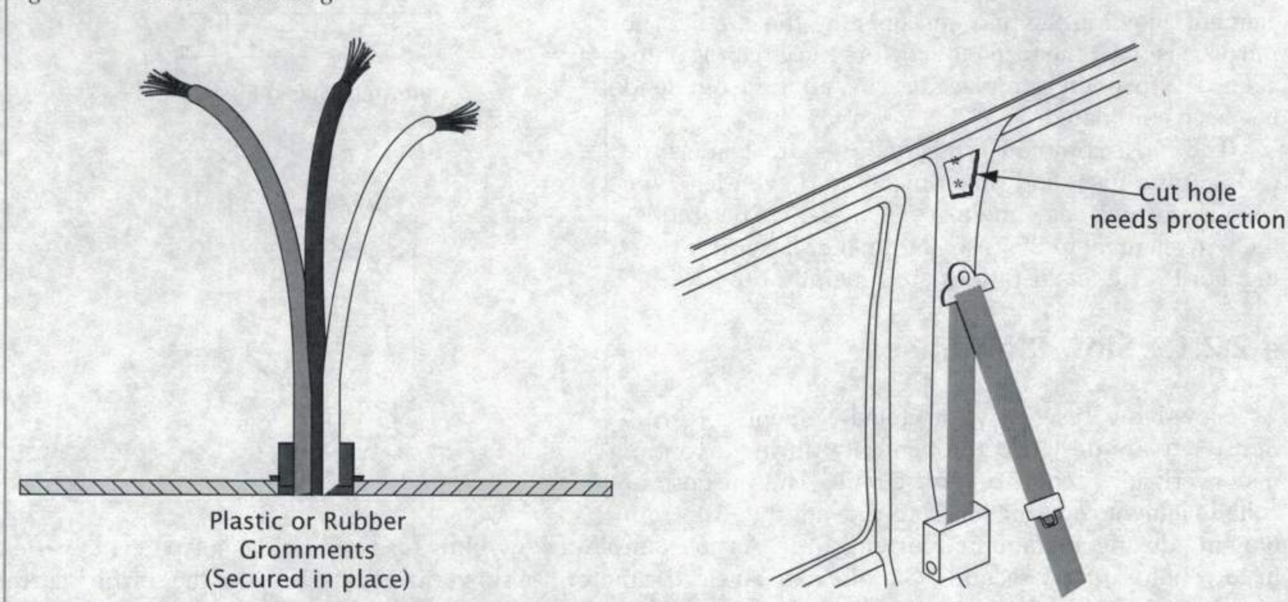
Low-voltage conductors used in the RV's interior must have a minimum insulation rating of 90°C. Low-voltage conductors used in the engine compartment or under the chassis where the conductors are within 10 in. of any exhaust system component must be rated at least 125°C. The temperature rating will usually be printed on the wire along with other information. If it is not, be sure to look at the wire spool for information. If the temperature rating of the wire cannot be determined, do not use it.

Aluminum wire is not allowed in the DC system of an RV. Most components are designed to be used with copper connections. If aluminum is used, galvanic corrosion could result from dissimilar metals at the terminals or connections, particularly where moisture is also involved. Always use copper conductors.

When adding a circuit or replacing faulty wiring, make sure the installation of the wire is done in such a way that it is protected from physical damage. Physical damage applies to the conductor's contact with sharp metal edges, screw points, heat sources, and moving parts. To protect the conductor from physical damage, examine the possibility of routing the conductor as high as practical in storage compartments where the upper corner of the compartment can offer protection from heavy items being tossed on top of it. If this is not possible, use covering boards, conventional electrical raceways, or convoluted tubing to provide the needed protection.

Where conductors pass through the vehicle's exterior skin, use grommets or similar items to protect the wire. The key is to be sure that road vibration will not eventually cause the wire to be cut or worn where it can become exposed and possibly short out.

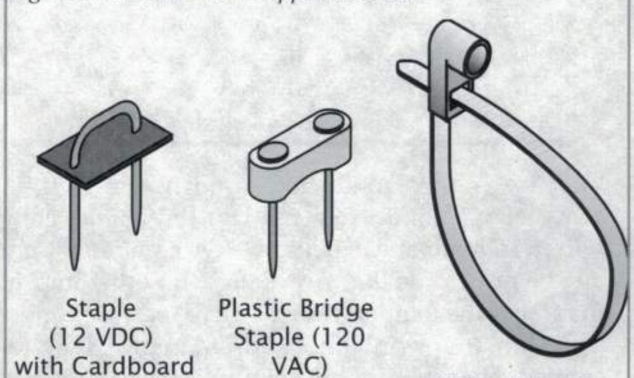
Figure 4-11 Conductor Routing



There is no specific requirement for how often 12 VDC conductor securement needs to be used. However, 120 VAC conductors are to be supported every 4 ft. With either type of conductor, the primary concern is not to have lengths of wires hanging free where they can pull on the connectors, or where they can get caught and pulled from the storage or removal of other camping equipment. This is likely to happen to conductors in storage areas. All these potential problems could lead to shorts and other faults in the DC system.

If the securement method used involves staples or similar fasteners that could damage the insulation on the wire, wrap the wire with two or three wraps of electrical tape to prevent damage. Insulated staples, as shown in *Figure 4-12*, are also permitted.

Figure 4-12 Conductor Support Devices



4-2.2 Overcurrent Protection

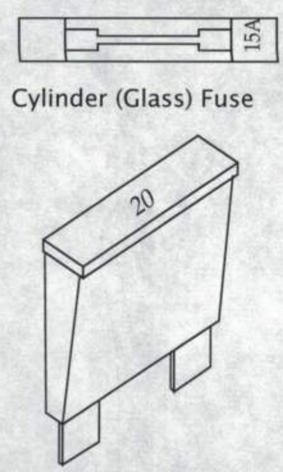
The correct wire conductor size and overcurrent protection are critical when adding new equipment to a 12 VDC system. Fuses and circuit breakers are designed to protect a circuit, including its conductors, by opening and interrupting the flow of electricity through the circuit in the event of an excessive flow of current. Both devices are marked with an amperage value to signify the maximum protection offered. Some overcurrent protection devices require replacement or resetting, while others are self-resetting. Regardless of what type of device is in the circuit, never substitute an overcurrent protection device with one of a higher rating. Typically, the overcurrent protection is located within 18 in. of the point where the power source connects to the vehicle chassis as specified in *ANSI/RVIA 12V* paragraph 3-5.

4-2.2.1 Fuses

Fuses are found in many circuits as a protection against an overload. Excessive current melts the fuse element, blowing the fuse and opening the circuit. The purpose is to let the fuse blow before the circuit is damaged. The fuse can be replaced easily, after the overload has been eliminated.

The most common types of fuses are blade type (ATC, mini-fuse and maxi-fuse) and cylinder type (AGC and SFE), as shown in *Figure 4-13*. The thinner the wire element in the fuse, the smaller the current rating. For RV fuses, the ratings are generally 1 to 60 A.

Figure 4-13 Fuses



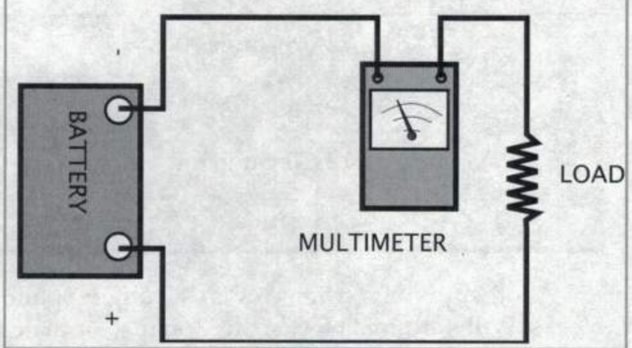
4-2.2.1.1 Slow-Blow Fuses

Slow-blow fuses have a coiled-element construction. They are designed to open only during a continued overload, such as a short circuit. The purpose of coiled-element construction is to prevent the fuse from blowing during a temporary current surge. As an example, a slow-blow fuse will hold a 400 percent overload in current for up to 2 seconds. Circuits with an electric motor use slow-blow fuses, because the starting current of a motor is much more than its running current.

4-2.3 Determining Loads

When installing or servicing low-voltage electrical devices, it is necessary to determine the amperage draw of the device. This is to ensure that the correct size conductor and overcurrent protection are provided for the circuit to the device. A load should never exceed the minimum rating of the conductor and overcurrent protection. A 21 A load should never be connected to a 20 A overcurrent protection device. Information regarding the load a device draws is often located on the data plate or in the manual or instructions for the device. If not, the amperage draw of a low-current device can be measured as follows:

Figure 4-14 Multimeter in Series



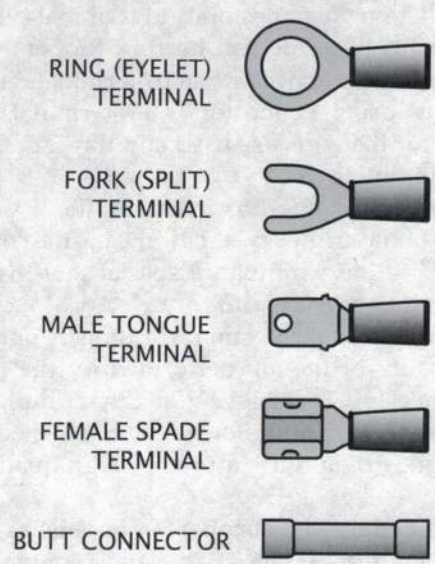
1. Use a multimeter that is capable of measuring the load of the circuit. Some multimeters are not capable of measuring over 10 A.
2. Install the multimeter in series between the source of current and the device being measured.
3. Set the multimeter to measure the current in amperes.
4. Turn on the device.
5. Read the current draw in amperes.

Alternatively, a clamp-on type ammeter may be used to measure current or amperage. The meter is simply clamped around one circuit conductor carrying current to the device, preferably the positive wire. The meter is set to measure current in amperes, and the current being drawn is read on the meter with the device on.

4-2.4 Connectors

Wire connectors come in all shapes and sizes, but the most common ones likely to be found on an RV and are shown in *Figure 4-15*. These type of connectors are commonly referred to as *solderless* terminals. The ring terminal connector is designed to fit over a stud or to be used with a screw connection. Ring terminal connectors are available in sizes to fit all wiring from 22 to 4/0 AWG.

Figure 4-15 Common Wire Connectors



Wire nuts are also common and need to be listed and used within the terms of their listing. Wire nuts, sized for the number and size of wire used, are also available for connecting wires together. If using wire nuts, it is good idea to wrap the connection with electrical tape to help maintain a good connection over an extended period of time.

Connectors that cut through or pierce the wire's insulation to make contact with the wire core (see *Figure 4-19*) are used throughout the RV industry. However, with the limited amount of surface contact of the connector to the wire, there is an increased chance that corrosion or looseness can occur over time.

Table 4-3 Common Connector and Terminal Color Codes

Gauge	Color
22–18 gauge	Red
16–14 gauge	Blue
12–10 gauge	Yellow
8 gauge	Red

Another popular connector is the tongue spade terminal. These connectors work well with wiring terminal blocks. With terminal blocks, the "tongue" or male receiver of the connector is screwed down to the block. This allows the female or "spade" end of the connector to be pushed onto the tongues. This provides a system where the wires can be connected and removed for service or testing without completely removing the hold-down screw from the block. Because of the ease in which these connectors are connected and disconnected, they are sometimes referred to as *quick disconnects*.

The commonly used butt-splice connector is used in joining the ends of two wires. The wires are inserted in both ends of the butt-splice connector and crimped in place.

There may be other types of connectors and terminals used in RVs, but the ones mentioned are the most common (see *Figure 4-19*).

4-2.4.1 Installation of Connectors and Terminals

Figure 4-16 Incorrectly Crimped Terminal

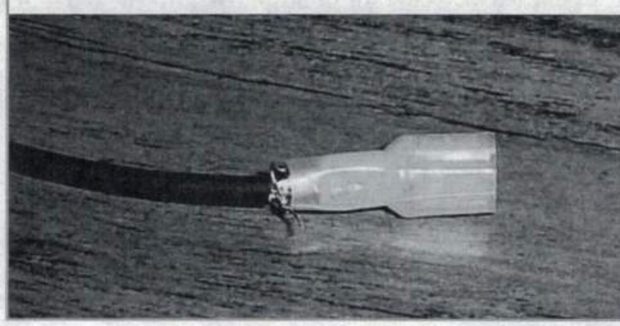


Figure 4-17 Correctly Crimped Terminal

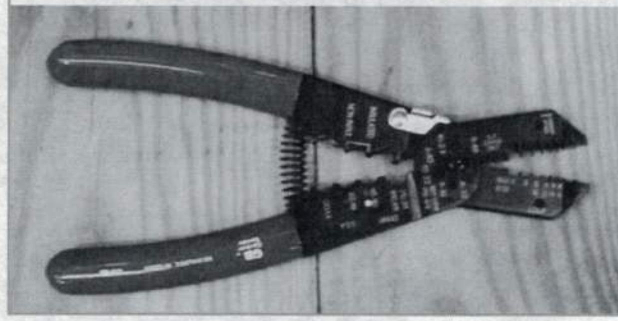
Conductors are to be spliced and joined with devices suitable for the intended use. The proper use and installation of connectors and terminals will reduce the possibility of accidental shorting. Proper installation of low-voltage connectors and terminals is accomplished by using connectors and terminals that are designed for the wire size used and through the proper use of crimping tools.

Almost all connectors used in the RV industry today are of the crimp style. This means the connector is "crimped" to the wire with a special tool that ensures that the wire and connector are electrically connected. Like any electrical connection, crimping is only as good as the quality of the job performed by the technician (see *Figure 4-16*). To achieve a quality crimp, as shown in *Figure 4-17*, the connector must be matched with the correct wire size and use a proper, high-quality crimping tool.

Combination wire strippers/crimpers, as shown in *Figure 4-18*, are used for cutting and removing insulation from wires and scraping the wire clean of oxides or wire enamels. They can crimp both insulated and non-insulated connectors. This type of tool is used on 22 to 8 ga wires. It is not recommended for use on larger size wires, such as battery cables.

Most multipurpose crimping tools feature other functions as well. The most often used feature is the wire stripper. The stripper usually has several openings to fit various gauge wires. When using the wire stripper, make sure that the wire is inserted into the correct hole, and strip back the amount of insulation required for the connector to be crimped. (Remember—a bad connection is a voltage drop in the circuit.) Cutting or eliminating some strands of a wire for connection will create a point of high resistance.

Figure 4-18 Wire Stripper/Crimpers



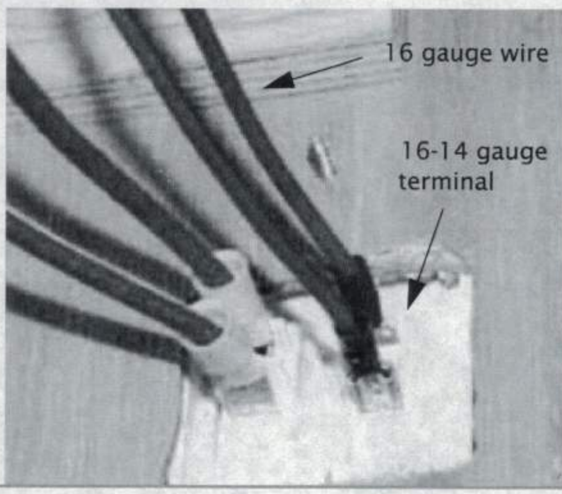
NOTE: Connectors and terminals in the low-voltage system are not required to be listed.

Connectors and terminals, as shown in *Figure 4-19*, used in the low-voltage system are marked for specific wire sizes. When splicing or joining conductors, the proper connector or terminal must be used.

Figure 4-19 Connectors and Terminals

Good connection design exists when proper terminals are used with the appropriate wire size, as shown in *Figure 4-20*.

Figure 4-20 Good Connection Example



Using mismatched terminals and wire does not ensure good connections, as shown in *Figure 4-21*.

Figure 4-21 Bad Connection: Mismatched Connector and Wire

The proper use of a crimping tool is a must. This tool, as shown in *Figure* 4-22, has the ability to crimp both insulated and noninsulated connectors and terminals. Be sure to use the insulated crimp area of the tool for insulated connectors or terminals.

Improper use of the crimping tool could break the insulation of the connector or terminal, as shown in *Figure* 4-23.

Figure 4-23 Broken Connector Insulation

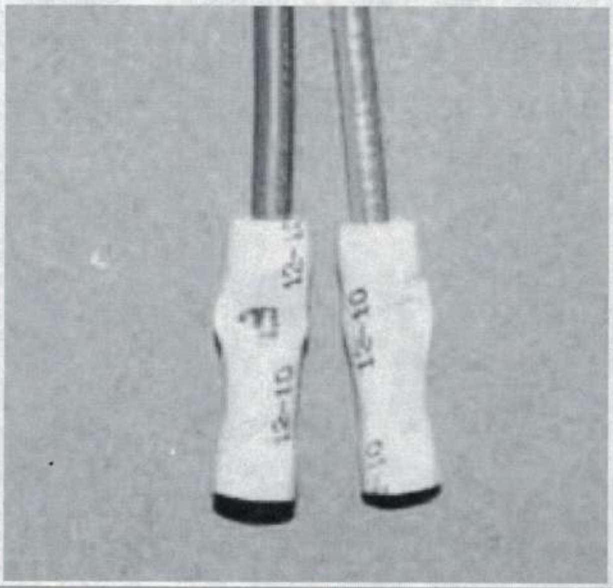
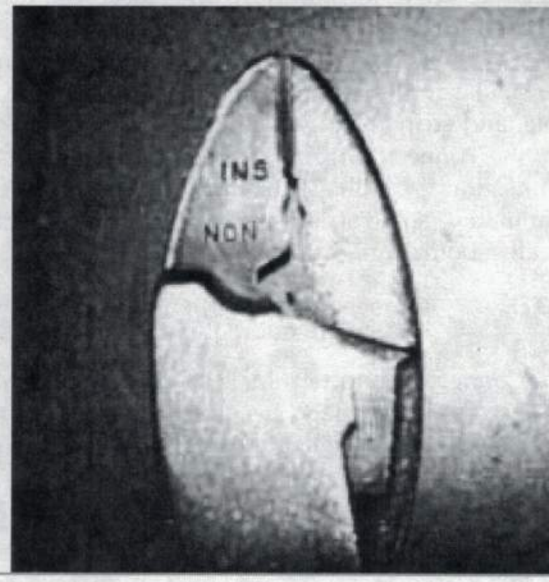
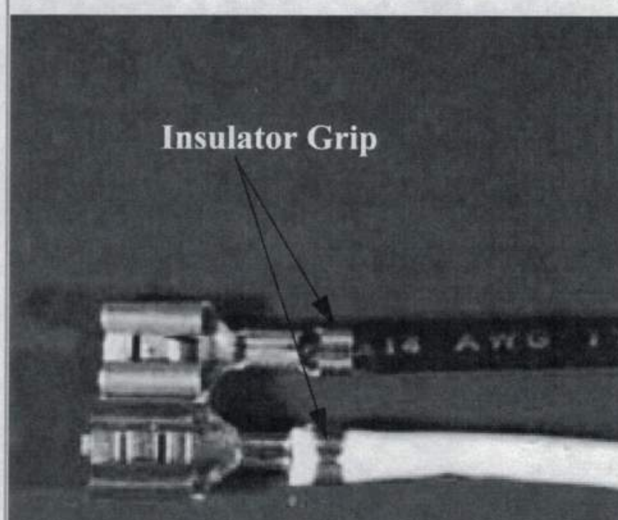


Figure 4-22 Crimping Tool



Proper installation must also be ensured when using noninsulated terminals. The black conductor shown in *Figure* 4-24 is incorrectly installed, because the insulation grip does not grip the conductor insulation.The white conductor shows a correct installation.

Figure 4-24 Connectors with Insulation Grips



Also, when using any type of noninsulated connectors or terminals, the connector or terminal must be flush with the insulation of the conductor, as shown in *Figure 4-25*. Any exposed wire must be wrapped with listed electrical tape.

Any exposed wire at a terminal must be wrapped a minimum of three times with electrical tape, as shown in *Figure 4-26*.

Figure 4-25 Noninsulated Terminals

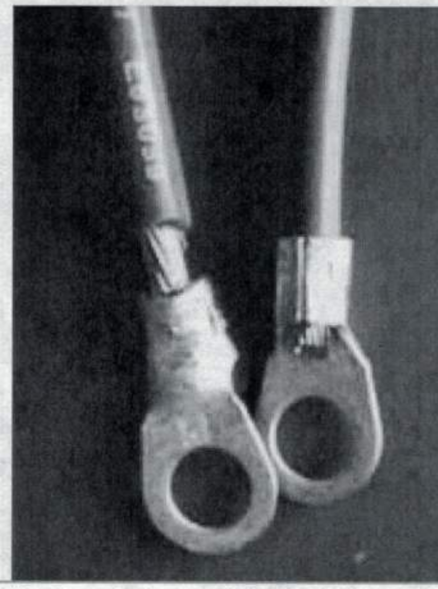
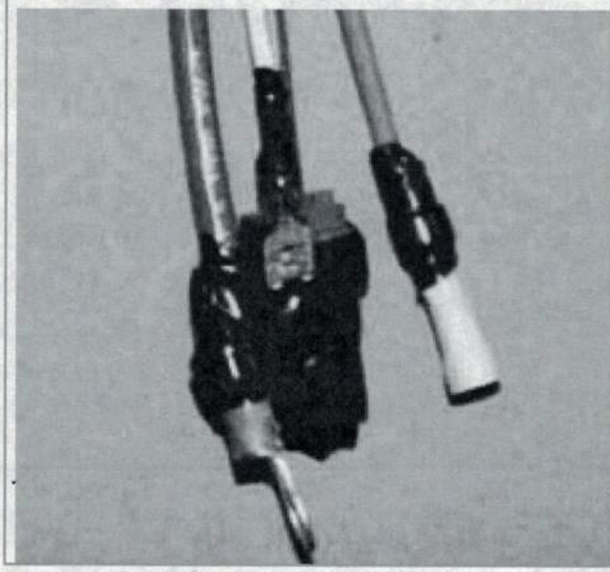


Figure 4-26 Wrapped Terminals



The electrical tape used to cover exposed wire needs to be of the listed type, as shown in *Figure 4-27*.

Multiple wires in a single terminal or connector, as shown in *Figure 4-28*, are acceptable, provided the total circular mil area of all conductors is within the range of the terminal being used.

Figure 4-27 Listed Electrical Tape

Figure 4-28 Incorrect Single Terminals with Multiple Wires

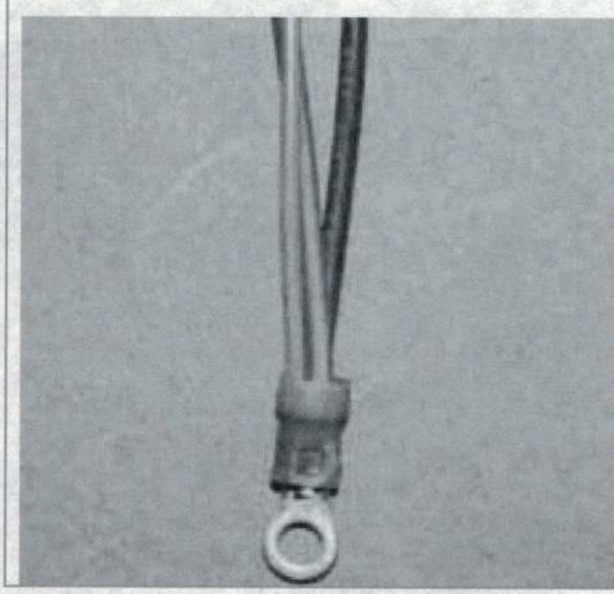


Table 4-4 Multiple Conductors within Terminals

Terminal Size	Allowable Conductor Combinations
18 ga	1–18 ga 2–20 ga
16 ga	1–16 ga 2–18 ga
14 ga	1–14 ga 2–16 ga 3–18 ga
12 ga	1–12 ga 2–14 ga 3–16 ga 4 or 5–18 ga
10 ga	1–10 ga 2–12 ga 3–14 ga 4 or 5–16 ga

When splicing conductors, merely twisting the conductors together and then taping them is not acceptable.

When using some wire nuts to join multiple conductors, the conductors should not be twisted together prior to being inserted into the wire nut, because the wire nut will twist the wires as it is screwed into place. Check the installation instructions to determine how the nuts are intended to be installed.

4-2.4.2 Soldering

Soldering is a process usually done with a metal called 60/40 solder, an alloy made of 60 percent tin and 40 percent lead. Other ratios are used for special applications, but 60/40 is the most common ratio. Solder is melted at a temperature of about 370°F (188°C) with a soldering iron. Most connections are made with a number 20 or 22 rosin-core solder.

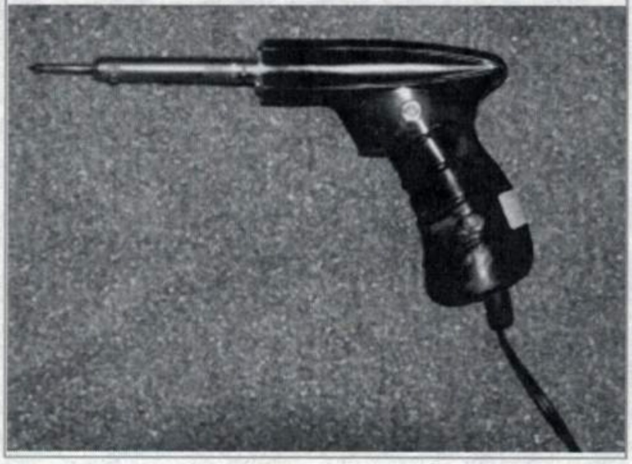
Figure 4-29 Soldering Iron

The soldering iron to be used depends on what is being soldered. A soldering gun is useful if only a few connections have to be made and excess heat is not a problem. Most soldering guns reach full temperature in seconds, so they can easily damage surrounding components. A 25 to 35 W soldering pencil iron is the most popular soldering iron for small work. It provides sufficient heat for most connections, but it is not so large that it can touch adjacent components or damage them with too much heat, as a soldering gun can.

Tinning the iron, a very important practice, means coating the tip of the soldering iron with a thin coat of solder. Tinning is done by heating the iron, wiping it off with a damp sponge, and adding more solder. The flux inside the solder cleans the oxide from the tip, and the solder keeps oxide from building up. An unclean tip is almost impossible to solder with, because the oxide reduces the transfer of heat. This tinning procedure must also be performed when using a new tip.

Good connections are easy to make. With in-line splices, it is required that the wires at the point of connection are twisted securely together before soldering. Do not expect the solder alone to hold the splice connection together; twisting the wires together before soldering provides the strength of the connection. Apply the heat to the "bottom" of the connection being soldered and the solder to the "top" of the connection. Let the transferred heat through the connection melt the solder. When the connection becomes hot enough, the solder will flow or draw into the connection through the stranded wire. This is called *wicking*. It will run quickly and spread over the connection. Do not move the connection until it cools. If the connection appears dull or porous after soldering is completed, it may be weak and have high resistance. This connection is called a *cold solder joint* and likely needs to be resoldered. A good solder connection will be shiny and smooth, and the solder will appear to have melted two stranded wires into one.

Figure 4-30 Soldering Gun



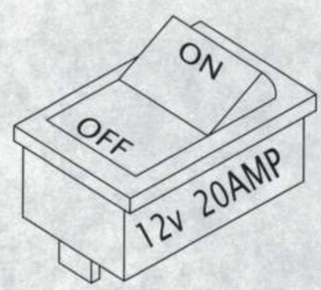
There are different soldering tools, as shown in *Figures 4-29* and *4-30*. Different power ratings, tip sizes, and tip shapes are available for a wide range of soldering situations.

4-2.5 Switches

Switches used in the low-voltage electrical system consist of many types, including toggle, rotary, rocker, and momentary. Switches used in the low-voltage system do not require listing but must have a DC rating equal to or greater than the connected load. The rating is usually marked on the switch as shown in *Figure 4-31*.

Low-voltage switches do not need to be installed in electrical boxes or other types of protective electrical housings. The wire connections to the back of the switch should not impinge too closely on surrounding materials such as paneling or vinyl and foam backings. Keeping these materials away from the switch connections will keep any potential heat buildup to a minimum.

Figure 4-31 Low-Voltage Switch



4-2.6 Relays/Solenoids

Relays/solenoids are basically electrically activated switches. A signal current tells the relay to open or close the circuit. Relays used in the low-voltage electrical system must have a DC rating equal to or greater than the connected load. The rating is usually marked on the relay. Relays/solenoids are available in both the normally closed and normally open types. A normally closed relay will allow current to pass until it receives the signal current and then will shut off the current. A normally open relay does not allow current to pass until it receives the signal current. For practical purposes, relays and solenoids perform the same function.

4-2.7 Diodes

Diodes are directional gateways used to help direct the flow of electricity in a circuit. This is done through the use of semiconductor materials that conduct electricity very well in one direction but very poorly in the other. Diodes are usually used as internal components of devices used in the RV. For example, diodes are used in converters to assist in the rectification of the AC to DC power, and they are used in generators, battery isolators, and many other items. Diodes are being integrated as a component of the circuit board.

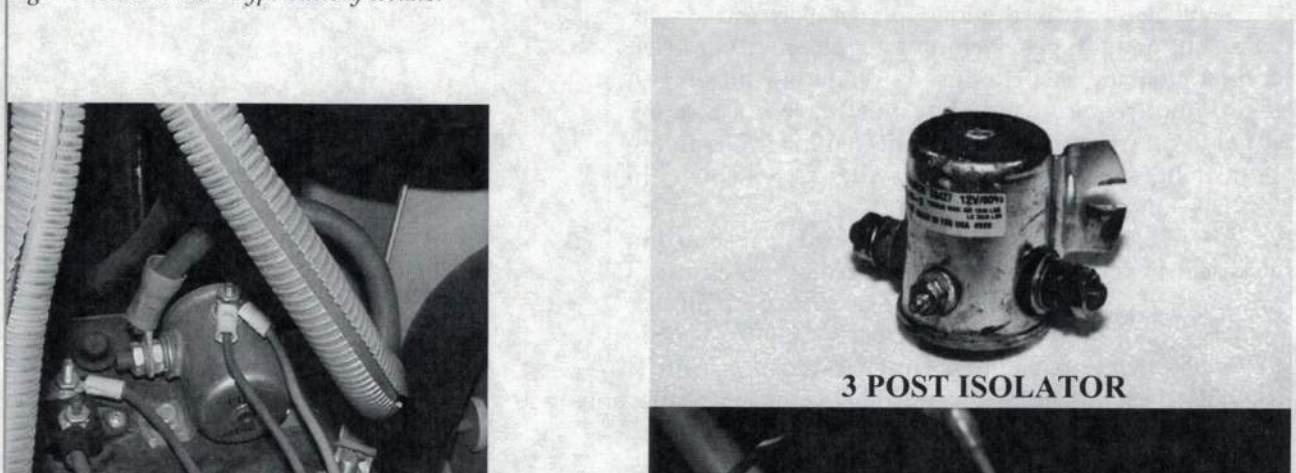
When working with devices that contain diodes, remember that, because of their construction, a voltage drop is always present when current is passed through a diode. The amount of voltage drop is dependent on the incoming current. But if this voltage drop is overlooked or unknown, diagnosing a system could be difficult.

To check a diode, check continuity in both directions. If continuity is present in only one direction, the diode is probably good. If continuity is present in both directions, the diode is probably bad.

4-2.8 Isolators

The battery isolator, usually mounted in the tow vehicle or motorhome engine compartment, separates the tow vehicle or chassis battery from the trailer or motorhome house battery. It allows the house battery to be charged when the tow vehicle or motorhome engine is running. It also prevents the tow vehicle or chassis battery from being discharged if the electrical equipment hooked to the house battery is being used. When the ignition on the tow vehicle or motorhome is turned on, the isolator completes the circuit, and the engine's alternator charges the house battery. When the ignition is off, the isolator breaks the circuit, preventing the tow vehicle's or motorhome's battery from supplying current to house/coach circuits. There are two types of isolators: solenoid (*Figure 4-32*) and diode (*Figure 4-33*).

Figure 4-32 Solenoid-Type Battery Isolator



To test a diode-type isolator, use the process described earlier for diodes. If continuity is present in both directions, the isolator is probably bad. To check a solenoid-type isolator, check that the isolator has power output at the appropriate terminals with the ignition turned on and does not have power at the appropriate terminals with the ignition turned off.

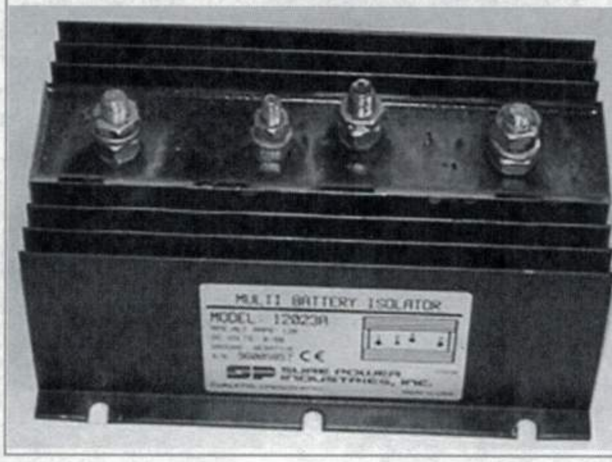


Figure 4-33 Diode-Type Battery Isolator

4-2.8.1 Circuit Breakers

Circuit breakers for the low-voltage system are available in many types. Manual-resetting circuit breakers are available in both the push-button (*Figure 4-34*), and toggle types (*Figure 4-35*). Automotive-type circuit breakers are available in three types, as shown in *Figure 4-36*.

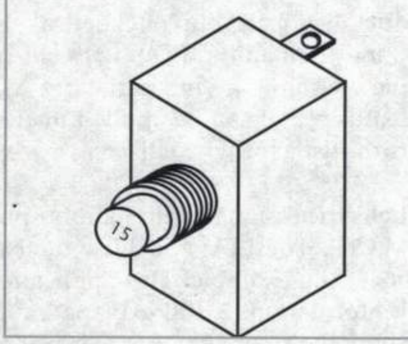


Figure 4-34 Push-Button Circuit Breaker

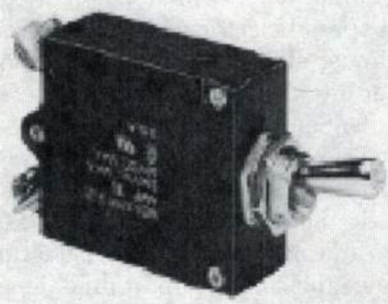


Figure 4-35 Toggle Circuit Breaker

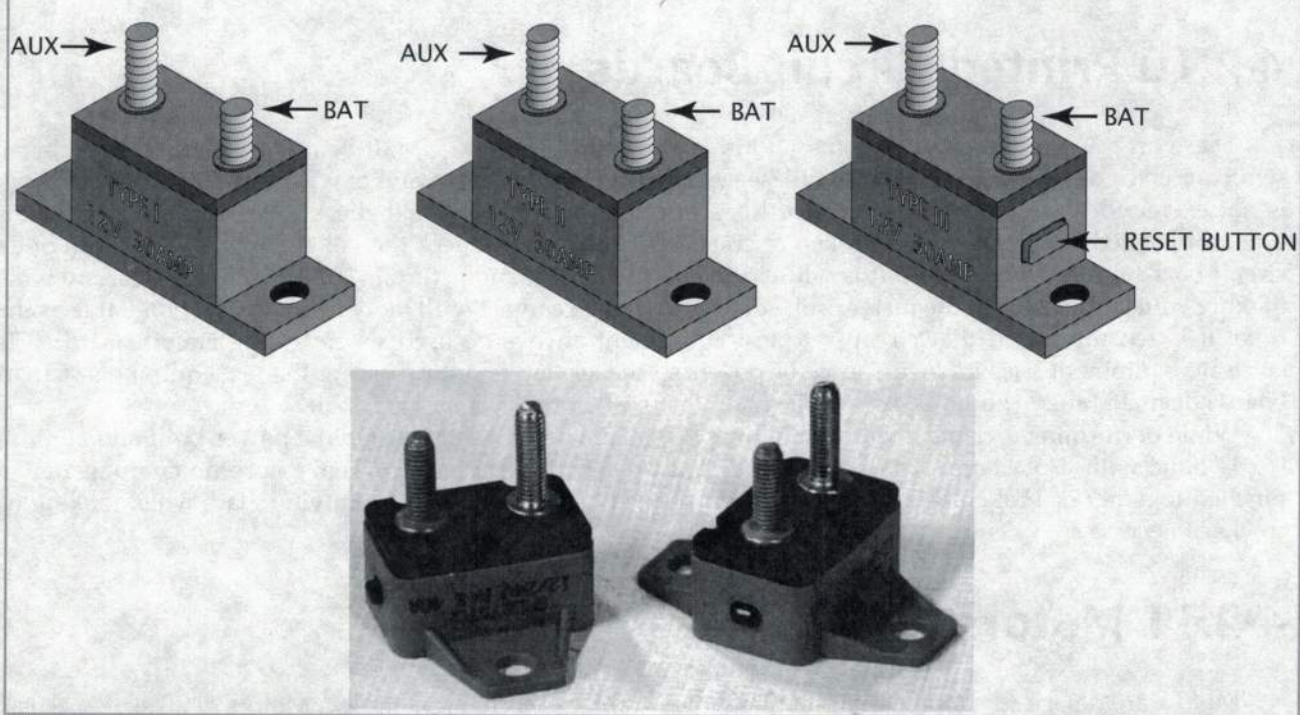


Figure 4-36 Automotive-Type Circuit Breakers

Type I circuit breakers are cycling or self-resetting units. These can cycle repeatedly without the owner/operator being aware. Type I breakers are typically used on loads controlled by momentary switches, safety devices, or self-limiting circuits. Type I and type II breakers look exactly the same on the exterior but are different internally. The type II remains open as long as the overload exists and until the power is completely removed. If a type II breaker trips, the power source to the breaker must be removed and the fault corrected before it will reactivate. The type III breaker is readily identifiable, because it has a reset switch or button on its exterior. If this breaker trips, the reset button needs to be pushed in to reset the breaker.

Most of these automotive-type circuit breakers have two posts, one marked "bat" and the other "aux." The post marked "bat" receives the conductor from the battery or source, and the "aux" holds the conductor going to the load. The "aux" post or terminal is the longer of the two. These circuit breakers need to be installed correctly, as described, to properly function. If the breaker is not marked as described, specific conductor placement is not an issue.

4-2.9 Solid-State Circuits

Solid state is a term that pertains to circuits and components using semiconductors. Examples of solid-state semiconductor components (made of solid material) include transistors, diodes, and integrated circuits. They are used for amplifiers, oscillators, rectifiers, and digital circuits. Semiconductors are a group of chemical elements with special electrical characteristics. Most common are silicon (Si) and germanium (Ge), with silicon used for almost all semiconductor components. The semiconductors have a unique atomic structure that allows the addition of specific impurity elements to produce very useful features that can be applied in electronic circuits. Semiconductors in general are rugged devices and perform satisfactorily in all areas except where there is excessive heat and voltage.

Also included in semiconductor components are devices that convert electrical signals into light output. These include the light-emitting diode (LED) and liquid-crystal display (LCD). The LED and LCD devices show letters and numbers for the visual display of the output of calculators, as an example. This application also illustrates the conversion of digital electrical signals to analog visual information. A full explanation of how solid-state devices work, how they are used in different circuits, and how their performance is specified by characteristics, circuit equations, and so forth, is beyond the scope of this text.

4-2.10 Printed Circuit Boards

There are several electrical systems within the RV using printed circuit boards that contain solid-state semiconductor devices. To troubleshoot these systems successfully, be aware of what can damage them if care is not exercised. If a defective circuit board is suspected, perform a visual check for the obvious problems. Look for burned components or a broken or cracked circuit board. Check the voltage input and output of the circuit board under load to see if it is within the circuit board manufacturer's specifications. Be careful when making voltage checks that the meter probe does not come in contact with more than one test point at the same time. It is recommended that circuit-safe test equipment always be used when testing circuit boards. Circuit-safe equipment uses its own source of power so the system is not powering the test equipment. Circuit boards deemed faulty should be sent to the manufacturer for replacement or repair.

While performing a visual inspection of the printed circuit board, be certain the power is off and all probing is done with a plastic probe. If the board is removed from the system, make sure no components are pinched together or broken off. Handle the circuit board carefully. Use a magnifying glass when looking for cracks, if necessary.

4-2.11 Motors

Motors are devices that convert electric energy into rotary mechanical energy. Motors of all sizes are used extensively in RVs today, so an understanding of their design and operation is essential to provide proper service. Motors have a rotating core (armature) inside a coil (windings or field coil), with electric contact being made by brushes.

In a motor, the electrical energy from the system is transmitted through the brushes to the armature or through the alternating magnetic field to the armature. The resulting magnetic field opposes another magnetic field produced by either a permanent magnet or electromagnets. The opposition causes the armature to turn, resulting in a rotational mechanical force. DC motors use either permanent magnets or electromagnets to produce a field. With a mechanical contact to supply current to the armature, a separate field is produced. This gives high start power (torque).

Many motors are equipped with safety devices to protect the motor in the event of unusual or dangerous situations. The most common device is a thermal switch. If the motor becomes overheated due to excessive current flow, the thermal switch will open the circuit and stop current flow to the motor. Once the heat dissipates, the switch will automatically close.

Solar Panel Sizing Exercise

System Load

1. Calculate the AC loads. If there are no AC loads, skip to second step. List all 120 VAC loads, wattage, and hours of use per day in the spaces below. Add up the figures in the W-h/day column to determine Total AC watt-hours per day.

Load Description	Watts	×	Hours/day	=	W-h/day
		×		=	
		×		=	
		×		=	
		×		=	
		×		=	
Total					

NOTE: Wattage of appliances can usually be determined from labels at the back of the appliance or from the owner's manual. If an appliance is rated in amps, multiply by volts to find watts.

2. Multiply total W-h/day by 1.15 to correct for inverter loss: ________________.
3. Inverter DC input voltage required (12 or 24 VDC): ________________.
4. Divide line 2 by line 3: ________________. This is the total amp-hours per day for AC loads.
5. List all DC loads, wattage, and hours of use per day in the spaces below. Add up figures in the W-h/day column to determine Total DC watt-hours per day.

Load Description	Watts	×	Hours/day	=	W-h/day
		×		=	
		×		=	
		×		=	
		×		=	
		×		=	
Total					

6. DC system voltage (usually 12 VDC): ________________.
7. Divide line 5 by line 6: ________________. This is total amp-hours per day for DC loads.
8. Total amp-hours per day for AC loads, from line 4, is ________________.
9. Add lines 7 and 8: ________________. This is the total amp-hours per day for all loads.

Solar Sizing

Complete this worksheet using the total amp-hours per day from the system load worksheet.

1. Total amp-hours used per day: ______________.
2. Multiply line 1 by 1.2 to correct for battery charging inefficiency: ______________.
3. Average peak sun hours per day in the area being designed for: ______________.

   Summertime use only, use 6 hr.

   Year-round use, use 4 to 5 hr.
4. Divide line 2 by 3. This is the total solar panel amps needed: ______________.
5. Peak amps of solar panel used: ______________.

   For 53 W panel, use 3.08.

   For 90 W panel, use 5.26.

   (Approximately 17 W per amp).
6. Divide line 4 by line 5: ______________.
7. Round off to next highest whole number: ______________. This is the number of panels necessary to be completely self-sufficient.

4-2 Review

1. What is the primary power source used in RVs?
2. List the two characteristics of direct current.

   A.

   B.
3. What is the most common type of wet cell battery used in RVs?
4. The type of battery used to power a flashlight is called a ________________.
5. A dry cell battery is actually dry.

   True False
6. List four advantages the gel-cell battery has over the liquid acid battery.

   A.

   B.

   C.

   D.
7. What is the major advantage of a deep-cycle battery?
8. Maintenance-free batteries are only available in automotive batteries.

   True False
9. Briefly describe the function of a power converter.
10. Match the following:

______	Isolator	A. External reset button
______	Diode	B. Prevents tow-vehicle battery discharge
______	Type III circuit breaker	C. Converts AC to DC

11. List the three types of power converters.

    A.

    B.

    C.
12. The power converter whose output will not vary when the input changes is called a ________________.
13. The power converter whose output will not vary when the input changes, and which provides such a dense and fast output that it seems solid to the connected load, is called a ________________.
14. The power converter whose output will vary when the input changes is called a ________________.
15. The ________________ is used to keep batteries charged and to provide necessary 12 VDC power when driving on the road.

16. List the four 12 VDC power sources that can be found on RVs.

    A.

    B.

    C.

    D.

17. Converter-only circuits work very well in RVs.

    True False

18. Use of a battery charger as a converter is not recommended because of high voltage.

    True False

19. Combination battery/converter circuits are the most common and versatile 12 VDC circuits in RVs.

    True False

20. Solar power can only be used for battery charging.

    True False

21. Devices used to help direct the flow of electricity in a circuit are called ________________.

22. Voltage drop is always present when current is passed through a diode.

    True False

23. Voltage drop has no affect on diagnosing an electrical system.

    True False

24. Solenoids/relays are used to open or close circuits.

    True False

25. Overcurrent protection devices can be replaced with ones rated with the same or a higher current rating.

    True False

26. Fuses are the only overcurrent protection devices authorized for use in RVs.

    True False

27. *Solid-state* is a term that pertains to circuits and components using semiconductors.

    True False

28. Light-emitting diodes (LEDs) and liquid-crystal displays (LCDs) are examples of semiconductors.

    True False

29. When installing or servicing low-voltage devices, it is necessary to determine the amperage of the device.

    True False

30. Determination of amperage can only be done using the device data plate or the device service manual.

    True False

31. The conductor and overcurrent protection must always be equal to or larger than the minimum load rating of the device.

    True False

32. Devices that convert electrical energy into rotary mechanical energy are called

    A. Converters

    B. Inverters

    C. Alternators

    D. Motors

Chapter
4-3 Maintaining 12 VDC Voltage System and Components

- Determine battery condition and charge.
- Identify charging circuits.
- Connect/size multiple batteries.
- Troubleshoot converters.
- Service dual-battery isolator.
- Identify various types of 12 VDC motors in RVs.
- Troubleshoot battery chargers/converters.
- Repair and/or replace 12 VDC motors.
- Identify components and describe operation.
- Identify different functions of monitor panels.

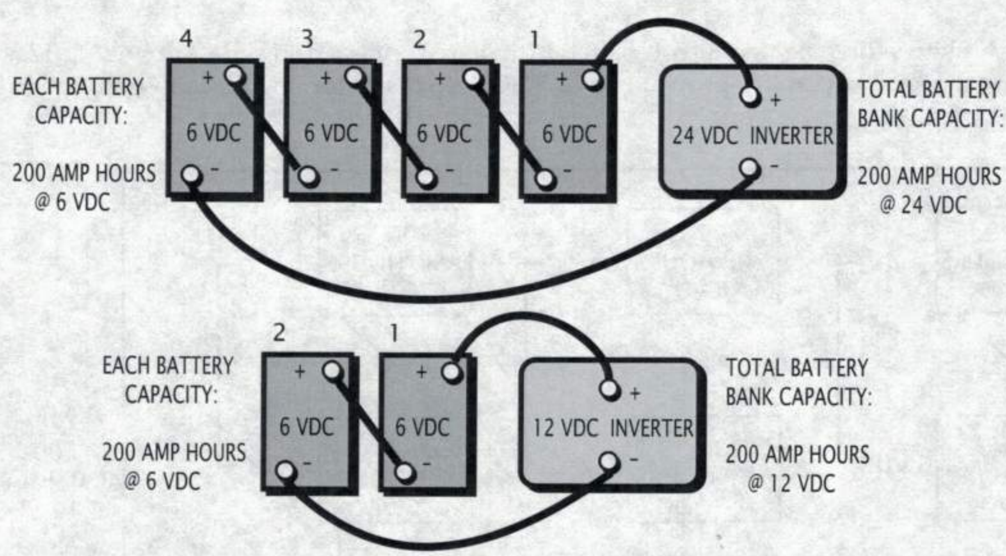
4-3.1 Combining Batteries

In many cases, there may be a need for more electrical energy than one battery can provide. The need may be for higher voltage or more current, and in some cases both. Under such conditions, it is necessary to combine, or interconnect, a sufficient number of batteries to meet the higher requirements. Batteries connected in series provide a higher voltage, while batteries connected in parallel provide a higher current capacity. To provide adequate power when both voltage and current requirements are greater than the capacity of one battery, a combination series-parallel network of batteries must be used.

4-3.1.1 Series-Connected Batteries

Figure 4-37 shows series connections for four 6 volt batteries. The four 6 volt batteries in series provide a total output voltage of 24 VDC. The negative terminal of the first battery is connected to the positive terminal of the second battery, the negative terminal of the second to the positive of the third, and so on. The positive terminal of the first battery and the negative terminal of the last battery in the group then serve as the terminals of the series combination resulting in a higher voltage output. The total voltage available across the combination of batteries is equal to the sum of the individual values of each battery. The current capacity of batteries in series is the same as for one because the same current flows through all the batteries.

Figure 4-37 Batteries Connected in Series

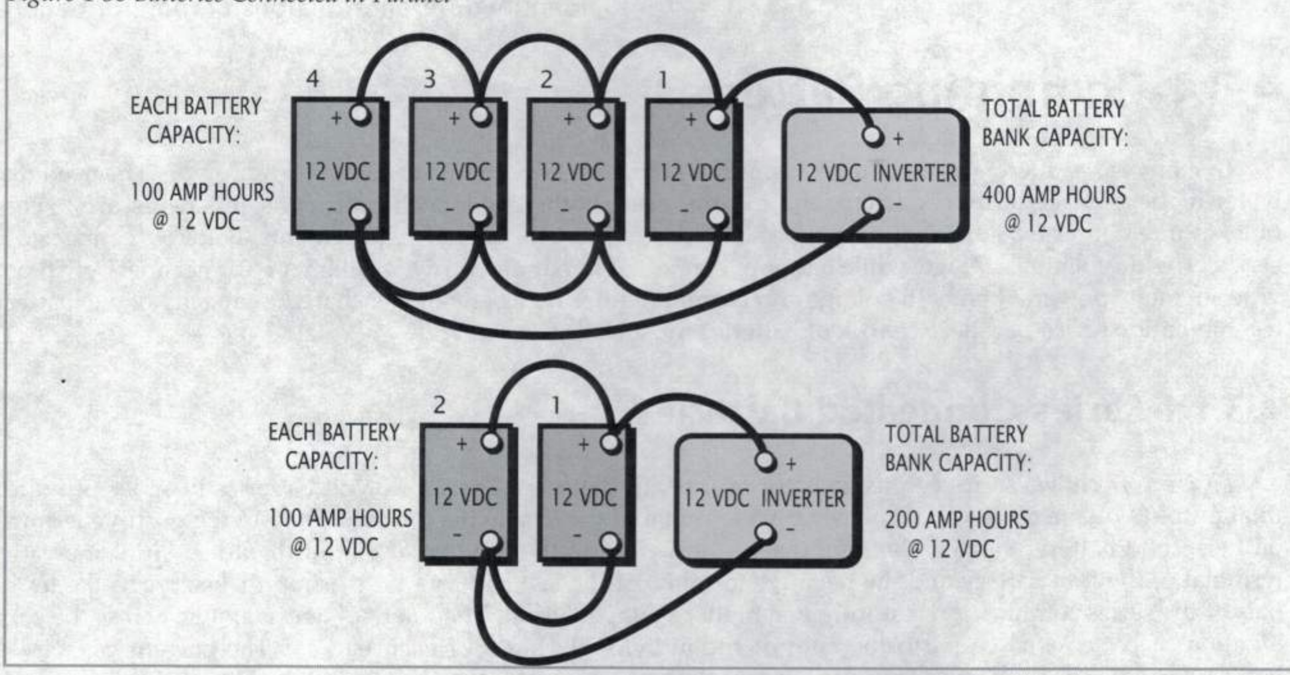


4-3.1.2 Parallel Connected Batteries

Figure 4-38 shows four 12-volt batteries connected in parallel, resulting in an increase in current storage (amp-hour) capacity. All the positive terminals are connected together, as are all the negative terminals. Any point on the positive side can be the plus terminal of the battery, and any point on the negative side can be the negative terminal, but cross-connecting the bank as shown is preferred. To balance the battery bank, connect the load positive to the positive post of battery #1 and the load negative to battery #4. The parallel connection is equivalent to increasing the size of the electrodes and the amount of electrolyte, which increases the current capacity. The voltage output of the four batteries, however, is the same as one 12-volt battery.

NOTE: It is important to remember that batteries connected in parallel must be the same voltages.

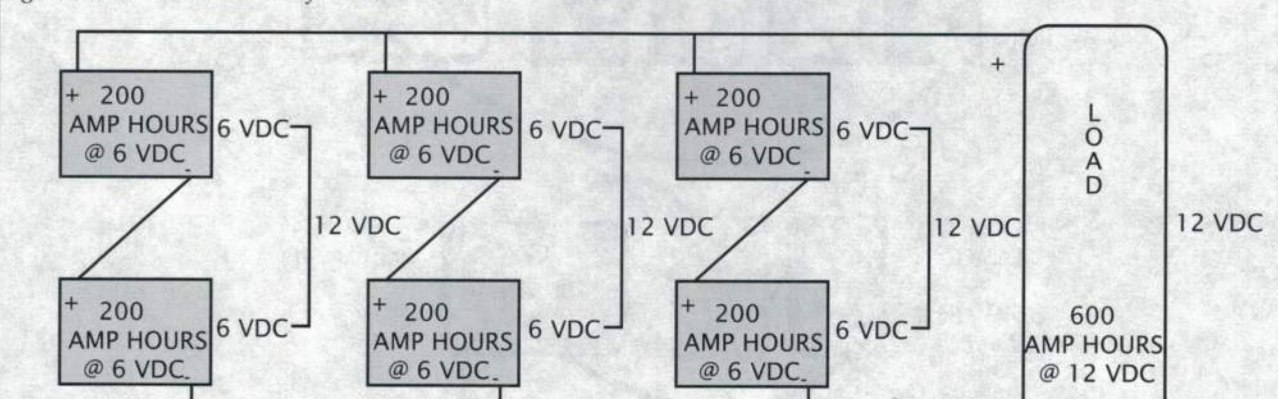
Figure 4-38 Batteries Connected in Parallel



4-3.1.3 Series-Parallel Connected Batteries

Figure 4-39 shows three pairs of 6-volt batteries that are connected in series, providing 12 VDC per pair. The pairs are connected in parallel, providing a 12 VDC output and tripling the amp-hour capacity.

Figure 4-39 Schematic View of Series-Parallel



3. Battery post and cable cleaner (wire brush)
4. Battery post clamp spreader
5. Cable clamp puller
6. Rubber gloves and apron
7. Hydrometer

To begin, always be sure the engine and all accessories are turned off. Then disconnect the cable from the negative terminal of the battery and perform these steps:

1. Check the rubber protectors on terminals.
2. Check the battery case for cracks or swelling.
3. Check the cable clamps for tightness.
4. Check the cables for cracked or damaged insulation and frayed cable ends.
5. If corrosion is present, remove the cable from its terminals and clean both the positive and negative terminals with a wire brush.
6. Reinstall the cables, positive first and then negative.
7. Check to see that the battery compartment is in good condition and the means of battery hold-down is tight.
8. Perform the specific gravity test to verify the condition of the cells.
9. Check the electrolyte level in each cell and add distilled water if low (unless it is a sealed battery).
10. If necessary, charge batteries as per manufacturer's charging procedures.

4-3.4.1 Specific Gravity

Measuring the specific gravity of the electrolyte checks the state of charge for a lead-acid cell. Specific gravity is a ratio comparing the weight of a substance with the weight of water. For instance, concentrated sulfuric acid is 1.835 times as heavy as water for the same volume and, therefore, its specific gravity is 1.835. The specific gravity of water is 1.0, and it serves as the reference. In a fully charged cell, the mixture of sulfuric acid and water results in a specific gravity of 1.265 at room temperatures of 80°F (27°C). As the cell discharges, less acid is present and more water is formed, lowering the specific gravity. When the specific gravity is down to about 1.120, the cell is completely discharged.

4-3.4.2 Specific Gravity Readings

Specific gravity readings are taken with a battery hydrometer, such as the one shown in *Figure 4-41*. When checking the specific gravity, hold the hydrometer vertically so the float is not rubbing against the side of the barrel. Draw an amount of electrolyte into the barrel so that, with the bulb fully expanded, the float will be lifted free. The float should not touch the side, top, or bottom stopper, and the surface of the liquid in the hydrometer chamber should be at eye level. Disregard the curvature of the liquid where the surface rises against the float stem and the hydrometer chamber due to surface tension.

Table 4-5 Hydrometer Readings

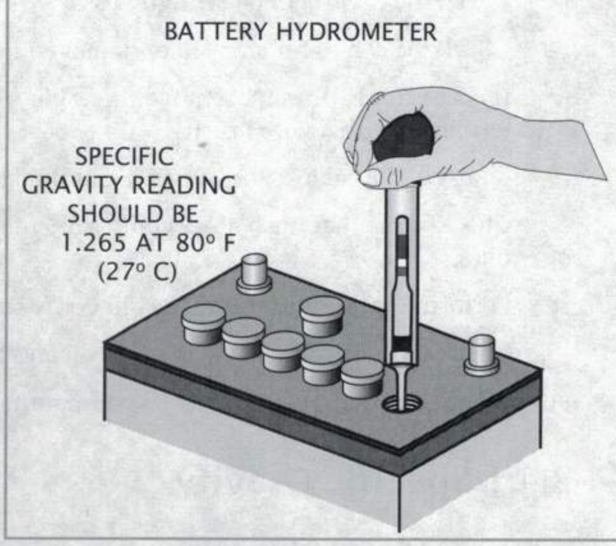
Hydrometer Reading	% Charged
1.265	100

Table 4-5 Hydrometer Readings

Hydrometer Reading	% Charged
1.225	75
1.190	50
1.155	25
1.120	0

Each cell of the battery should be checked. The readings for each cell should be approximately the same. If a reading of one or more cells is substantially lower than the other cells, it would be an indication that these cells are bad. Make sure the hydrometer is clean and does not have any cracks. Never take a hydrometer reading right after water has been added or immediately after a charge. A false indiction will occur. Let the electrolyte stabilize for about 20 minutes. Never add electrolyte to a battery after the initial service. The chemical balance will be off, and the battery won't perform correctly. When adding water, distilled water should be used. Any mineral content could affect the chemical reaction and add to sulfation. The specific gravity will change as the temperature changes. A temperature-compensated hydrometer needs to be used to ensure accuracy.

Figure 4-41 Battery Hydrometer



4-3.4.3 Charging Batteries

It should be remembered that adding the active ingredient (such as sulfuric acid or potassium hydroxide) to the electrolyte of a discharged battery does not recharge the battery. Adding the active ingredient only increases the specific gravity of the electrolyte. It does not convert the plates back to active material or bring the battery back to a charged condition. A charging current must be passed through the battery to recharge it.

The service area where the battery is being charged should be well ventilated. Do not put a battery on charge unless safety goggles and a face shield are being used. It must be assumed that explosive mixtures of hydrogen gas are present within the battery cells at all times. Even a battery standing idle generates small quantities of hydrogen due to the self-discharge action. This gas collects in the cells and can be exploded by a torch, match flame, lighted cigarette, sparks from a loose connection, or metal tools making contact between the terminals or the ungrounded terminal and adjacent metal parts that are grounded. Never expose batteries to these sources of ignition.

It is recommended that the battery vent caps be left in place during charging. Vent cap removal increases the possibility of battery explosion by an external spark. Always wear eye protection when working with batteries.

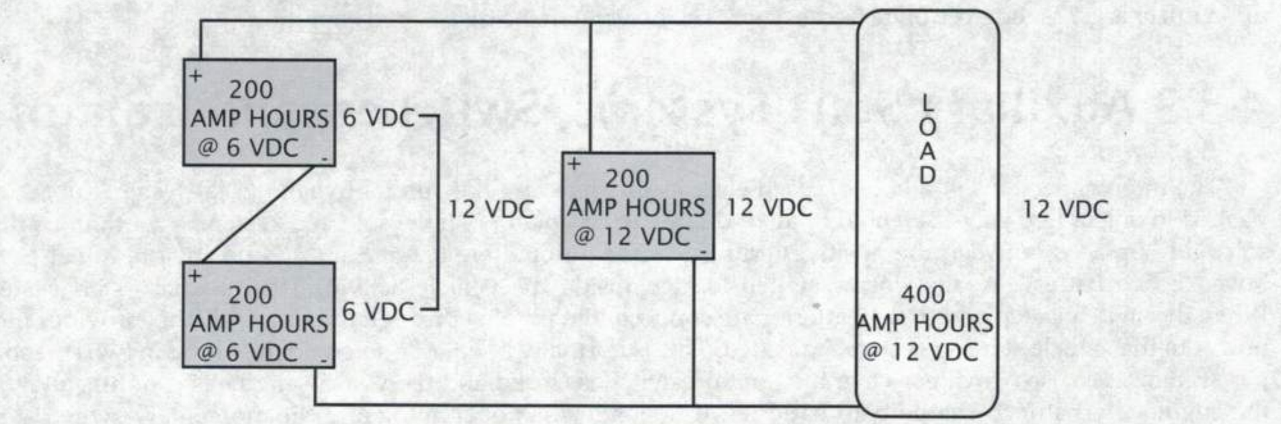
Charge a battery only when the step-by-step procedures are familiar. Follow the manufacturer's instructions on the charger. When possible, use chargers with alternator or polarity protection that prevents charging a battery in reverse. The charge a battery receives is equal to the charge rate in amperes multiplied by the time in hours. To fully charge a battery, the amp-hour or amp-minutes removed from it must be replaced, plus an additional 20 percent charge. This is due to the fact that batteries are not 100 percent efficient on recharging.

Turn the charge rate switch and timer to the OFF position before connecting the leads to the battery. Next, connect the charger leads to the battery terminals, red positive (+) lead to the positive terminal and the black

Figure 4-40 shows a pair of 6-volt batteries that are connected in series, doubling the output voltage to 12 VDC. This is then connected in parallel with the 12-volt battery. This setup will provide 12 VDC output and increase the amp-hour (A-h) capacity.

NOTE: It is not recommended to mix battery sizes in a bank. The example herein is to illustrate how series-parallel battery bank voltages can be derived.

Figure 4-40 Schematic View of Series-Parallel



NOTE: Cables and connectors between batteries in series or parallel need to be rated equal to or greater than the battery supply conductors.

4-3.2 Battery Sizing

When replacing a battery, the replacement battery should equal or exceed the electrical size of the battery installed by the manufacturer. Replacing the original with one smaller in capacity may result in poor performance and shorter life. A replacement battery with more amp-hours than the original battery will give longer service. It may even become necessary to combine batteries to meet higher requirements. When replacing batteries in a group, it is recommended that all the batteries be replaced at the same time. If one battery is weaker than the rest, the others will be affected in terms of output.

Make certain the battery or combination of batteries is compatible with the hold-down devices and fits in the compartment with the necessary clearances. Be sure to examine the cables, making certain they are the correct size to handle the larger currents if the battery was upgraded. Be sure the insulation is intact and the terminal and its bolt are not corroded. Also check to be sure all cables are fastened securely, are protected by grommets when routed through bulkheads, and are not exposed to any heat source that could potentially damage the insulation.

4-3.2.1 Deep-Cycle Battery Capacity

Deep-cycle batteries are generally rated in terms of how much discharge current they can supply for a specified period of time. The output voltage must be maintained above a minimum level, which is approximately 1.5 to 1.8 volts per cell. A common rating for deep-cycle batteries is ampere-hours based on a specific amount of current for a specific time, typically 20 hours. Typical values for deep-cycle batteries are 100 to 300 amp-hours. As an example, a 200 A-h battery can supply 10 A over a 20 hour period at 72°F (22°C). The battery can supply less current for a longer time or more current for a shorter time.

4-3.2.2 Primary Mover Engine Starting Battery Capacity

Automotive starting batteries will be rated for cold cranking amps (CCA), which is related to the function of starting the primary mover engine. A typical rating is 450 A for 30 seconds at a temperature of 0°F (–18°C). Higher temperatures increase the chemical reaction, but operation above 110°F (43°C) shortens the battery life. Low temperature reduces the current capacity and voltage output. The amp-hour capacity is reduced approximately 0.75 percent for each decrease of 1°F below normal temperature ratings. At 0°F (–18°C), the available output is only 60 percent of the battery rating at 77°F (25°C). In cold weather, it is very important to have all batteries up to full charge, as the electrolyte freezes more easily when in the discharged condition.

4-3.3 Auxiliary Start Systems, Switches, and Isolators

The interconnections of a house/coach electrical system and the automotive electrical system are accomplished in one of two ways: solenoid relay or dual-battery isolators. In the solenoid system, a continuous-duty solenoid is placed between the positive terminal of the automotive battery and the positive terminal of the house/coach battery. A momentary switch located inside the vehicle activates the auxiliary start system. When the switch is depressed, the batteries are connected in parallel through the solenoid. This provides more power to the vehicle starting system, if needed. This is normally a separate solenoid, resulting in two solenoids per system. It is also activated when the ignition switch is closed and the vehicle engine is running, allowing the engine alternator to charge both batteries. If the engine is not running and the momentary switch is not depressed, the solenoid is in the deactivated position, preventing the house/coach system from draining the automotive battery. Pressing the momentary switch or turning on the ignition switch and listening for a clicking sound at the solenoid can help diagnose the system. If no clicking is heard, check for a voltage reading at the coil terminals of the solenoid. If voltage is present, the solenoid is defective. If not, the circuit wiring must be checked. When the solenoid is activated, also check the voltage at the line and load side to be sure they are the same. However, a minor voltage drop is common.

The dual-battery isolator is a circuit consisting of a diode pack that will allow the current from the alternator to charge the house/coach and automotive batteries together when the vehicle engine is running. When the engine is not running, the diode action blocks the current flow from the automotive battery, preventing the house/coach system from draining the automotive battery. When an isolator is in the circuit, the voltage regulator must connect to a battery for the ignition to work properly. Reading the diodes with an ohmmeter can check the isolator circuit (see *"Diodes" on page 4-26*). They should read high resistance one way and low resistance the other.

NOTE: A dual-battery isolator should not be added to an RV with a one-wire alternator. The isolator has a 1V drop that prevents proper operation.

4-3.4 Battery Troubleshooting and Maintenance

The following information concerns the maintenance and inspection of batteries and is of a general nature. The appropriate manufacturer's manuals for the type of battery or battery group being used must be checked for specifications prior to performing maintenance. When checking or servicing batteries, certain precautions must be followed. Hydrogen gas, which is highly flammable, is always present in the battery cells, so keep all flames and sparks away from it. The electrolyte inside the battery is actually diluted sulfuric acid, which will cause injury if splashed on skin or in eyes. It will also ruin clothes and painted surfaces.

NOTE: Disconnect the grounded terminal first and reconnect the grounded terminal last.

There are several tools and materials required when performing battery maintenance and checks:

1. Face shield
2. Baking soda and water (to neutralize acid)

negative (–) lead to the negative terminal. "Rock" the charger lead clamps to make certain a good connection has been made. Now turn on the charger and slowly increase the charging rate until the desired ampere value is reached. Do not charge in the red zone. If smoke or dense vapor comes from the battery, shut off the charger and reject the battery. If gasses of electrolyte gassing or boiling occurs, reduce or temporarily halt the charging. Never touch the charger leads when the charger is ON. This could break a connection at the battery terminal, creating a spark, which could ignite the explosive gases in the battery. Never break a "live" circuit at the battery terminals for the same reason. Always turn the charger OFF before removing a charger lead from the battery.

When charging or testing a side terminal battery out of the compartment, always use the side terminal charging and testing posts that have been designed for this purpose.

Follow the manufacturer's battery charging guide if available. If not available, the charging guide in *Table 4-6*, showing the recommended rate and time for a fully discharged battery, may be used.

Table 4-6 Charging Guide

Rated Battery Capacity (Reserve Minutes)	Slow Charge	Fast Charge
80 minutes or less	15 hr @ 3 A	2.5 hr @ 20 A 1.5 hr @ 30 A
Above 80 to 125 minutes	21 hr @ 4 A	3.75 hr @ 20 A 1.5 hr @ 50 A
.Above 125 to 170 minutes	22 hr @ 5 A	5 hr @ 20 A 2 hr @ 50 A
Above 170 to 250 minutes	23 hr @ 6 A	7.5 hr @ 20 A 3 hr @ 50 A
Above 250 minutes	24 hr @ 10 A	6 hr @ 40 A 4 hr @ 60 A

A fully charged lead-acid battery will show 12.65 VDC when checked with a voltmeter. A gel cell battery will be slightly higher at 13.0 VDC.

4-3.4.4 Overcharging the Battery

Overcharging a battery can raise internal battery temperatures, causing the water to boil until the battery is damaged. One indication of an overcharged battery is blackened plates. Needing to frequently add water to a battery also indicates over charging. If battery charging continues once the battery is fully charged, the current can no longer convert the lead sulfate and instead decomposes the water, releasing hydrogen and oxygen. This condition is called "gassing," a process causing explosive hydrogen gas to be produced by the battery. Extreme caution should be exercised if this condition exists.

4-3.5 Troubleshooting the Starting Motor Circuit

If the starter cranks the engine slowly or not at all, several preliminary checks can be made to determine whether the trouble lies in the battery, in the starter, in the wiring between them, or elsewhere. To make a quick check of the starter system, turn on the headlights. They should operate with normal brilliance. If they do not, the battery may be run down, and it should be checked. If the battery is in a charged condition so the headlights burn brightly, operate the starting motor. Any one of three things will happen to the headlights:

1. The headlights will go out.
2. The headlights will dim considerably.
3. The headlights will stay bright without any cranking action taking place.

If the headlights go out, this typically indicates there is a poor connection between the battery and the starter. Inspect the battery cables and connections. In most cases, the poor connection is found at the battery terminals. If so, remove, clean, and tighten the terminal connections.

If the headlights dim considerably, this typically indicates that something is imposing a high discharge rate on the battery. Check the battery with a hydrometer. If it is not charged, charge the battery and retest. If it is charged, the trouble probably lies in either the engine or the starter motor itself.

If the headlights stay bright without any cranking action, it typically indicates an open circuit at some point—either in the starter itself, the starter switch, or control circuit. The circuit and control units must be checked to locate the problem.

4-3.6 Troubleshooting Converters

Converters are fairly trouble free and, in most cases, performing a visual inspection of fuses, connectors, loose terminals, and so forth will locate most problems. If converter operation is questionable, the following procedures may help.

4-3.6.1 Linear (Converter Output)

1. Pull all the DC fuses from distribution panel.
2. Power up the converter (connect shore power).
3. Measure the AC voltage—it should be above 103.5 VAC.
4. Measure the DC voltage at the converter—it should be above 12 VDC.
5. If the voltages are correct, the converter is functioning correctly.

4-3.6.2 Linear (Charging Section)

1. Pull all the circuit fuses, including the accessory fuses, if any.
2. Install a fully charged and known-good battery into the coach.
3. Power up the converter (connect the shore power).
4. Measure the AC voltage—it should be above 103.5 VAC.
5. Measure the DC voltage at the battery—it should be above 12.65 VDC.
6. Disconnect the AC to the converter (unplug the shore power).
7. Measure the DC voltage at the battery—it should be 12.65 VDC.
8. If the voltages are correct, the charging section is functioning correctly.

4-3.6.3 Ferroresonant

1. Pull all the DC circuit fuses from the distribution panel.
2. Power up the converter (connect the shore power).
3. Make sure a fully charged and tested battery is installed in the coach.
4. Measure the DC voltage at the converter—it should be above 13.4 VDC.
5. If the voltages are correct, the converter is functioning correctly.

4-3.6.4 Electronic

1. Pull all the DC fuses from the distribution panel (unwire the converter from the coach).
2. Disconnect the batteries(s) and isolate the terminals.
3. Power up the converter (connect the shore power).
4. Measure the DC voltage at the converter—it should be above 13.2 VDC.
5. If the voltage is correct, the converter should be OK.

NOTE: These are very general tips concerning the operation of converters used in recreation vehicles. Please refer to all the manufacturer's instructions for the specific troubleshooting instructions.

If additional testing is required, refer to the individual manufacturer's manual for more detailed troubleshooting procedures, schematics, and pictorial views.

4-3.7 Troubleshooting Solar Cells

Troubleshooting solar cells is also limited to a visual inspection of connectors, open solar cells, loose terminals, and so on. If additional testing is required, refer to the individual manufacturer's manual for more detailed troubleshooting procedures, schematics, and pictorial views.

4-3.8 Troubleshooting Alternator/Charger Systems

The charging system does not ordinarily require periodic maintenance. However, the drive belt, battery, wires, cables, and all connections should be inspected at intervals outlined by the chassis manufacturer. Be very careful when working around the charging system and note the following general rules:

1. When reconnecting cables or wires from the battery to the alternator, always connect positive to positive and negative to negative.
2. Disconnect wires from the battery and the alternator before using arc welding equipment to make repairs on an RV.
3. Always disconnect both battery leads before using a battery charger.
4. Always observe safety rules when working with batteries.
   (Check the manufacturer's manual for more detailed safety tips.)

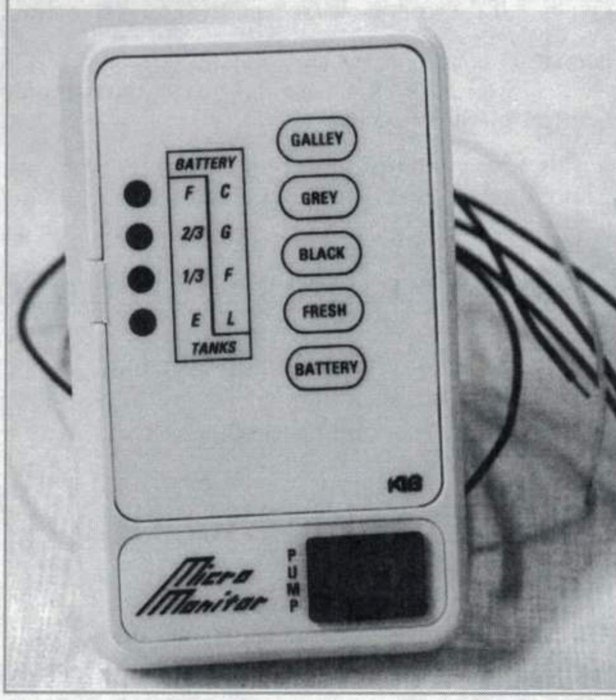
If a malfunction occurs in the charging circuit, do not immediately assume that the alternator is causing the problem. Be sure to check the following items first:

1. Make sure the battery cable connections are clean and tight.

2. Check the battery electrolyte specific gravity. If it is low, charge the battery.
3. Check the alternator wiring and connections.
4. Check the drive belt condition and tension (see manufacturer's specifications).
5. Check the alternator mounting bolts for tightness.
6. Run the engine and check the alternator for abnormal noise.
7. Using a voltmeter, check the battery voltage with the engine off. It should be approximately 12.65 VDC.
8. Start the engine and check the battery voltage again. The battery voltage should now be approximately 13.5 to 14.5 VDC. Temperature-compensated alternators could give variable output.
9. If the voltage is less or more than the specified charging voltage, the regulator could be at fault.
10. If the problem still exists or if the system has an internal regulator, the alternator should be removed and bench checked or replaced.

4-3.9 Monitor Panels

Figure 4-42 Monitor Panel Example



Monitor panels (see *Figure* 4-42) monitor propane, water, and waste levels as well as battery condition. They are also very convenient for controlling water pumps and water heaters. They are complex in construction and wiring. Any attempt to service the monitor panel other than a visual inspection without a manufacturer's service manual, is not recommended. For information on individual monitor panels, consult the component manual.

4-3.9.1 Propane (LPG) Level Switch

This switch will enable the level of the propane container to be read. When this switch is depressed and held upward, the amount of the propane in the container will be shown as red lights under the corresponding level indication. The lights will illuminate from "E" up to the highest level in the container. If the container is full, then all five of the lights (E, 1/4, 1/2, 3/4, and F) will be on. If the container is only half full, then only the E, 1/4, and 1/2 lights will be on. After taking the level reading of the container, release the switch. The input for the propane level indicator comes from a remote sender that is attached to the liquid level gauge on a container. The device has a float inside the container that tracks the liquid propane level and provides a corresponding electrical signal to the monitor panel. More information can be found in the *RV Propane Systems* textbook.

4-3.9.2 Water (Fresh) Level Switch

This switch will enable the level of freshwater in the freshwater storage tank to be read. When the switch is depressed, the amount of freshwater will be displayed. The level lights will be shown and operate in the same manner as the level lights described in the propane level switch instructions. After taking the level reading of the storage tank, release the switch.

4-3.9.3 Holding Tank (Grey or Black) Level Switch

This switch will enable the level in either holding tank (grey or black) to be read. If depressed and held down, it will show the level of holding tank. The amount of liquid in the tank being checked will be shown on the same lights and operate in the same manner as described in the propane level switch instructions. After the level reading of the desired tank has been obtained, release the switch.

4-3.9.4 Water Pump Switch

This switch is used to turn on or turn off the water pump system. When the switch is turned on ("closed"), a red indicator light will come on, indicating that the water pump has been turned on and will be able to operate. When the switch is turned off ("open"), the indicator light will go off, and the water pump will not operate.

4-3.9.5 Water Heater Switch

This switch will turn the water heater on when it is depressed. When the water heater is igniting, the red light on the panel will flash on. After the water heater is on and working, the light will go off until the water cools and calls for more heat. The red light will again flash on during ignition and go off after full ignition. If the red light remains on, the water heater is in the lockout mode. This means that ignition did not take place, and the red light will remain on until the switch is turned off. Wait 30 seconds and repeat the starting process. Leave the switch in the ON position as long as hot water is desired.

4-3.9.6 Range Hood Light Switch

This switch will turn the light in the range hood on or off. To turn the light on, press the switch upward. To turn off, press the switch down. Some monitor panels have an additional switch to control the hood vent fan.

4-3.10 Maintenance and Repair of Motors

Many motors in the RV are 12 VDC powered. These motors generally fall into two groups: permanent magnet and wound field. They all have armatures with windings on them, commutators, and brushes. The most common problems with DC motors are bad bearings and worn brushes. Defective commutators and burned or broken wires are other possibilities.

When a motor does not operate properly or is erratic (speed varies), visually inspect the brushes and commutator through the end of the motor while it is running. If there is excessive arcing, the motor must be disassembled and examined. If the motor does not run, try turning it by hand with the power on. If it starts or jerks, the possibility exists that there is a bad section on the armature.

If the above preliminary checks do not correct the problem, it is time to disassemble or replace the motor. If the brushes can be removed externally, take them out and examine them before disassembling the motor. If the brushes are smooth and not less than 3/8 in. long, they are probably OK. If they are defective, replace them and retry the motor. If this is not successful, the motor will need to be taken apart. Scribe a line across the length of the motor housing. This will help when reassembling the motor. When reassembling, align the scribed mark on the motor housing to be sure the parts are in proper alignment. While performing this operation, be careful not to break wires or brushes.

Once apart, check the bearings for wear and pitting. Then examine the brushes (if not already replaced). If the brushes are smooth and not less than 3/8 in. long, they are probably satisfactory. Next, examine the armature for bad commutator sections or burned wires. Either one of these conditions will require replacing the motor. If the results of the visual inspection are satisfactory, take resistance readings between the segments of the commutator. If there is a noticeable difference found between the segments, look for broken wires where they attach to the segments. Place the multimeter probes on the wires attaching to each end of the segment. If a broken wire is found, soldering will eliminate the problem in most cases. There are times when the springs on the brushes lose their tension, and the brushes will arc. Usually, cleaning the commutator and replacing the brushes and springs will correct this situation.

How much time is spent checking a defective motor depends on the situation. The cost of the motor, the availability of parts, the results of the visual inspection, and customer desires will all play an important role.

Refer to appropriate service manuals for specific repair instructions.

4-3.11 Expandable Room Systems

Some expandable room systems are composed of many 12 VDC components such as switches, relays, motors, current limiters, overcurrent protectors, and alarms. If the expandable room is inoperable, check the battery, overcurrent protection devices, and grounds. Refer to the appropriate service manuals for specific repair instructions.

4-3.12 Electric Step System

The components used in an electric step system circuit include the 12-volt chassis battery, ignition switch, fuse or circuit breakers, kill (power) switch, door sensor or switch, and the step itself. For specific service and repair instructions, always refer to appropriate service manuals.

If a step is inoperable, first check the battery to see if it is properly charged. Next, check the grounds for good electrical contact, check the tightness of the connection(s), and ensure that the connections are free of corrosion. Check the circuit breakers or fuses to see if they are tripped or blown.

NOTE: There are typically three fuses or circuit breakers required by the step: main power, power switch, and ignition.

Once it has been determined that the circuit breakers or fuses are OK, check the vehicle wiring using a voltmeter at the vehicle-to-step four-way plug. The red power wire should have 12 VDC at all times.

NOTE: The vehicle may have a battery disconnect switch and this switch must be on.

The power switch wire should have 12 VDC when ON and 0V when OFF. If it does not, check the switch, switch connections, and wiring. The ignition wire should have 12 VDC with the ignition ON and 0V when the ignition is OFF. If it does not, check the ignition source, connections, and wiring. The door switch and wiring must be checked with an ohmmeter. The ohmmeter should show either "0" or "×" when the door is open. It should read the opposite when the door is closed. The initial reading will depend on whether the switch is normally open or normally closed. Check all connections including the connection to ground.

4-3.13 RV Alarm Systems

Alarm systems for RVs use either a siren or an auto horn, or they transmit a signal to a beeper when in the alarm mode. Methods to trigger the alarm include door switches, window switches, voltage sensors (trigger when current is drawn from the battery), pressure-sensitive floor mats, infrared detectors, and vibration sensors. With all the equipment available, almost any degree of security can be attained.

Most alarm systems use a closed-loop system with both an instant loop and a delayed loop. A *closed loop* means the alarm circuit with the trigger sensors is closed when the alarm is active. Triggering any sensor will open the circuit, setting off the alarm. On the instant loop, the triggering of a sensor will immediately set off the alarm. On the delayed loop, a period of time is provided between the triggering of a sensor and the setting off of the alarm. Some alarm systems will arm when set and the door is closed; others will arm with an infrared or UHF transmitter. Make sure the system used has an auto reset system that will shut off the alarm and rearm itself after 10 to 15 minutes.

Also, when mounting the module and horn, make sure the wires cannot be disconnected from the battery or unit without setting it off. Installation procedures for alarm systems, in terms of routing wires and drilling holes, are similar.

4-3.14 12 VDC Lighting

Maintenance and repair of most 12 VDC light fixtures is limited to the replacement of lamps or switches. Repair of the fixture is not practical. In most cases, the fixture will have to be replaced.

When working with 12 VDC fluorescent fixtures, repair techniques will have to be evaluated. For example, fluorescent lights typically use an inverter circuit to produce the AC voltage required for operation. Servicing these light fixtures may include lamp and/or ballast replacement. If attempting to repair a fluorescent light fixture, follow the light fixture manufacturer's service instructions. Generally, if the light fixture has problems beyond the need to replace a bulb, it is economically better for the customer to have the light replaced.

Causes of ballast overheating:

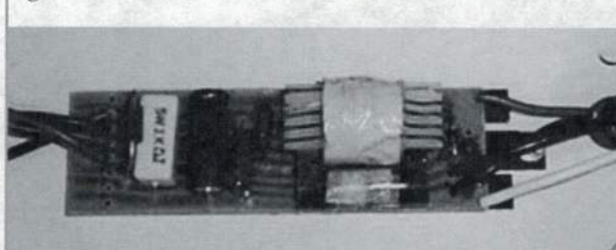
1. Misapplication
   - Incorrect lamp size or type
   - Incorrect number of lamps
   - Incorrect supply voltage
2. Abnormal conditions
   - Dead or burned-out lamp
   - Rectifying lamp (nearing end of lamp life, blackened ends)
   - Excessive ambient heat
3. Fixture design
   - Improper design resulting in inadequate dissipation of heat from the ballast and lamp
4. Other possible causes
   - Incorrect wiring—use of too small wire gauge for the circuit
   - Excessive line voltage fluctuation
   - High or low operating voltage
   - Use of improper lamps
   - Lamps improperly installed in lamp holders
   - Light fixture surrounded by heavy insulation ceiling of low heat conductivity

To prevent damage to the ballast and fixture from overheating, and to maintain proper light output, simple precautionary measures can be taken to ensure long, trouble-free ballast life.

Most fluorescent ballasts and lamps are designed for optimum performance (starting dependability and light output) at an ambient temperature of 77°F (25°C).

All ballasts have a limitation as to their ability to start lamps at a low ambient temperature.

Figure 4-43 Ballast



Although a ballast may start a lamp reliably, in low temperatures, light output will be reduced until the lamp wall temperature reaches 100°F (38°C) to 120°F (49°C). This temperature will be reached when bare lamps are exposed to still air of 70°F (21°C) to 80°F (27°C). Drafts and moving cold air may cause the lamp to flicker. To avoid this problem, the use of enclosed fixtures is recommended. In this way, heat generated by the lamp is confined within the enclosure, thus raising the lamp temperature to a level that will maintain proper light output. Bear in mind that excessive lamp shielding may cause lamp and ballast overheating in the summertime.

NOTE: Ballast should be protected from weather, moisture, and other abnormal atmospheric conditions.

Subjecting a ballast to excessive voltage for an extended period of time results in deterioration of the insulation. This insulation breakdown will cause early ballast failure.

Low voltage has a damaging effect on the ballast. The lamp may not start with the desired reliability, and early lamp failure could result. This can cause early ballast failure.

Fluorescent tubes are not designed for dimming. Dimming produces the same effect as low voltage. It will cause premature lamp failure, which will cause premature ballast failure. Fluorescent tubes are not designed to be turned on and off frequently. When turned on, they should be left on at least long enough for the bulb's wall temperature to reach 100°F (38°C) to 120°F (49°C) to allow all of the gases to heat. Otherwise, the gases collect at one end of the lamp, causing the lamp to fail prematurely.

NOTE: Don't leave faulty lamps in a light fixture. This can cause ballast failure prematurely.

4-3.14.1 Installing 12 VDC Lighting Fixtures

When installing light fixtures, there are many choices of types and sizes. If the old light fixture is to be replaced, the one chosen must fit the old space and operate on the power available at that location. When talking to the RV owners, show them the possible fixtures and discuss the illumination required at that location. If the light fixture is to be located where there was no light before, find the nearest 12 VDC circuit that is not connected to the engine battery or engine circuits. Then determine if that circuit has enough reserve capacity to handle the new fixture. Once a source has been found, a route to get wires to the new location must be determined. On fiberglass-insulated units, the wires can be snaked through the fiberglass. When working on styrofoam units, a pointed 3/4 in. rod will make the required hole. A little heat applied to the rod may help in some situations. Most cabinets have false bottoms where wires can be hidden.

Once wires have been routed to the new location, all that is left to do is mount the fixture. When mounting to wood or metal, sheet metal screws work best. However, make certain they are not too long and that there are no wires at the screw locations. When mounting fixtures on ceilings, extreme care must be taken not to puncture the roof. If the mounting surface is 1/8 in. material bonded on styrofoam, it may be necessary to use expanding anchors to get sufficient holding power.

4-3 Review

1. Batteries are connected in series to provide higher ________________.
2. Batteries are connected in parallel to provide higher ________________.
3. When four 6-volt, 200 A batteries are connected in series, the output is ________________.
   A. 6-volt, 200 A
   B. 24-volt, 200 A
   C. 6-volt, 800 A
   D. 24-volt, 800 A
4. When four 6-volt, 200 A batteries are connected in parallel, the output is ________________.
   A. 6-volt, 200 A
   B. 24-volt, 200 A
   C. 6-volt, 800 A
   D. 24-volt, 800 A
5. When two 6-volt, 200 A batteries are connected in series with one 12-volt, 200 A battery in parallel, the output is ________________.
   A. 12-volt, 200 A
   B. 12-volt, 400 A
   C. 24-volt, 600 A
   D. 24-volt, 800 A
6. When connecting batteries in series, connect the positive terminal to positive terminal and negative terminal to negative terminal.

   True False
7. List the two ways that an RV coach electrical system and the vehicle electrical system can be interconnected.
   A.
   B.
8. A 200 A-h rated deep-cycle battery can supply 10 A for ________________ hr at 72°F (22°C).
   A. 5
   B. 10
   C. 20
   D. 40
9. When working on a battery, always disconnect the negative first and reconnect the negative first.

   True False
10. Face shield, rubber gloves, and aprons should always be worn when working with batteries.

    True False
11. Highly flammable hydrogen gas is present in battery cells.

    True False
12. Electrolyte is not a safety hazard, because it is diluted with water.

True False

13. In a fully charged lead-acid cell, the specific gravity of the electrolyte at 70°F (21°C) to 80°F (27°C) is 1.265. A fully discharged cell at the same temperature will have a specific gravity of ______________.

   A. 1.45

   B. 1.11

   C. 1.15

   D. 1.22

14. Never take a hydrometer reading immediately after adding water or charging a battery.

   True False

15. The process that causes explosive hydrogen gas to be produced by the battery is called

   A. Boiling

   B. Dehydration

   C. Evaporation

   D. Gassing

Chapter

4-4 AC Electrical Systems

- Identify 120 VAC components and describe operation.
- Service the 120 VAC systems (including distribution panelboard, circuit breakers, and power supply cord components).
- Test 120 VAC breakers, GFCI, switches, cords, and outlets.
- Check and troubleshoot the fuse or breaker panels.
- Perform wire maintenance (including soldering, terminal types, crimping, etc.).

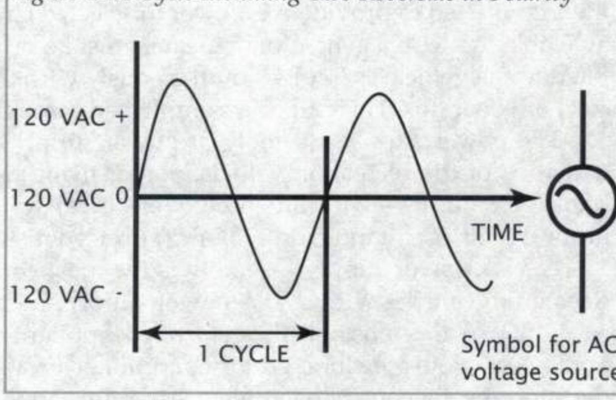
4-4.1 Introduction and Overview

Even though the RV is a vehicle, it has a 120 VAC system similar to that found in homes. The need for 120 VAC in the RV exists because some of the appliances used in the RV (such as air conditioners and microwave ovens) consume large amounts of power and would require a very large conductor and have too much line loss (voltage drop) even if enough battery power to run them were provided. Remember that it takes approximately ten times more current to run a device on 12 VDC than it does on 120 VAC.

The current North American power standard is 120 VAC 60 Hz, defined in the National Electric Code (NEC) as "a nominal value assigned to a circuit or system for the purpose of conveniently designating its voltage class."

The DC chapter of this textbook states that current flows in the same direction at all times. Alternating current (AC), however, reverses in polarity and amplitude periodically with time. *Figure 4-44* shows one cycle that includes two reversals in polarity. The number of cycles per second is the frequency whose unit is the hertz (Hz). One hertz is equal to one cycle per second. The AC power line frequency is standardized at 60 Hz (60 complete cycles in one second).

Figure 4-44 Cycle Including Two Reversals in Polarity



For an AC voltage:

- The voltage reverses polarity at a specific rate. Consider one terminal of the AC source positive at a given time, with respect to the other terminal. A little later in time, the positive terminal will become negative to reverse the polarity of the AC output voltage. The polarity reversals are continuously repeated at a regular rate.
- For either polarity, the AC voltage varies in amplitude.

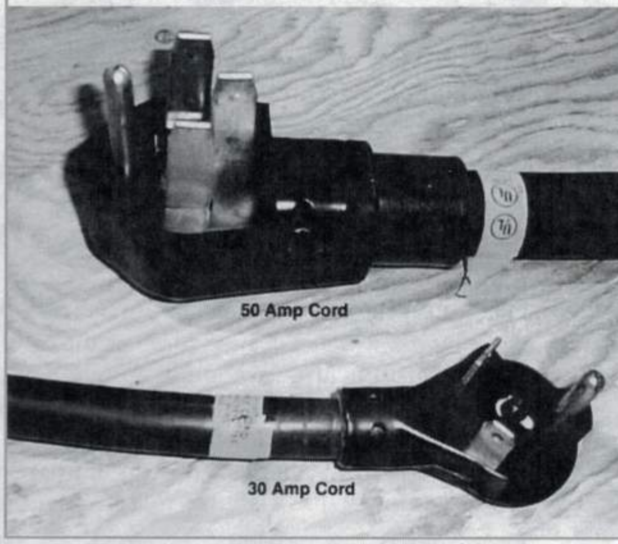
The resulting alternating current that results has the following features:

- The current reverses in direction with the polarity reversal in voltage.
- The amplitude of the current varies with the changing values in voltage.

Ohm's law calculations apply to both AC and DC series and parallel circuits. However, a new factor to consider with an AC source is that voltage alternately reverses in polarity to produce current that reverses in direction. Most important is the fact that, between the polarity reversals, the voltage and current values are changing in amplitude instead of remaining at a steady value. This effect is not important for resistance in a circuit, but the change in amplitude of voltage or current form the basis for many practical applications of inductance and capacitance.

4-4.2 Power Sources

Figure 4-45 Power Supply Cords 50 Amp/30 Amp



Recreation vehicles are provided with different size 120 VAC electrical systems, depending on their power demands. There are three different ways that AC power is commonly provided to the RV. The first is through the use of a power supply cord (commonly called a *shore cord*), as shown in *Figure 4-45*, that is plugged into an outside source when the RV is parked. The second way of powering the RV's 120 VAC electrical system is with an on-board generator that is listed for RV use. Generators are provided to allow a means of using the 120 VAC circuits on the RV when the RV is not plugged in. Typically, the same 120 VAC branch circuits powered by the power supply cord are also powered by the generator. In some cases, there may be additional circuits powered by the generator that are not powered by the power supply cord. A means must be provided so that these two different power sources cannot supply current to the same circuits at the same time. The third common method of providing AC power is through the use of an inverter. Inverters take DC current supplied by batteries and change it into 120 VAC power. The RV inverter is used to provide AC power to selected circuits when an outside source or generator AC power is not available. As with a generator, a means must be provided so that the inverter 120 VAC current cannot be supplied to the vehicle's circuits simultaneously with that from any other power source such as the power supply cord or generator. This can be accomplished through the use of a transfer switch or relay.

The power supply assembly or power supply cord provided with an RV is sized to match the electrical demands of the recreation vehicle. Some smaller RVs have a 15 A power supply cord with one single 15 A branch circuit. RVs with this type of electrical system are required by the *National Electrical Code* to provide ground fault circuit interrupter (GFCI) protection at the distribution panel.

A 30 A power supply assembly is the most common size power supply cord used in recreation vehicles. Recreation vehicles with a 30 A power supply assembly are allowed to have up to five branch circuits as long as only two thermostatically controlled appliances are supplied. Examples of thermostatically controlled appliances would include an air conditioner or a water heater. (Microwave ovens are not considered to be thermostatically controlled appliances for this application.) This means that, in RVs with a 30 A power supply assembly, if more than two thermostatically controlled appliances are supplied, isolation switching and/or energy management systems also must to be supplied. For example, on one branch circuit a switch may be employed to switch between two air conditioners or to switch between an air conditioner and a water heater. A 50 A power supply assembly is supplied in larger RVs where many 120 VAC appliances are present.

Some older RV units may have two power supply cords. In a two power supply cord system, the RV may have two 30 A cords or a 30 and a 15 A cord. At one time, the NEC allowed more than one power supply cord, but changed in 1996 to limit the RV to only one cord, since there was only one power pedestal supplied at each unit site in parks. When dealing with a two power supply cord system, there are two distribution panelboards, and these needed to be electrically independent of each other.

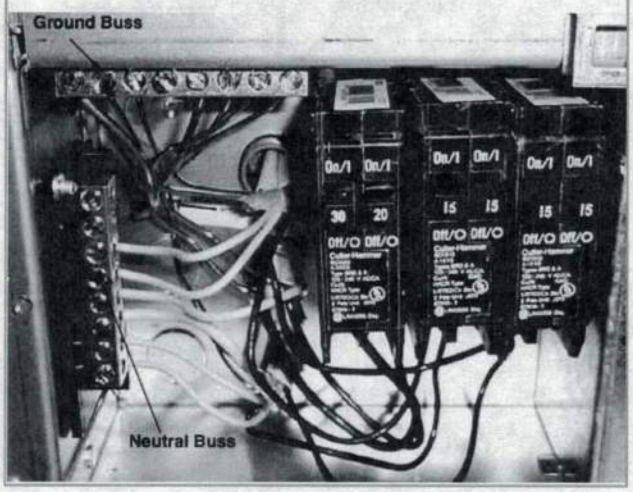
A 50 A 120/240 VAC power supply system has three current-carrying conductors as opposed to only two conductors in a 30 A or 15 A 120 VAC system. The three conductors (black, red, and white) provide two 120 VAC "hot legs" in parallel supplying 50 A each. This means 100 A of 120 VAC current is available for use in the RV. The electrical components are rated at 120/240 VAC. The 50 A 120/240 power source (50 A 120 VAC through the black wire, 50 A 120 VAC through the red wire) is actually two 120 VAC systems in parallel. Because the voltages in the red and black hot legs are 180° out of phase with each other, all the current can safely pass through the neutral (white) wire without overloading or causing other electrical problems.

Inverters are not usually designed to supply a very large amount of AC current. Therefore, they are generally used only to supply one or two branch circuits that could be used when the 120 VAC shore cord is not plugged in or when the generator is not running. Remember, any inverter used must be listed and installed according to its installation instructions.

4-4.3 120 VAC Distribution System

The 120 VAC is distributed within the RV the same as it is in a home, with the exception of the neutral buss. The AC voltage is fed into a distribution panelboard that distributes the power through circuit breakers to circuits that are connected to outlets or designated appliances. Wiring practices for RVs are the same as residential, and the wire used is usually 14-2 or 12-2 nonmetallic sheathed cable (type-NMC), commonly called Romex®. The outlets may be conventional or special outlets designed for NM cable. The three wires used in 120 VAC lines are black (hot), white (neutral), and bare or green (ground). These must never be interconnected or mixed. When connecting to a plug or outlet, the white wire goes to the silver terminal (which is the wide prong or slot), the black wire to the brass terminal, and the bare or green to the green screw.

Figure 4-46 30 Amp 120 VAC Distribution Panelboard



In the distribution panelboard, there are two terminal strips, or buss bars, for connecting wires (see *Figure 4-46*). One buss bar (insulated from the box) is for the neutral, and the other (screwed to the box) is for the grounds that are bonded to the vehicle chassis. In other words, the white and bare wires are isolated from each other. This ensures that the neutral (white) remains ungrounded. If the neutral becomes grounded while there is also reversed polarity in any circuit, the metal components or chassis of the RV can become energized or "hot." In a house, the polarity of the incoming conductors cannot be reversed, since the conductors are permanently connected to the distribution panelboard. Since the RV is connected by a detachable power supply cord, it is possible that the polarity could be reversed. In this case, the skin of the RV could become energized if the neutral is not insulated from ground. *Figures 4-47, 4-48*, and *4-49* show examples of basic 120 VAC wiring systems.

Figure 4-47 One-Breaker 120 VAC Wiring System

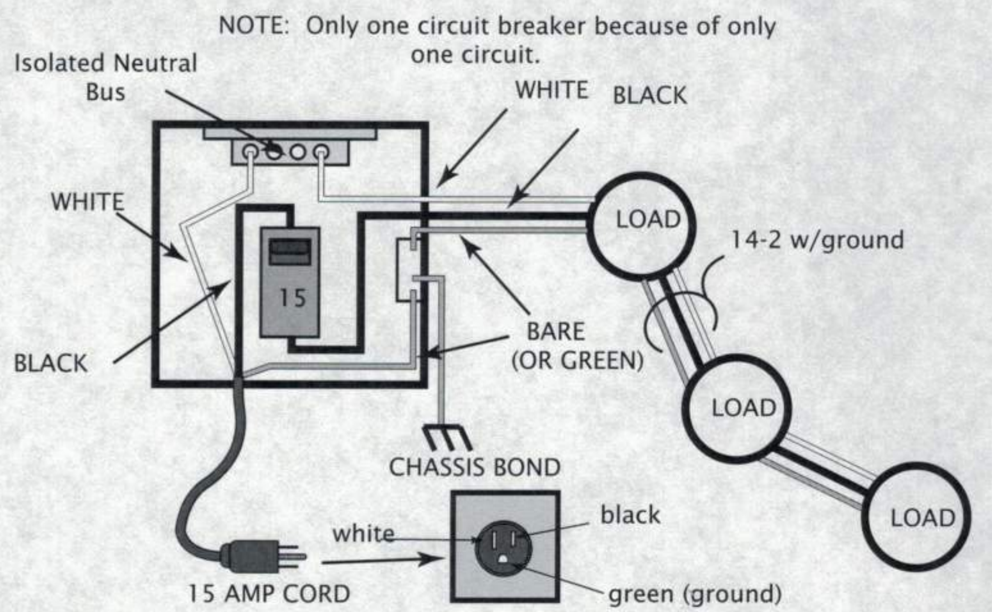
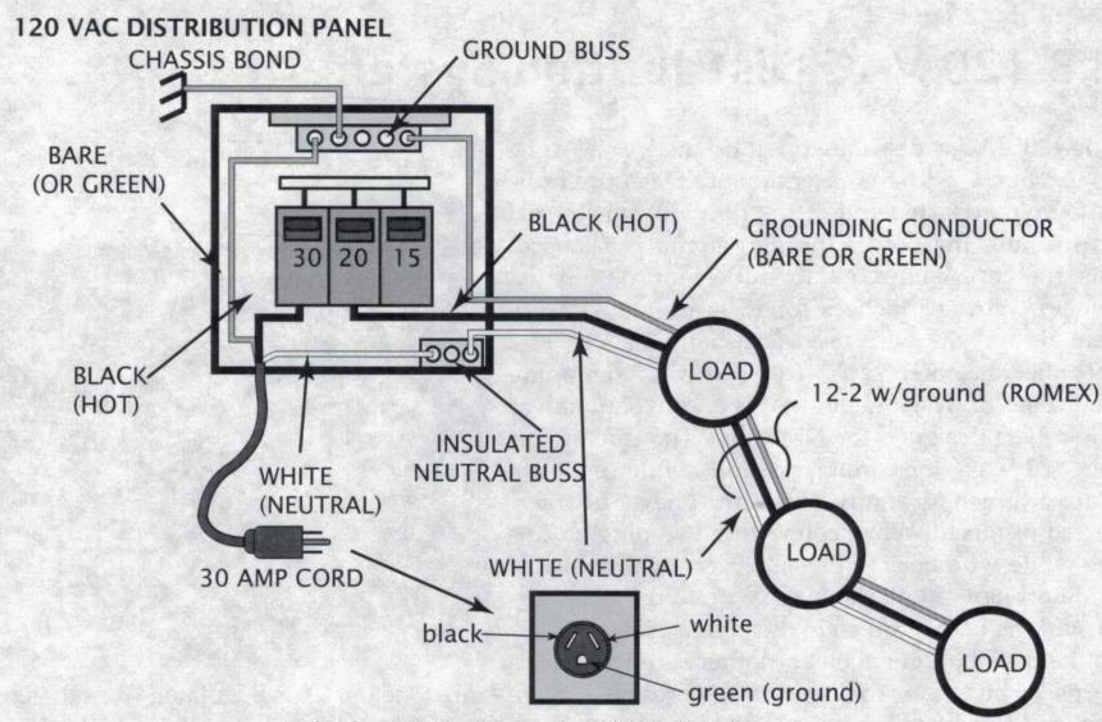
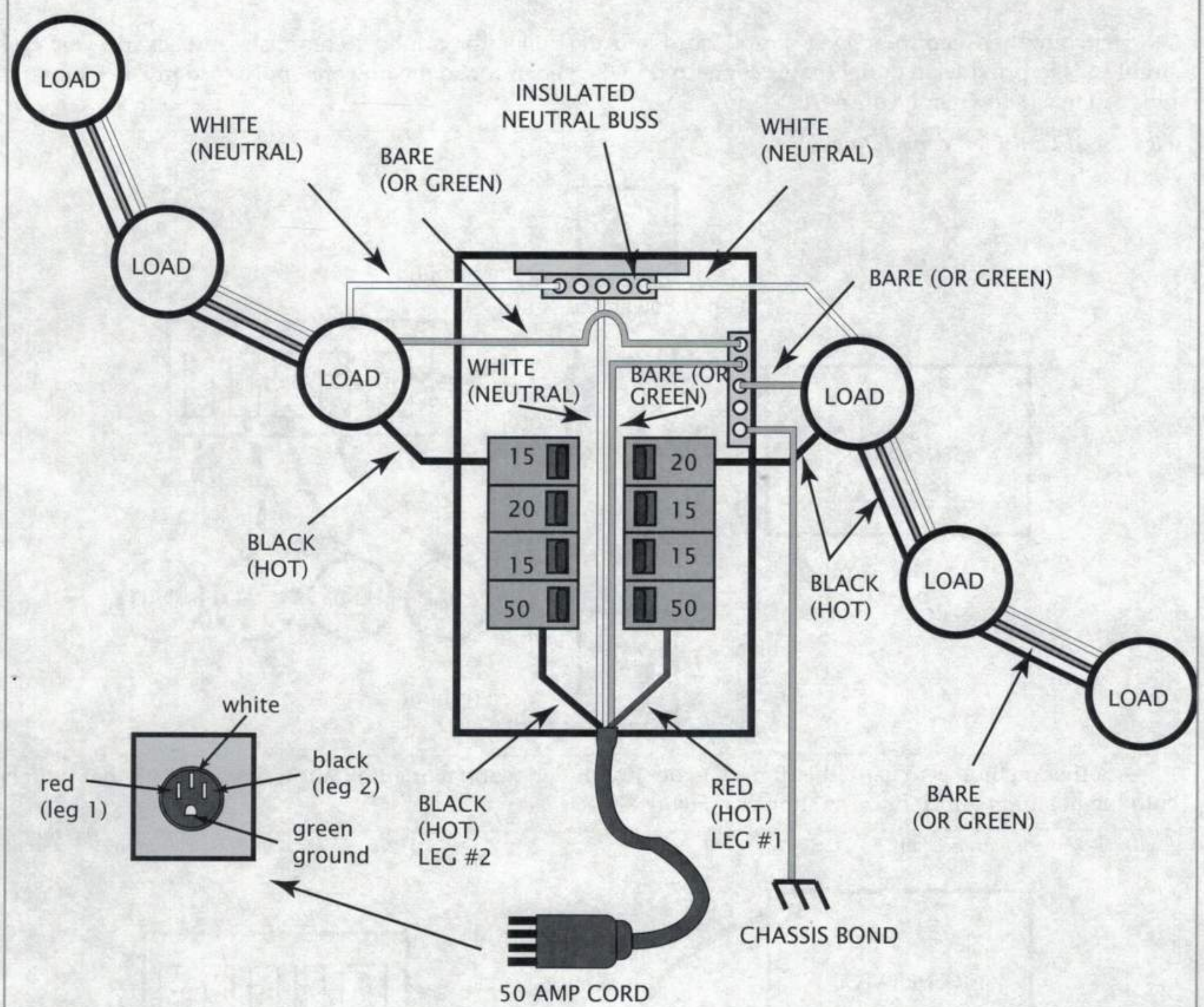


Figure 4-48 Multiple-Breaker 120 VAC Wiring System



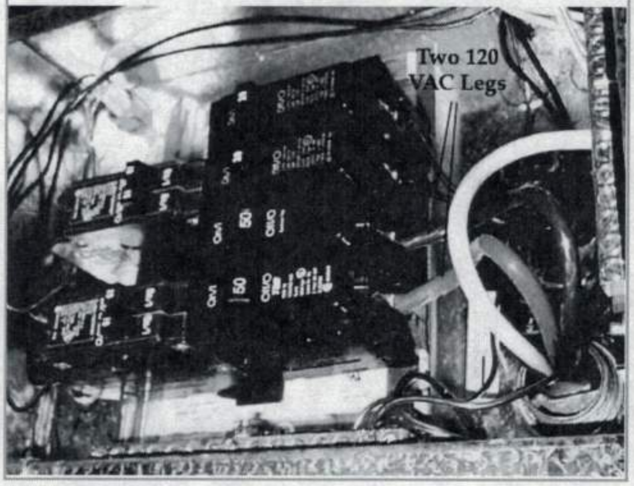
Multiple circuits demand multiple breakers.
This diagram shows one typical circuit.

Figure 4-49 50 A Circuit 120 VAC Wiring System



A 50 A circuit is actually supplied by a 120/240 VAC connection divided within the distribution panelboard into two 120 VAC lines, or legs. See *Figure 4-50*. Each 120 VAC leg then supplies several branch circuits. The voltage draw of branch circuits should be divided as equally as possible between the two legs in this system for balance. The 50 A circuit allows more equipment to be installed in the system, because each leg offers 50 A each or 100 A total at 120 VAC (12,000 W, or 12 kW).

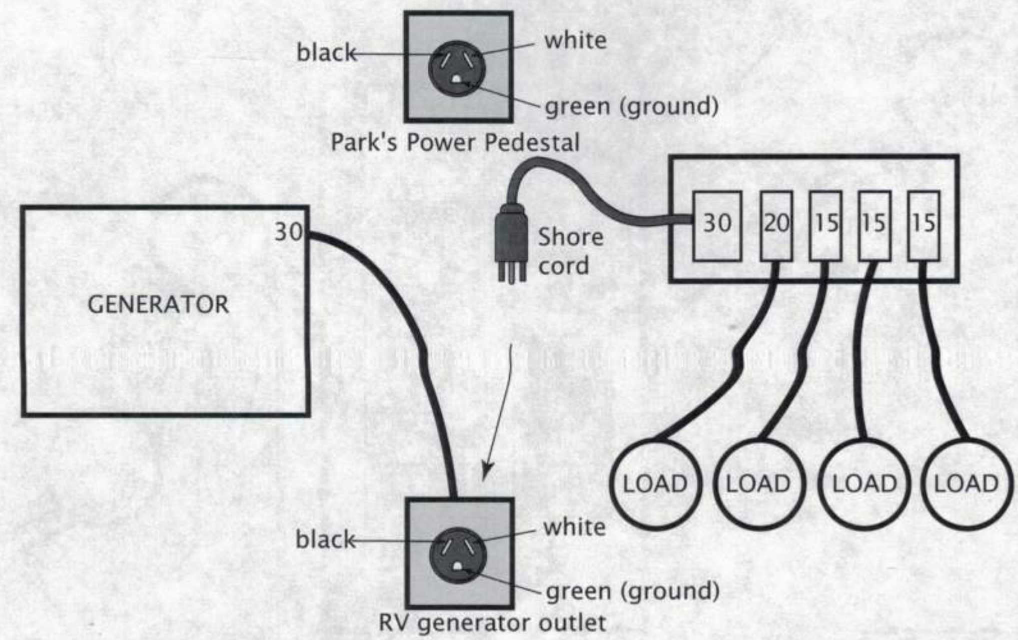
Figure 4-50 50 A 120 VAC Distribution Panelboard



4-4.4 Switching between AC Sources

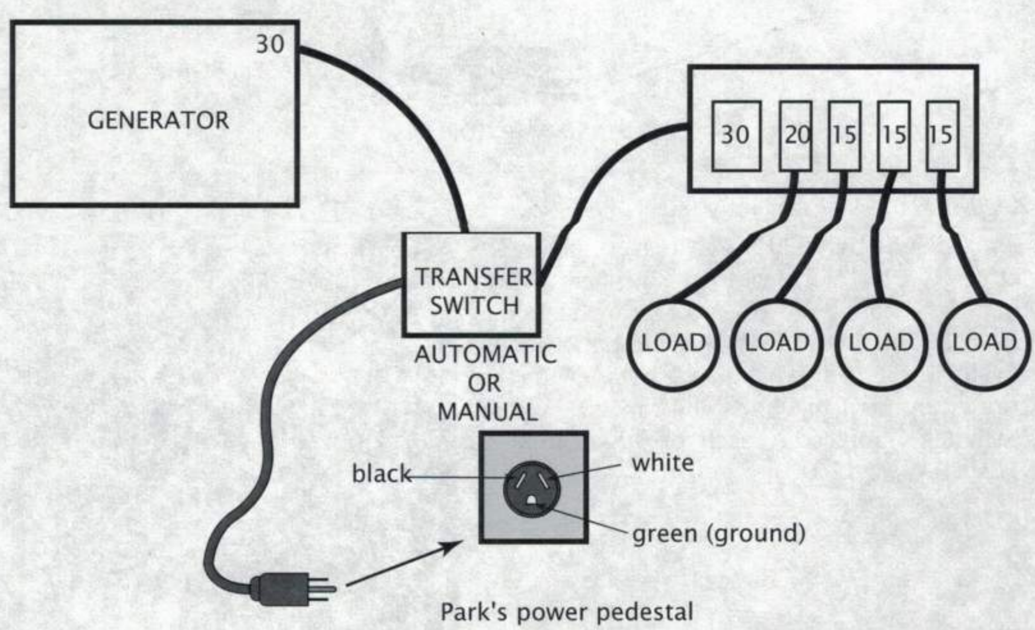
Switching between the power supply cord and the generator can be accomplished in several ways. The simplest is to provide an outlet that is connected to the generator so the power supply cord must be manually plugged in as shown in *Figure 4-51*.

Figure 4-51 Outlet for Manual Plug In



Another method is to use either the RV generator outlet, manual or automatic transfer switch that switches both the hot and neutral lines, as shown in *Figure 4-52*.

Figure 4-52 Automatic Relay Switches



The third way is to use an automatic transfer switch that shifts from the shore power to the generator when the generator starts.

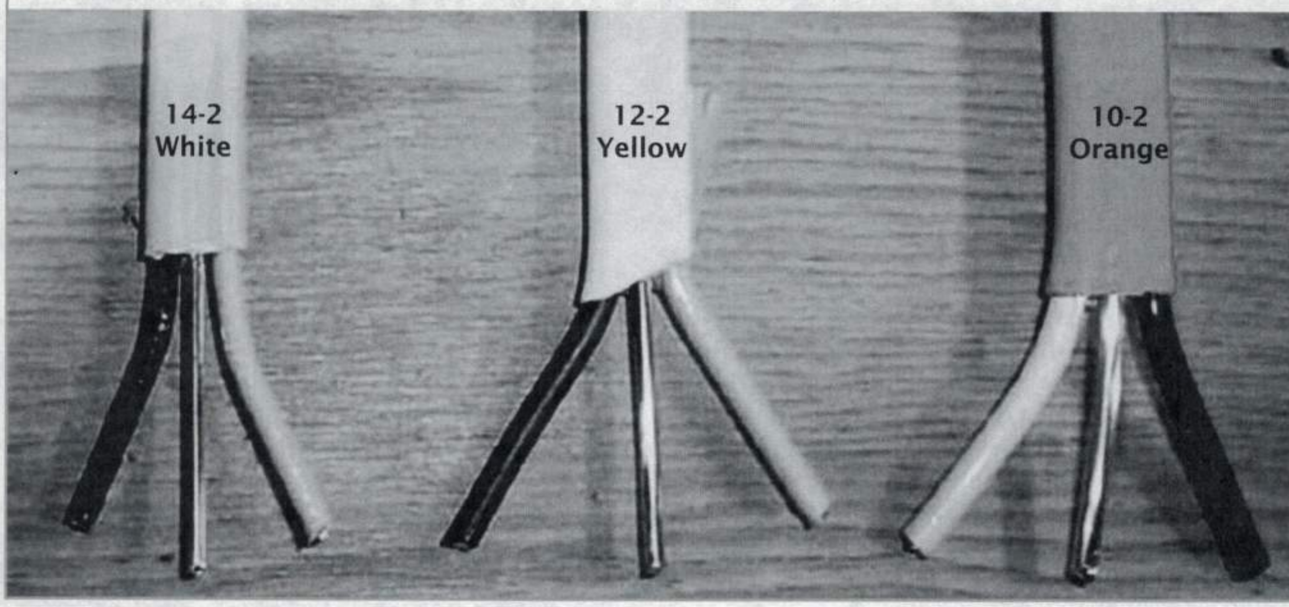
Many manufacturers incorporate an automatic transfer switch (either separate from or mounted in or on a combination panelboard/converter) to switch power from the outside source to the generator. When started and running, the generator automatically activates the transfer even if the shoreline is plugged in and receiving power. The automatic transfer switch may give priority to shore power or generator power. See the component manufacturer's installation instructions for specifics.

4-4.5 Conductors

Conductors, or wires, have a very low resistance, which enables a good flow of electricity. A resistance of 0.1 ¾ or less for 10 ft of copper wire is a typical value. The function of the conductor is to connect a source of applied voltage to a load with minimum voltage loss. Conductors used in the RV AC system are normally copper. They are permitted to be stranded or solid, although solid is commonly used (NMC cable).

Any conductors used in the 120 VAC system must be listed. The outer covering or *sheathing* of the wire encloses the individual insulated conductors and will usually have a mark such as UL or CSA to indicate listing. Only listed conductors should be used. Beginning in 2002, NMC is available with color-coded sheathing to indicate size—white for 14-2, yellow for 12-2, and orange for 10-2.

Figure 4-53 Conductor Size Examples



Conductors used in the 120 VAC system of an RV are usually nonmetallic sheathed cable. Nonmetallic sheathed cable *(NM cable)* is commonly called Romex®. Nonmetallic sheath cable is available in several sizes. Those used in RVs are commonly between 6 and 14 ga. Nonmetallic sheath cable is commonly designated using the size and number of current-carrying conductors contained within the cable; i.e., a 10-2 cable is 10 ga with two conductors (one black, one white). See *Figure 4-53*. These conductors also have a ground, but it is not designated in the call size of the wire. The typical call size of a conductor would be 14-2 with ground. Branch circuits for most devices in RV 120 VAC electrical systems are either 14-2 or 12-2 NM cable, with ground. Also, 10-2 cable is sometimes used. For example, it may be used between a 30 A power supply cord junction box and the distribution panelboard. Sizes 10-3 and 6-3 are examples of nonmetallic sheath cable containing three principal conductors and a fourth for the ground. A 10-3 nonmetallic sheathed cable contains two hots (a black and a red), one neutral (white), and a ground (bare or green). A 10-3 cable would commonly be used to service a 240 VAC appliance. A 6-3 nonmetallic cable is often used in wiring between junction boxes or transfer switches in a 50 A system on the feed side of the distribution panelboard. Always use equivalent size NM cable when replacing any conductors in the 120 VAC or 120/240 VAC electrical system.

4-4.5.1 Gauge of Wire

Wire size is expressed in terms of gauge. Gauge indicates the cross-sectional area of the copper wire. The amount of current a wire will carry increases as the area of copper increases. Likewise, the amount of voltage drop that will occur within a wire decreases as the copper area increases given the current remains constant. Therefore, in order to carry the same loads without excessive voltage drop, long wires must have a larger copper diameter than short ones. Remember that a long length of wire offers more resistance to current flow than a short wire.

The gauge numbers specify the size of a round wire in terms of its diameter and cross-sectional area. Note the following:

1. Higher gauge numbers indicate thinner wire sizes.
2. The higher the gauge number and the thinner the wire, the greater the resistance of the wire for any given length

Figure 4-54 Toggle Switch Example

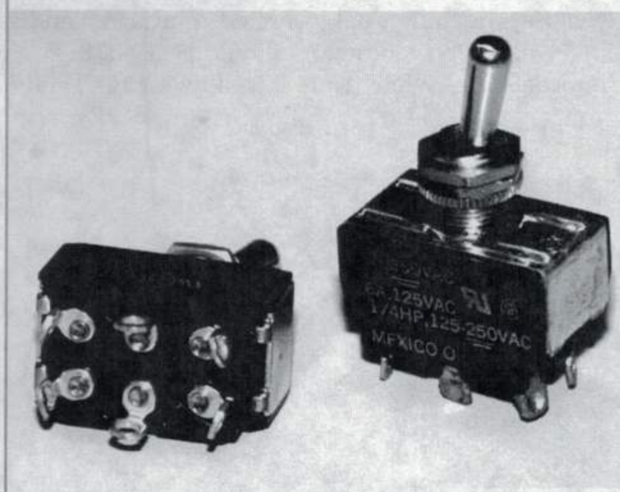


Figure 4-55 Round Dimmer Switch Example

4-4.6 Switches

Switches are used to open or close a circuit. Closed is the ON position and open is the OFF position. This terminology can be confusing initially. When the switch is open (off), the electrical path is disconnected, preventing the flow of current. When the switch is closed (on), the electrical path is connected, allowing the flow of current. The switch is in series with the voltage source and its load. In the ON position, the closed switch has very little resistance. Then maximum current can flow in the circuit, with practically zero voltage drop across the switch. Open, the switch has infinite resistance, and no current flows in the circuit.

Several different types are available, including the toggle switch (*Figure 4-54*), rotary switch (*Figure 4-55*), knife switch, push-button switch, and rocker switch. Some are spring loaded in the open position. Others are spring loaded in the closed position. Regardless of what types are used, they are all performing the same task, which is to open or close a circuit.

To test a switch, isolate it from the circuit, turn the power off, and place an ohmmeter across its contacts. Then move its control back and forth between open and closed. When the switch is open, or off, the meter should indicate infinity. When the switch is closed, or on, the meter should read zero resistance.

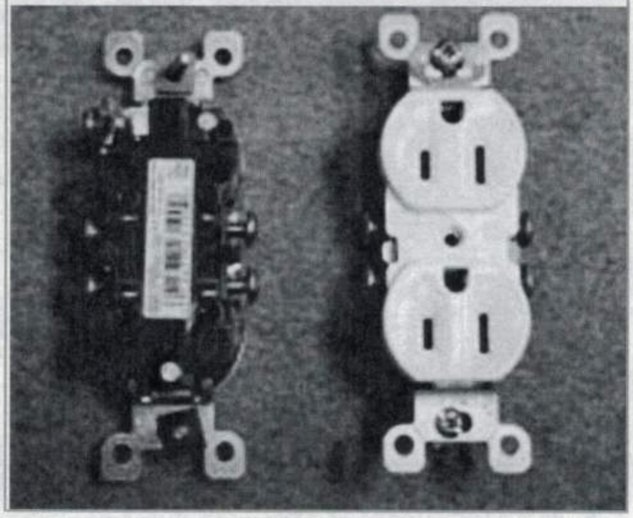
4-4.6.1 Relays

Relays are electrically operated switches with contacts that can be closed or opened by current in the relay coil. In operation, a small current in the coil activates the relay. Its magnetic field attracts the iron armature, which contains the movable switch contacts. Common coil voltages are 12, 24, and 120 volts. The main contacts, however, are rated at much higher voltages and currents.

Testing a relay is accomplished in two steps. First, test the coil. With the power off, isolate the coil from the circuit, then place an ohmmeter across the coil. It should measure a very low resistance. (This will depend on the value of the coil.) A reading of infinity at this time indicates a faulty relay.

The second test is accomplished by applying the rated voltage of the relay to the coil. Then listen for the "clicking" of the contacts opening and closing. An ohmmeter can also be placed across the switch terminals to determine continuity. A normally open relay would read "0." A normally closed relay would read infinity.

Figure 4-56 Receptacles

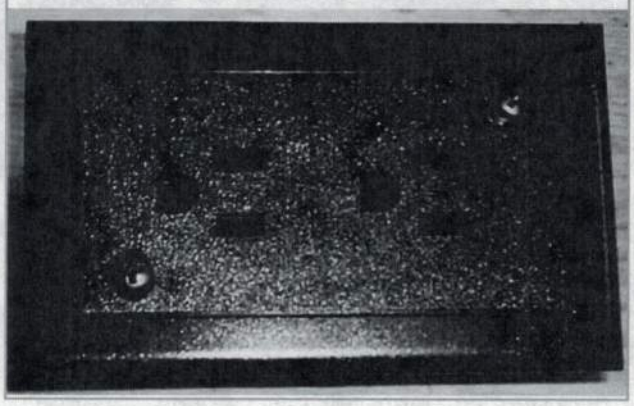


4-4.7 Receptacles

The National Electrical Manufacturers Association (NEMA) has developed standards for the physical appearance of plugs, receptacles, and switches. The differences are based on the current and voltage ratings of the device. When replacing receptacles or switches, refer to the manufacturer data and replace them with a device of the same rating.

4-4.7.1 Interior Receptacles

Figure 4-57 Self-Contained Receptacle (Front)



Receptacle outlets currently installed in RVs are usually one of two distinct types. The first is the common house-type receptacle outlet, as shown in *Figure 4-56*, that is installed in an outlet box. The second is a type of receptacle outlet that is not installed in a box but has its own plastic enclosure as part of the receptacle. These are commonly called *self-contained* receptacles. See *Figures 4-57* and *4-58*.

Replacement or repair of the standard receptacle is exactly the same as a house receptacle. First, verify that the power has been disconnected, then replace the receptacle by removing the black, white, and ground wire from the old receptacle. Install the new unit by either pushing the black and white wires into the designated holes on the back of the receptacle (ensure that the wire is stripped back by the specified amount) and attach the ground wire to the green ground screw. The black and white conductors can also be connected to the terminals on the side of the receptacle. When attaching wires to screw-type terminals, always ensure that the wire wraps around the terminal screw by at least two-thirds of a wrap and that it is wrapped in the direction of the turn (clockwise) as shown if *Figure 4-59*.

Figure 4-58 Self-Contained Receptacle (Back)

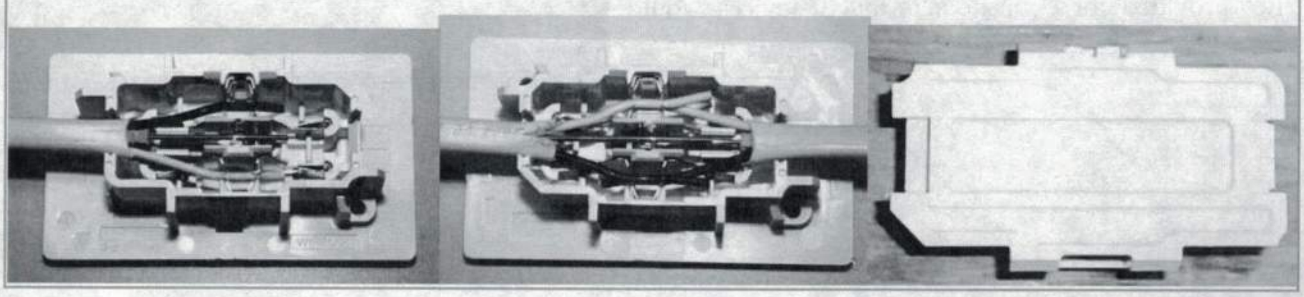
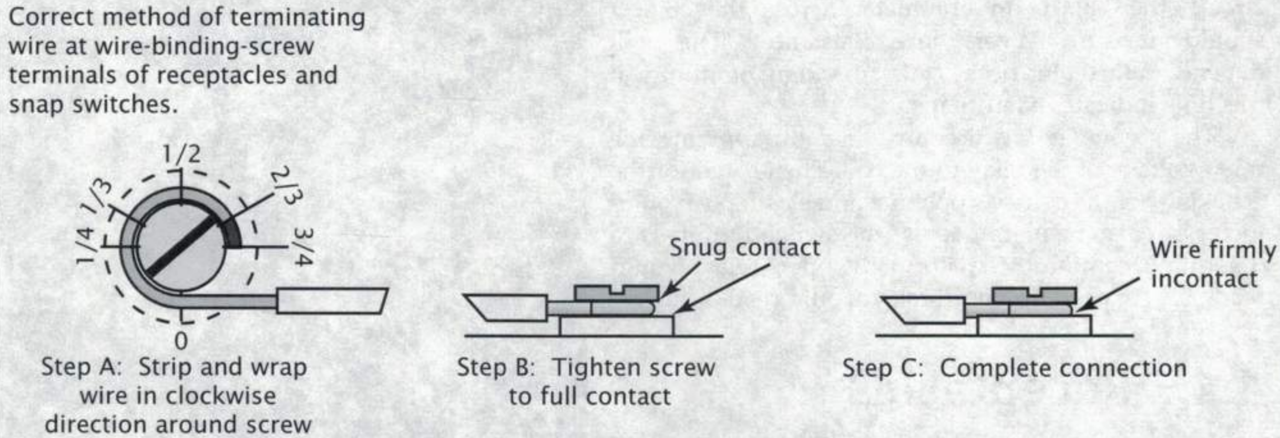


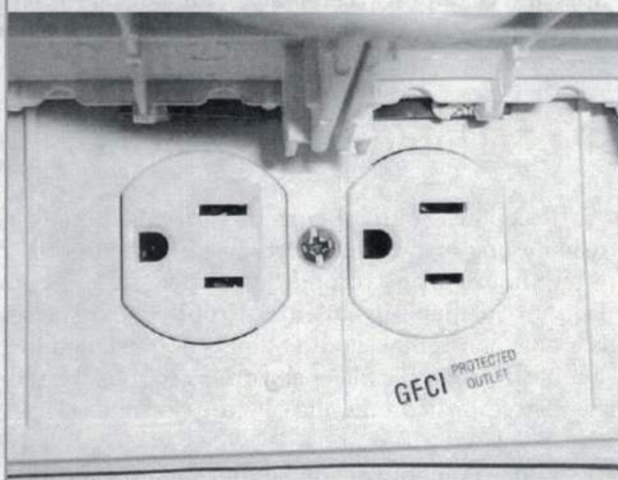
Figure 4-59 Correct Method for Connector Looped under Screw-Type Terminal



4-4.7.2 Exterior Receptacles

When replacing or installing exterior receptacles, remember that these receptacles are required to be protected by a ground fault circuit interrupter (GFCI) protection) device. Exterior receptacles also must have a special wet location cover installed (see *Figure 4-60*). "Wet location" is part of the listing and will normally be either stamped on the cover or contained in the documentation of the cover for the receptacle.

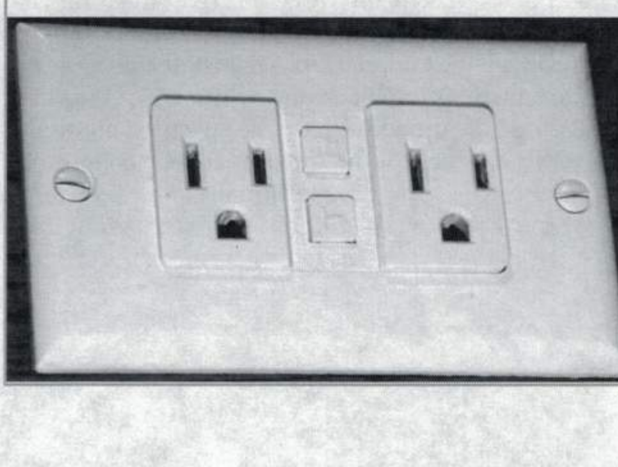
Figure 4-60 Exterior Receptacle (Open)



4-4.7.3 GFCI-Protected Receptacles

Ground fault circuit interrupter protection is a special type of protection for a circuit that will shut the circuit down immediately in the event of a fault current. This function is provided to protect personnel from electrocution. GFCI protection can be provided through the use of either specific GFCI receptacles or GFCI circuit breakers that protect the entire circuit. Regardless of the means employed, receptacles in the following locations must be provided with GFCI protection: (1) in the bathroom, (2) within 6 ft of any sink, and (3) on the exterior of the vehicle. The term "on the exterior" of the RV does not include single outlets for the refrigerator. Receptacles in the refrigerator compartments that are not provided for dedicated, installed devices would need to be GFCI protected.

Figure 4-61 GFCI Receptacle



4-4.8 AC Circuit Breakers

Figure 4-62 AC Circuit Breaker

An AC circuit breaker is a protective device that opens when excessive current flows in the circuit. AC circuit breakers must be manually reset. The tripping mechanism of this type of breaker (thermal-magnetic) is enclosed in a molded plastic case and will have the rating stamped or molded on the handle (see *Figure 4-62*). Testing a circuit breaker can be accomplished with a voltmeter by reading from the breaker output to the neutral bar with the power on. A voltage reading of 120 VAC (approx.) indicates a closed breaker. A reading of 0 VAC indicates that the breaker is open. An ohmmeter can also be used if the circuit breaker is removed from the circuit and tested for continuity as if it were a switch. Refer to *"Switches" on page 4-58* of this textbook for testing.

4-4.9 Hardware

Common hardware used in the 120 VAC electrical system includes, but is not limited to, outlet boxes, switches, junction boxes, distribution panelboards, and circuit breakers. Remember that all electrical equipment in the 120 VAC electrical system must be listed. Look for the mark of a listing agency such as UL, CSA, or other approved listing agencies. Markings will normally be located somewhere on the electrical component. Also remember that all electrical equipment must be used according to the terms of its listing. This means the technician must follow the installation instructions supplied with any electrical device being installed. This also means that devices listed for the specific application must be used. An example would be the need to use a wet location type enclosure where exposed to moisture. Another example of using a device within the terms of this listing is ensuring that circuit breakers used for air conditioner circuits have a special heating, air conditioner, refrigeration (HACR) rating. When in doubt about the installation of an electrical device, always consult the installation instructions. Contact the supplier or distributor of the component if necessary to ask that installation instructions be supplied.

4-4.10 Motors

AC motors use the principle of the electromagnet for a field, but the "poles" of this magnet change 60 times per second. These alternating fields act on the armature, setting up its magnetic field and causing it to rotate. Most AC motors do not require an electromechanical contact between the field coils and the armature.

AC motors needing more starting torque (power) can include a "start capacitor" in the electrical system to give a "kick" to the start process. A start winding is another set of windings that greatly increase the magnetic field and its effect for a short period of time. A centrifugal switch is used to disconnect this winding at the right time. If the start winding were left connected, the motor would quickly overheat and be damaged. A start capacitor produces a "jump start" of stored current that supplies enough momentary power to force the motor to start against a load. Common uses for these "assisted-start" motors are pumps and compressors.

4-4.11 Testing Overcurrent Protection Devices

When measured with an ohmmeter, almost any overcurrent protection device has practically zero resistance. An open would indicate infinite ohms. The power must be off or the device must be out of the circuit to test with an ohmmeter. With most fuses, it is usually easy to see if the wire element inside is burned open.

When testing with a voltmeter, a good device has zero volts across its two terminals. If appreciable voltage is measured, this means it is open. In fact, the full applied voltage is across the open device in a circuit. This is why most types of overcurrent protection devices also have a voltage rating, which gives the maximum voltage without arcing in the open device.

Circuit breakers used in the RV 120 VAC electrical system are just like those used in a house electrical system. A circuit breaker is designed to trip when current exceeding the value of the circuit breaker is present in the circuit. A fault or excessive load will create this situation, and the tripping of the circuit breaker prevents overheating of the wire beyond its capacity. Circuit breakers used must always be listed. Always replace a circuit breaker with one of equivalent size, and ensure that any installed circuits have properly sized circuit breakers at the source.

NOTE: If a breaker has tripped repeatedly because of an overload, it may test OK out of the circuit, but it may not be able to handle the rated current. These breakers should be replaced. This is particularly true for GFCI breakers.

Each 120 VAC circuit installed in a recreation vehicle must have a circuit breaker or a fuse. The sizing for circuit breakers or fuses relative to wire size is provided in *Table 4-7*.

Table 4-7 Overcurrent Protection Sizing

Conductor Size	Overcurrent Protection
6 ga	50 A
8 ga	40 A
10 ga	30 A
12 ga	20 A
14 ga	15 A

A conductor can always be larger than the size designated for a specific overcurrent protection device (i.e., it would be OK to use 12 ga conductor with a 15 A circuit breaker but not OK to use 14 ga conductor with a 20 A circuit breaker).

4-4.12 Ground Fault Circuit Interrupter (GFCI)

A shock hazard exists whenever the user can touch both the defective equipment or appliances and grounded surfaces, such as water pipes, or any other metal grounded to earth grounds.

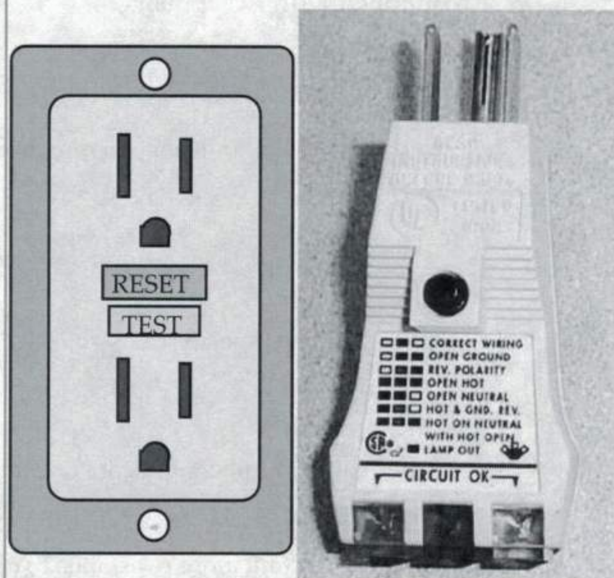
To protect against electrical shock, the use of GFCI protection is required in designated circuits. A GFCI monitors the current balance between the ungrounded "hot" conductor and the grounded "neutral" conductor. As soon as the current flowing through the "hot" conductor is in the range of 4 to 6 mA or more than the current flowing in the "return" grounded conductor, the GFCI senses the unbalance and trips to the circuit off. The unbalance indicates that part of the current flowing in the circuit is being diverted to some path other than the normal return path along the grounded return conductor. If the "other" path is through the human body, the outcome could be fatal. The GFCI protection can be provided by GFCI receptacles or by GFCI circuit breakers.

4-4.12.1 Testing the GFCI

Note that the GFCI receptacle has "T" (test) and "R" (reset) buttons as shown in *Figure 4-63*. Pushing the test button places a small ground fault on the circuit. If operating properly, the GFCI receptacle should trip to the off position. Pushing the reset button will restore power. To test for GFCI protection on receptacles downstream of a GFCI receptacle, a circuit tester with GFCI test as shown in *Figure 4-63* needs to be used. Insert the tester into any downstream receptacle and push the test button on the test device. The upstream GFCI receptacle should trip. If the GFCI receptacle does not trip, most commonly the GFCI receptacle is defective or miswired. This tester can also be used to test an individual GFCI receptacle.

NOTE: AC power must be present at the GFCI device for the test and reset buttons to function.

Figure 4-63 GFCI Receptacle and Tester



GFCI Receptacle GFCI Tester

The operation is similar for the GFCI circuit breaker. GFCI circuit breakers also have a test button for testing, as shown in *Figure 4-64*. Once the test button is pushed, if working properly, the breaker will trip. Resetting the breaker will restore power to the circuit.

Individuals with heart conditions or other problems that make them sensitive to electric shock can still be injured by faults on circuits protected by a GFCI. The device does not completely eliminate shock. It interrupts a live circuit quickly enough to prevent electrical injury to most people. There is no substitute for care in handling electricity. No safety device exists that will forgive carelessness or misuse of equipment.

Figure 4-64 GFCI Circuit Breaker

4-4 Review

1. What is required in an RV that has a 30 A power supply assembly and more than two thermostatically controlled 120 VAC appliances?

   A.

   B.

2. List the three methods of switching between AC sources.

   A.

   B.

   C.

3. Gauge numbers specify the size of round wires in terms of diameter and cross-sectional area of the copper in the wire.

   True False

4. Higher gauge numbers indicate thicker wire sizes.

   True False

5. A long wire offers more resistance to current flow than a short wire.

   True False

6. The amount of current a wire will carry increases as the area of copper increases.

   True False

7. The amount of voltage drop that will occur within a wire decreases as the copper area decreases.

   True False

8. The closed position on a switch is the off position.

   True False

9. The open position on a switch is the on position.

   True False

10. A switch is being checked. The switch has been isolated from the circuit. An ohmmeter has been placed across the switch contacts. When the switch is open, the meter should read ________________. When the switch is closed, the meter should read ________________.

11. Automatic switches with contacts that can be closed or opened by current in a coil are called ________________.

12. All exterior receptacles must be ________________ protected.

13. A ________________ produces a "jump start" of built-up current that supplies enough momentary over-power to force a motor to start against a load.

14. What minimum gauge wire should be used for a 30 A circuit?

    A. 8

    B. 10

    C. 12

    D. 14

15. The term *60 Hz* means that an AC power line frequency cycle occurs ________________.
    A. 60 times every minute
    B. 60 times every second
    C. Once every second
    D. Once every 60 seconds
16. List the three possible sources of AC power to an RV.
    A.
    B.
    C.
17. The three wires used in 120 VAC lines are
    A. black, which is ________________.
    B. white, which is ________________.
    C. bare or green, which is ________________.
18. When connecting 120 VAC wiring to an outlet terminal, the
    A. white wire is connected to ________________.
    B. black is connected to ________________.
    C. bare or green is connected to ________________.

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Chapter

4-5 AC System Operation

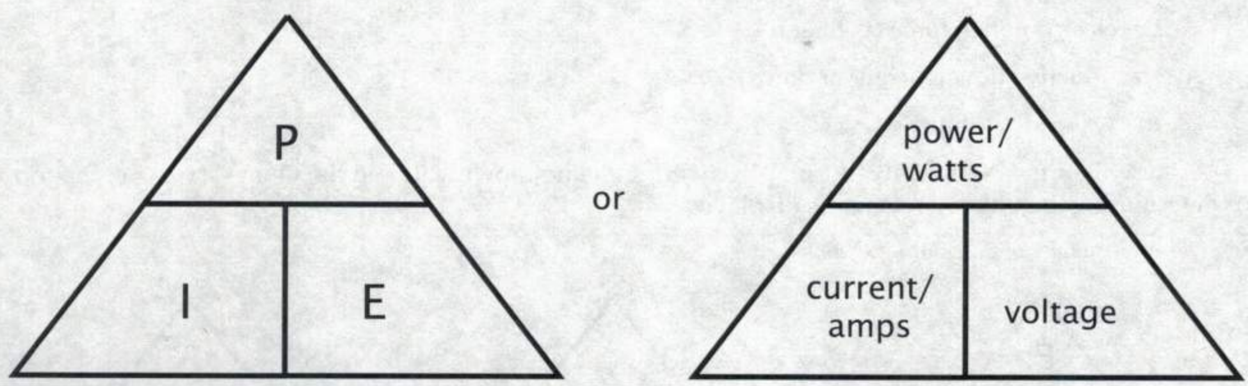
· Demonstrate the ability to perform necessary mathematical and measurement techniques.

4-5.1 Typical AC Loads (Amperage Draw)

Typical devices connected to the 120 VAC electrical system include lights, air conditioners, fans, microwave ovens, and water heaters. These are called the *loads* on the system. The amount of current drawn by each device can be determined in a couple of ways. It will often be available on the rating plate or in the device manual. The rating is the current draw of a device. The current draw can also be measured by putting an ammeter in line with the device running. The rating is often given in watts.

To convert to amperes, use Watt's law: P = I × E (amps = watts/volts).

Figure 4-65 Watt's Law P = I × E (Triangle)



P = I × E is the correct formula for Watt's law. The second formula is the same formula expressed in everyday technician terms. In some texts, V is used instead of E. This does not change the formula.

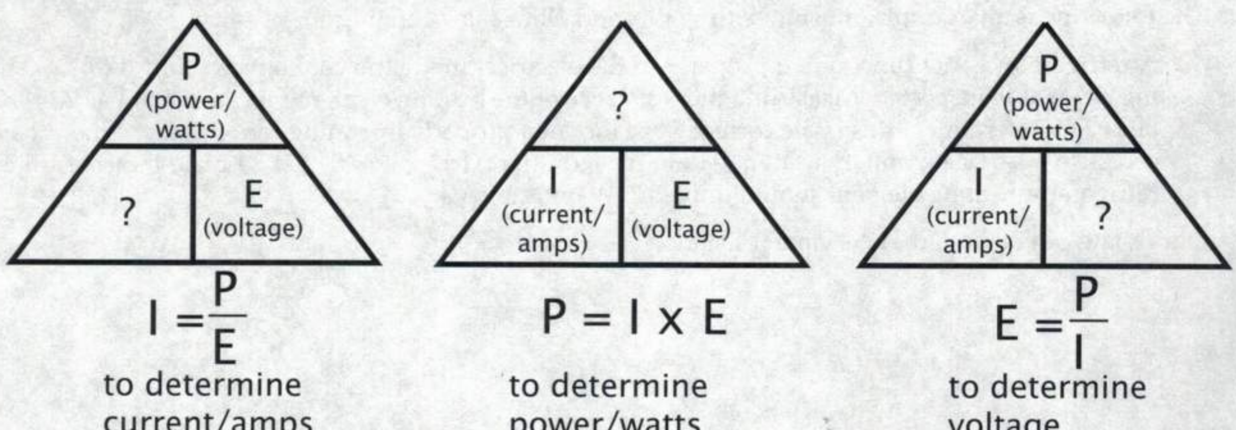
P = power/watts

I = inductive flow (current or amps)

E = electromotive force (voltage)

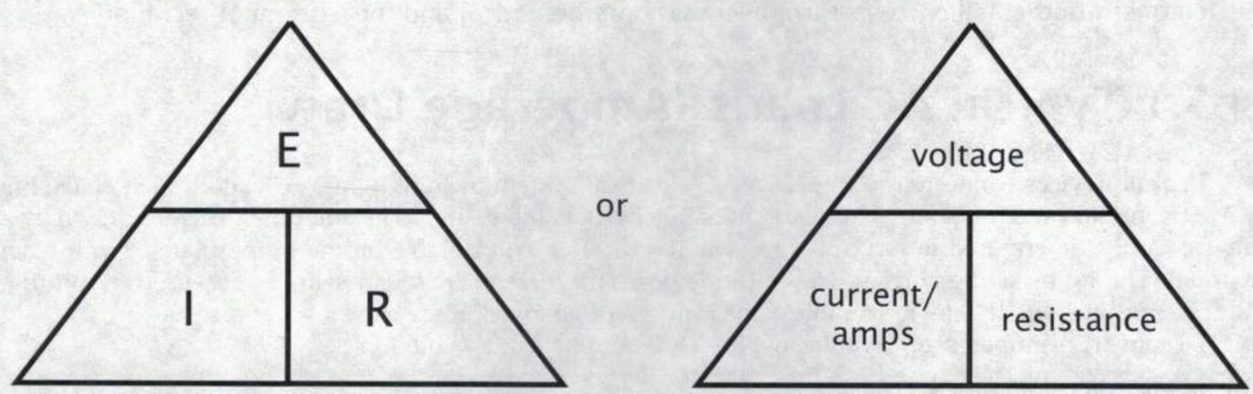
If the values for any two factors are known, the third can be determined. By simply covering the unknown value in the Watt's Triangle, the formula for determining the unknown factor is displayed.

Figure 4-66 Examples of Calculating Watt's Law



Watt's law covers the determination of power, current or amps and voltage. To determine resistance, use Ohm's law (E = I × R).

Figure 4-67 Ohm's Law (E = I × R)



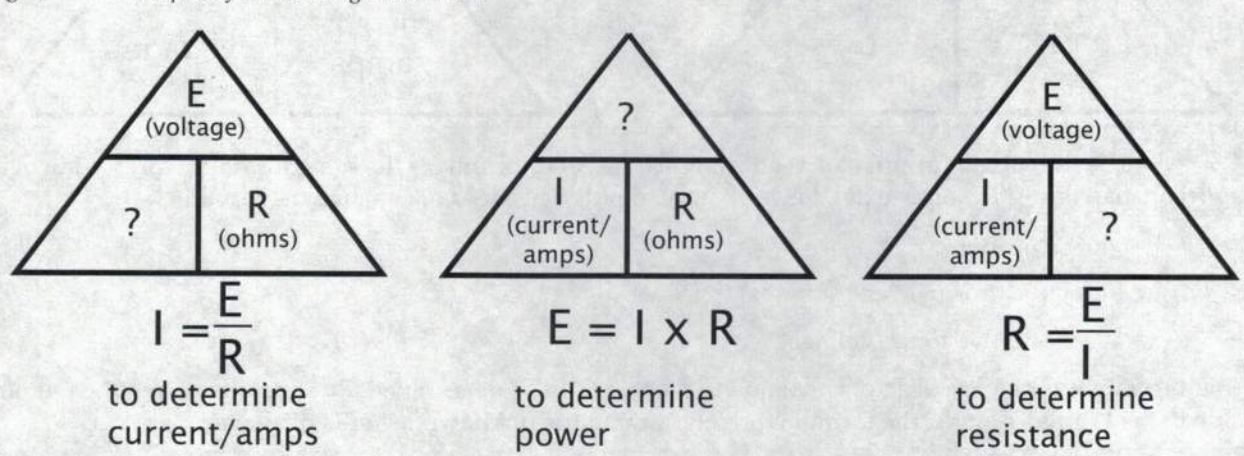
E = electromotive force (voltage)

I = inductive flow (current or amps)

R = resistance (ohms)

As described for Watt's Law, by simply covering the unknown value in the Ohm's Triangle, the formula for determining the unknown factor is displayed.

Figure 4-68 Examples of Calculating Ohm's Law

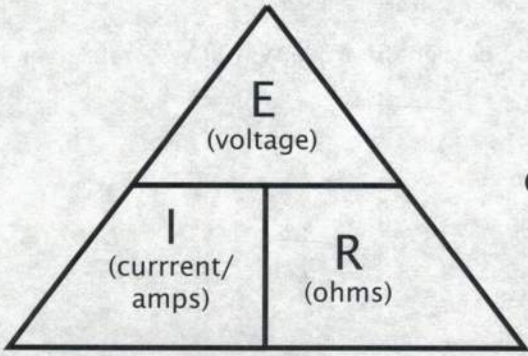


The following is an example of using both Watt's and Ohm's laws on the job:

> A refrigerator is not functioning properly in the electrical mode (no cooling). A faulty 120 VAC heating element is suspected. Measuring the resistance of the heating element reveals that it has 20 ¾ resistance. To determine if this is the correct resistance of a properly operating refrigerator without having access to a service manual, locate the data plate on the refrigerator. The data plate indicates that the refrigerator heating element should draw 325 W on 120 VAC.

Ohm's law can be used to determine resistance.

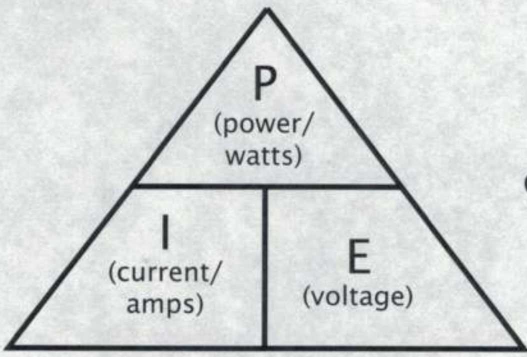
Figure 4-69 Resistance Formula



or voltage divided by current/amps

In the example given, the voltage (120 VAC) is known, but the current/amps is not. Using Watt's law, the current/amps can be determined if the power and voltage are known. In the example, the power is 325 W, and the voltage is 120 VAC. To determine the power, use the formula shown in *Figure 4-70.*

Figure 4-70 Power Formula



or power/watts divided by voltage

The answer is 2.7 A.

Now that the amperage is known, Ohm's law is used to determine the proper resistance as shown in *Figure 4-69*.

The correct resistance of the heating element in the example is 44-3/4 (120 VAC divided by 2.7 A = 44.4 or 44 ¾).

In the example, the measured resistance of the heating element was 20-3/4. The tolerance for a heating element resistance is 10 percent of the correct resistance (see *Section 9-5.3.3.1 Heating Elements of the RV Refrigerators* textbook). In this case, the correct resistance should be 48.4 to 39.6-3/4 (44-3/4 ± 10 percent). Since 20-3/4 falls outside this range, the heating element should be replaced.

4-5 Review

1. Calculate the amperage of a 120 VAC, 300 W refrigerator.
2. Calculate the wattage for a 120 VAC, 1.5 A computer monitor.
3. What should be the resistance of a 120 VAC heating element for a 300 W, 120 VAC refrigerator?

Chapter 4-6 Maintaining/Installing AC-Voltage System Components

- Service the 120 VAC systems (including distribution panelboard, circuit breakers, and power supply cord components).
- Differentiate between isolated/floating system and bonded system.
- Add 120 VAC circuits.
- Determine 120 VAC wire routing.
- Add or move 120 VAC outlets.
- Install/troubleshoot inverters.

4-6.1 Safety Practices

4-6.1.1 Grounding

Grounding ensures electrical safety. Grounding can be divided into two areas: (1) system grounding, and (2) equipment grounding. System grounding is the intentional connection of a current-carrying conductor to ground (earth) or something that serves in place of a ground (vehicle chassis). System grounding does not occur in the RV but is accomplished when the power supply cord is connected to a power pedestal in the park or some other power supply receptacle, where the neutral is intentionally grounded. Equipment grounding is the intentional connection of all noncurrent carrying metal parts of the electrical system to ground. In the RV, this is accomplished by the ground wire in the conductors of the 120 VAC system.

There are four reasons for grounding:

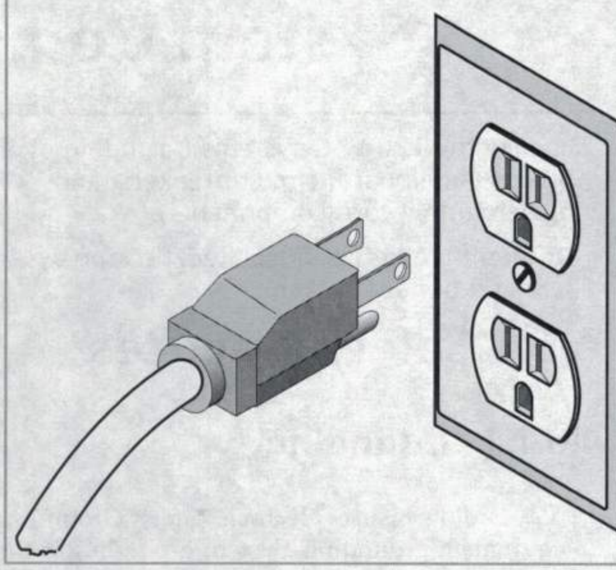
1. Grounding serves to limit the voltage caused by lightning or by accidental contact of the supply conductors with conductors of higher voltage.
2. Grounding stabilizes the voltage under normal operating conditions.
3. Grounding provides a low-resistance electrical path for current flow, so if a person comes into electrical contact with a piece of equipment, the current will follow the ground path to complete the circuit instead of flowing through the higher resistance of the human body.
4. Grounding facilitates the operation of overcurrent devices such as fuses, circuit breakers, and relays, under ground fault conditions.

4-6.1.2 Grounding System

RVs are wired differently from houses, and the differences are based on the grounding system. In an RV, the white or neutral conductor is isolated from the ground conductors. This means there is no electrical interconnection of the white wire and the bare ground wire in the RV. These two wires are not interconnected until connected at the power supply at the park pedestal or other suitable power source. In a house, the white and ground wires can be interconnected without concern because, in a house, polarity cannot be reversed. Reverse polarity occurs when the white and black wires are reverse connected. In an RV, the power supply cord or power supply adapter plug can provide reverse polarity. This is especially possible if someone cuts off the ground pin of the cord or uses an ungrounded (two-wire) extension cord. In a situation of reverse polarity where there is also a short, the power could be "fed" to the white wire, bypassing the overcurrent protection provided and energizing the exterior skin or other metal parts, leading to severe burns or possibly death.

In normal operation, the electric circuits function the same way with or without the ground, but the grounding is an important safety precaution. *Figure 4-71* shows one type of plug/receptacle for the AC power line that helps in providing protection because this type is polarized with respect to the ground connections. Although AC voltage does not have any fixed polarity, the plug's configuration ensures grounding to the chassis or frame of equipment, connected at the power source. The illustration shows two slots for the 120 VAC load connector. One blade is wider and will fit only the side of the outlet that is connected to the neutral wire. This wiring is standard practice. The rounded pin is for a separate grounding wire, usually bare or color coded green. If the polarity of a circuit is questionable, use a ground monitor (polarity tester) to check the wiring polarity of all receptacles.

Figure 4-71 One Type of AC Plug/Receptacle



4-6.1.3 Bonding

Bonding serves a different purpose from grounding. It is the permanent joining of metallic parts not intended to be energized to form an electrically conductive path that will ensure electrical continuity and the capacity to conduct safely any current likely to be imposed, in the event they become energized. Bonding paths are to be designed and installed to have the capacity to conduct safely any current likely to be imposed. Bonding jumpers accomplish this by bonding all metal and equipment together to keep voltage buildup on the different sections of the RV the same, so there will be no difference of potential between the various pieces of equipment or chassis parts. There should be no voltage drop detected. This can be checked with an ohmmeter by placing the probes on any two pieces of equipment and reading resistance with the power off. There should be little or no resistance.

4-6.1.3.1 Distribution Panelboards

Work done by service technicians involving the distribution panelboard includes replacement of circuit breakers and, in some cases, the addition of circuits to the panelboard. To remove and replace circuit breakers, use the following procedure:

1. Disconnect any power source, power supply cords, generator, or inverter.
2. Remove the panelboard cover by removing the screw(s) attaching the cover.
3. Unscrew the terminal holding the wire connected to the circuit breaker to be replaced. This is usually a screw-type terminal. Pull the conductor out of the terminal of the circuit breaker.
4. Grasp the circuit breaker with the index finger and thumb by the top and bottom. Pull on the top of the circuit breaker, tipping it forward, and it should snap out of its location.
5. Insert the new circuit breaker in the reverse manner of how the old one was removed. Grasp with the index finger and the thumb set the bottom into the holder and push the top of the circuit breaker into its position in the distribution panelboard.
6. Reattach the conductor for the circuit using the screw terminal provided on the circuit breaker. Tighten the screw securely to the torque specified for the circuit breaker. If it is not tightened properly, there can be voltage drop, causing heat buildup and leading to the replacement of the breaker again. When hooking up conductors to circuit breakers, refer to the sizing table (*Table 4-7*). A 15 A circuit breaker should only be connected a minimum 14 ga wire, a 20 A circuit breaker should only be

attached to a minimum 12 ga conductor, and a 30 A circuit breaker should only be hooked up to a minimum 10 ga wire. When additional circuits are being added, the size of the conductor and overcurrent protection should be sufficient for the load that will be attached to the circuit. For example, if the circuit is being run for an air conditioner, and the air conditioner draws 16 A of current, a 20 A circuit breaker and minimum 12 ga wire would need to be provided. Never install a circuit breaker larger than the ampacity of the circuit or conductors. For example, never install a 20 A circuit breaker with a 14 ga conductor.

When installing auxiliary distribution panelboards, the panelboard should never be installed in a closet or area that can be used for storage unless it is within 2 in. of the outer edge of the compartment wall. This prevents the panelboard being hidden by stored items [reference NEC 551.45(B)].

An important factor to remember when working on distribution panelboards is that the RV is unlike a house! The RV has the neutral circuit isolated from ground. As explained earlier, this is so that reverse polarity cannot cause energizing the skin of the RV. The neutral in the distribution panelboard of an RV must always remain isolated from ground. Never attach the bonding strap or bonding screw (comes with a panelboard). These would normally be used in a house panelboard to connect the neutral bar to the distribution panelboard, as grounds and neutrals can be interconnected. If a bonding strap or bonding screw is present in a distribution panelboard intended for use in the RV, it should be immediately discarded.

NOTE: If the neutral is not isolated from ground in an RV, a serious hazard could exist.

4-6.1.3.2 Shore Power

Power supply cords for RVs are available in 120 VAC 15 A, 120 VAC 30 A, and 120/240 VAC 50 A versions. When replacing a damaged power supply cord, always replace it with one of equal capacity. Ensure that the power supply cord used is listed specifically for recreation vehicle use. This will normally be printed or embossed right on the power supply cord, but it may be marked only on its shipping carton. The power supply cord also must have a molded end where it attaches to the RV park pedestal. Never substitute extension cord-type materials for a listed RV power supply cord. Since the power supply cord's male end is required to be of the molded type, it cannot be replaced if damaged. The entire power supply cord must be replaced.

4-6.1.3.3 Generators

When installing a generator, it is often necessary to provide the supply cable from the generator to either a transfer switch or receptacle mounted on the RV, classified as the "first point of termination on the RV." The conductors from the generator to the first point of termination must be stranded and enclosed in some type of listed conduit. The service technician should always ensure that this conduit is not damaged. The conduit is to protect these conductors running from the generator to the first point of termination, since vibration could subject them to potential physical damage. When installing a generator, the junction box at the first termination of the generator supply conductors must be installed on the generator compartment wall or mounted to the floor of the vehicle or generator attachment bracket (NEC 551.30). NM cable commonly will be used to carry the generator current from the first termination junction box to a point of transfer method between generator and shore power. Since the generator and shore power circuits are not permitted to be attached to the vehicle circuits at the same time, some means must be used to ensure that the generator and shore power cannot be supplying current to the RV panelboard at the same time. One means used to do this is to run a conductor from the generator to a receptacle that matches the power supply cord's attachment configuration. When a generator is used, the RV's power supply cord must be plugged into this generator receptacle in order to get current from the generator to the distribution panelboard. In this way, it is not possible for the power supply cord to be plugged into the park receptacle and the generator's receptacle at the same time.

Another means of preventing generator and shore power from being supplied to the panelboard simultaneously is the use of a transfer switch. A transfer switch will allow only one source of current to be supplied to the distribution panelboard at a time. When the power supply cord is plugged in, the transfer switch will not allow current from the generator to flow to the distribution panelboard, and vice versa. Transfer switches used in recreation vehicles must be listed and must switch both hot and neutral wires. Transfer switches are available in both manual and automatic types. Many combination load centers on recreation vehicles have automatic transfer switches built right into the load center.

When installing wiring from the generator's first termination point to the transfer switch or receptacle, always ensure that a correct size conductor is used. If the generator circuit has a 30 A breaker, a minimum 10 ga conductor must be used. If the generator has a 20 A circuit breaker, a minimum 12 ga conductor must be used.

Overcurrent protection for the generator typically will be installed by the manufacturer if the generator is prewired. If not, generators listed for RV use will have built-in circuit breakers. Install only generators that are listed for RV use.

4-6.1.3.4 Conductor Routing and Securing

When adding accessories or new circuits, or troubleshooting existing circuits, make sure all conductors that pass through bulkheads and partitions have grommets or equivalent and are secured with clamps to prevent chafing due to vibration. All conductors that pass through bulkheads to the outside elements should be weatherproofed and sealed to help prevent carbon monoxide infiltration.

All 120 VAC conductors must be routed to prevent any potential for physical damage. Conductors must be routed along upper edges and corners of any area that could be used for storage. Conductors are not allowed to be routed along the floor of any storage area, even if protected by convoluted tubing. Where 120 VAC conductors pass through structure, grommets or equivalent must be used to protect from sharp edges. Where 120 VAC conductors pass through the actual vehicle wooden framing members in the wall, some type of steel plate protection must be used if the conductor is within 1-1/4 in. of either the inside or the outside surface of framing members. This is to prevent the conductor from being penetrated when cabinets, wall, ceiling, or floor coverings are reattached. Steel sleeves and steel plates are commonly available for this purpose. Anytime a 120 VAC conductor is routed on the vehicle exterior, it must be inside a listed conduit. Where exposed to physical damage, the conduit used must be approved for direct burial use. ("Direct burial" is a listing type that addresses "physical damage" that otherwise could not be defined. This listing allows many types of conduit previously not allowed.)

4-6.1.3.5 Power Inverters

An inverter changes direct current (DC) to alternating current (AC). Many RVs now have power inverters to provide AC at times when shoreline power in not available or the use of an auxiliary generator is not possible. An inverter will furnish quiet, vibration-free 120 VAC for those periods when generator use is not practical. Inverters are now common to the RV industry. However, it must be noted that inverters will not replace generators. They supplement generator usage by limiting generator run time for small AC loads. Similar to generators, inverters are rated in watts.

A power inverter must rely on good deep-cycle batteries to perform properly. When installing any inverter, always ensure enough battery capacity by checking the inverter installation instructions.

Inverters are solid state, which means they are subject to heat and vibration breakdown. It is important they be kept cool and dry. If installed according to the inverter manufacturer's installation instructions, any unit will be reliable, but care in their use must be observed.

Inverters are not easily repaired in the field. Since most inverters are solid state, there are few parts accessible to the technician. In-field service is typically limited to checking inputs and outputs, loose connections, broken or crimped wires, fuses, and so forth. The inverter manufacturer's service or installation manual should also be checked for additional troubleshooting procedures. When testing a modified sine wave inverter, a true RMS meter must be used for accuracy. Some inverters are supplied with an integral battery charger or transfer switch.

4-6.1.4 Connections

Any splice or connection in the 120 VAC wiring system must be inside a listed enclosure. Never install a 120 VAC device without using a listed enclosure or approved splicing device to protect the connections. Wiring connections in the 120 VAC system are commonly made using listed wire nuts. When using a wire nut, do not twist the wires together before putting the wire nut on. Simply strip the wires to equal length (approximately 1/2 in.), parallel the wires, and screw on the wire nut. Using listed electrical tape to help secure a wire nut is often recommended and is required by Canadian RV code (*CSA-Z240*).

4-6.1.5 Switches and Receptacles

On occasion, the service technician will have to replace switches and receptacles. There are two types of switches and receptacles used in RVs, as discussed earlier. One type is the self-contained receptacle that encloses the receptacle or switch connections in a self-contained box, and no separate outlet box must be used. The procedure for replacing this type of switch or receptacle is as follows:

1. Turn power OFF.
2. Remove the receptacle from its mounting by releasing the two screws holding the device to the wall. (These screws attach to two tabs that grip the paneling from behind.)
3. Pull the receptacle out from the wall to allow room to work on it.
4. Remove the back plastic snap-in piece by prying it off.
5. Pull the wire out of the cradle it is pushed into on the receptacle. Ensure that the wire is not damaged.
6. Install a new self-contained receptacle front onto the wire. Attach the back plastic piece using the special tool provided by the receptacle manufacturer and designed for this purpose.
7. Replace the receptacle back into the wall.
8. Turn power ON.

The other type of switch or receptacle used in an RV is exactly like those used in homes. The procedure for replacing a receptacle or switch of this type is as follows:

1. Turn power OFF.
2. Remove the switch or receptacle cover plate.
3. Remove the switch or receptacle using the two machine screws at the top and bottom.
4. Remove the wire from the old receptacle's terminals or push-in type connections. Connect the wire to the new receptacle or switch, push-in connection, or terminals. Push the receptacle back into the outlet box and connect to the outlet box using the two machine screws at top and bottom.
5. Reinstall the cover plate.
6. Turn power ON.

When reinstalling a switch or receptacle, always ensure that the ground wire is reconnected to the green grounding screw on the receptacle or switch. After a receptacle has been replaced, always double check to ensure that it has been installed with the correct polarity. Use the circuit tester for this purpose (see *"Testing the GFCI" on page 4-63*).

Also, when installing or replacing GFCI receptacles, the receptacle will be marked with connections for "line" and "load." Connect the conductor coming from the source to the "line" connection and the conductor going to other receptacle(s) downstream, where present, to the "load" connection.

4-6 Review

1. The wider blade of an AC plug will only fit into the slot connected to the ________________ side of a correctly wired receptacle.
2. A/an ________________ can be used to quickly determine whether a receptacle is wired properly.
3. RVs have the neutral circuit ________________ so that reverse polarity within the RV cannot cause the skin of the RV to be energized.
4. When replacing a damaged power supply cord on an RV,
   - A. Always replace it with one of equal capacity.
   - B. Always ensure that the power supply cord is listed for RV use.
   - C. Always ensure that the power supply cord has a molded end where it attaches to the RV park pedestal.
   - D. Never substitute extension cord type materials for a listed RV power supply cord.
   - E. All of the above.
5. Match the circuit breaker amperage rating with the minimum wiring requirement.

________	20 A	A. 12 ga wire
________	30 A	B. 10 ga wire

6. Automatic transfer switches do not have to be listed for RV use.

   True False
7. All conductors that pass through bulkheads to the outside elements must be weatherproof and sealed.

   True False
8. Anytime a 120 VAC conductor is routed on the vehicle exterior, it must be inside a listed conduit.

   True False
9. An inverter converts ________________ to ________________.
10. As a general practice, when using a wire nut for splicing, twist the wire strands together prior to putting the wire nut on.

    True False
11. Whenever a receptacle has been rewired or replaced, check the ________________ using a ________________.

Chapter

4-7 Wire Drawings and Symbols

- Read and interpret drawings, symbols, and schematics.

4-7.1 Electrical Drawings

In order to have an understanding of or to discuss problems of an electrical nature, it is important to be able to read electrical drawings. Schematics and pictorial drawings are the maps of electrical circuits and are among the most important aids to troubleshoot, maintain, adjust, and repair electrical systems.

There are three types of electrical drawings: pictorial drawings, ladder diagrams, and schematics. RV electrical systems make use of one or all three types. Many manufacturers furnish a set of drawings with their equipment to aid understanding of the equipment. These drawings may come in the form of a pictorial wiring diagram, which is an actual sketch of the unit components clearly showing all connections between them. *Figure 4-72* and *Figure 4-73* show sample pictorial drawings.

Figure 4-72 Sample 12 VDC Pictorial Electrical Drawing

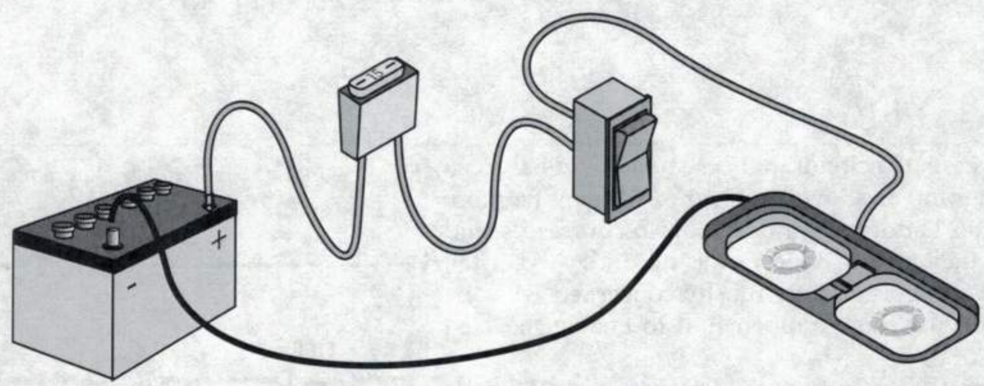
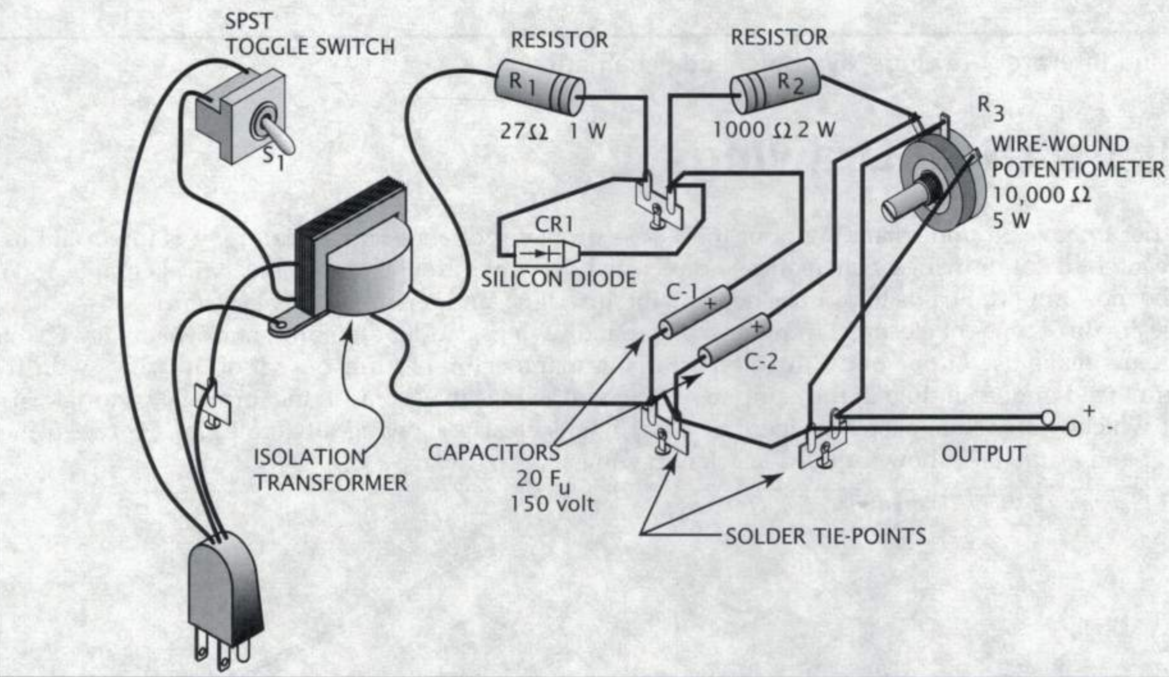


Figure 4-73 Sample 120 VAC Pictorial Electrical Drawing



In the case of a circuit that is sequential in nature, a ladder diagram, as shown in *Figure 4-74*, may be more appropriate. Ladder diagrams indicate processes and parts, but their physical location is not indicated. They use circuit symbols and are mostly concerned with the process of what must happen first to enable the next step to occur.

The most frequently used drawing is a schematic diagram, as shown in *Figure 4-75* and *Figure 4-76*. Schematics use standard circuit symbols and standardized drawing techniques. This drawing technique allows recognition of parts and connections as well as the electrical process and steps. Symbol identification is a must when using schematics or ladder diagrams.

Figure 4-74 120 VAC Ladder Diagram

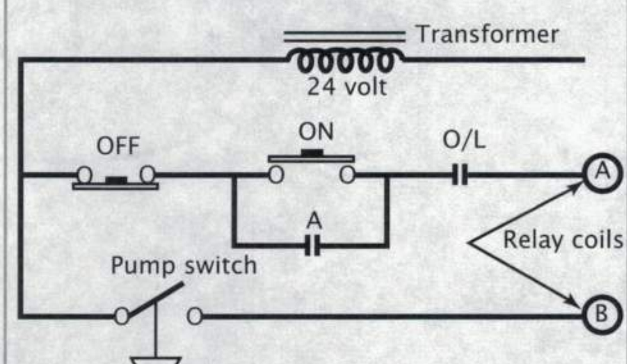


Figure 4-75 12 VDC Schematic

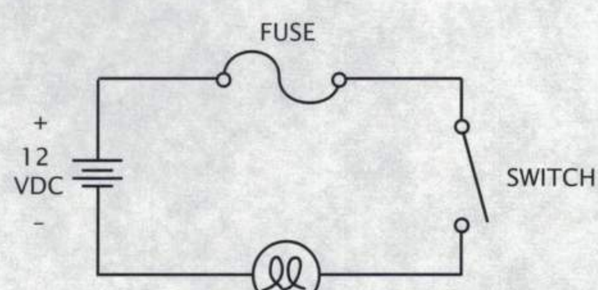
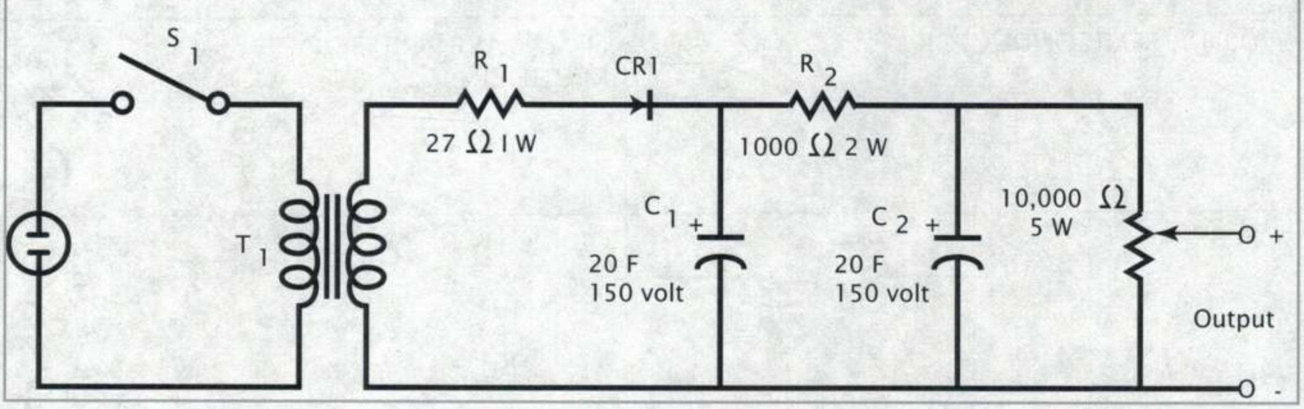
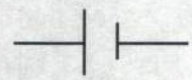
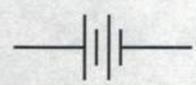
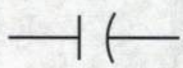
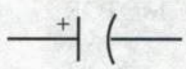
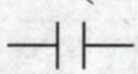
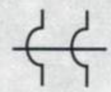
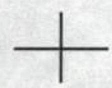
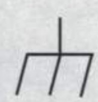
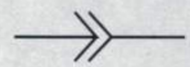
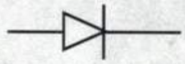
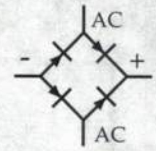
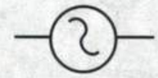
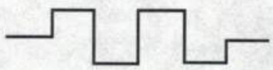
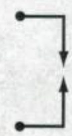
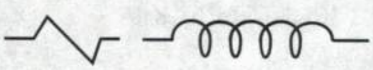
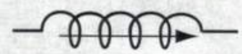
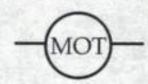
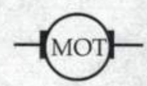
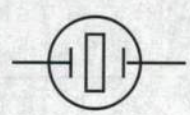


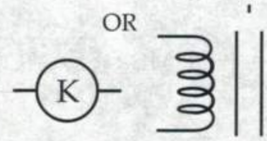
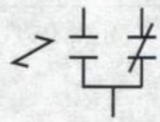
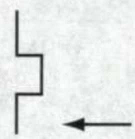
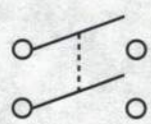
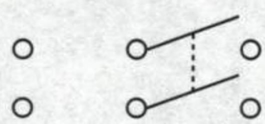
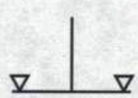
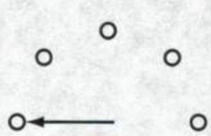
Figure 4-76 120 VAC Schematic

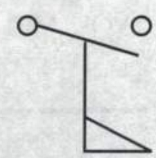
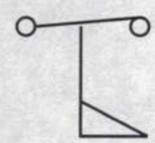
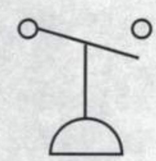
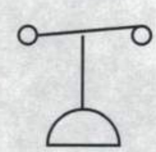
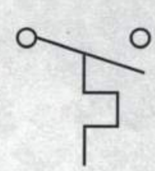


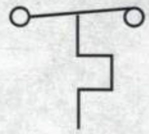
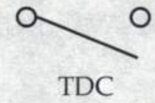
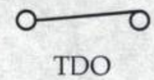
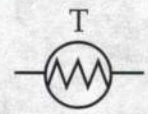
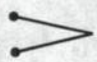
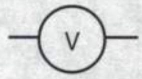
4-7.2 Electrical Symbols

COMPONENT/SYMBOL	COMPONENT/SYMBOL
AMMETER 	BATTERY (LONG LINE IS ALWAYS POSITIVE) SINGLE CELL  MULTICELL 
CAPACITOR FIXED  POLARIZED 	CIRCUIT BREAKER
CONTACTS CLOSED (BREAK)  OR  OPEN (BREAK)  OR 	CROSS, NO CONNECTION  OR 
CONNECTION  OR 	CONNECTION, CHASSIS (GROUND) 
CONNECTION, EARTH GROUND 	CONNECTOR 

COMPONENT/SYMBOL	COMPONENT/SYMBOL
DIODE, SEMICONDUCTOR 	FULL-WAVE, BRIDGE-TYPE RECTIFIER 
FUSE 	GENERATOR AC  DC 
HEATER 	IGNITORS GLOW COIL; GLOW BAR; HOT WIRE  SPARK IGNITOR, GROUNDED  SPARK IGNITOR, UNGROUNDED 
INDUCTOR (COIL) 	INDUCTOR (SOLENOID) 
LAMP 	MOTOR AC  DC 
OHMMETER 	PIEZOELECTRIC CRYSTAL UNIT 

COMPONENT/SYMBOL	
RELAY	
BASIC OPERATING COIL	 OR 
RELAY WITH TRANSFER CONTACTS	
THERMAL OPERATION RELAY WITH NORMALLY OPEN CONTACTS	
SWITCHES	
SINGLE-POLE, SINGLE-THROW (SPST)	
SINGLE-POLE, DOUBLE-THROW (SPDT)	
DOUBLE-POLE, SINGLE-THROW (DPST)	
DOUBLE-POLE, DOUBLE-THROW (DPDT)	
PUSH-BUTTON MOMENTARY NORMALLY CLOSED (PBNC)	
PUSH-BUTTON MOMENTARY NORMALLY OPEN (PBNO)	
ROTARY	

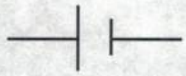
COMPONENT/SYMBOL	
RESISTOR	
FIXED	
VARIABLE	
SWITCHES (CONT'D)	
FLOW-ACTUATED SWITCH—CLOSES ON INCREASE IN FLOW	
FLOW-ACTUATED SWITCH—OPENS ON INCREASE IN FLOW	
PRESSURE (P) OR VACUUM (V) ACTUATED SWITCH, CLOSES ON RISING PRESSURE—LETTER IN SYMBOL	
PRESSURE (P) OR VACUUM (V) ACTUATED SWITCH, OPENS ON RISING PRESSURE —LETTER IN SYMBOL	
TEMPERATURE-ACTUATED SWITCH, CLOSES ON RISING TEMPERATURE	

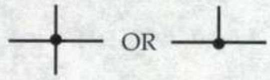
COMPONENT/SYMBOL	COMPONENT/SYMBOL
SWITCHES (CONT'D) TEMPERATURE-ACTUATED SWITCH, OPENS ON RISING TEMPERATURE 	SWITCHES (CONT'D) OPEN SWITCH WITH TIME-DELAY CLOSING (TDC) FEATURE  CLOSED SWITCH WITH TIME-DELAY OPENING (TDO) FEATURE 
TERMINAL 	THERMISTOR 
THERMOELECTRIC GENERATOR SINGLE THERMOCOUPLE 	THERMOPILE 
VOLTMETER 	

4-7 Review

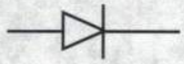
1. Match the following:

_______  A. Connection

_______  B. Earth ground

_______ 

C. Diode semiconductor

_______  D. Push-button momentary normally open switch

_______  E. Single-cell battery

_______  F. Fuse

2. List the three types of drawings a technician must be familiar with.

   A.

   B.

   C.

3. Ladder diagrams are more appropriate when a circuit is ________________ in nature.
4. The type of drawing that is used most frequently is a ________________ drawing.
5. A sketch of the actual components and wiring is called a ________________.

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Chapter

4-8 General 120 VAC Maintenance Procedures

- Demonstrate care for equipment and tools.
- Service the 120 VAC systems (including distribution panelboard, circuit breakers, and power supply cord components).
- Test 120 VAC breakers, GFCI, switches, cords, outlets.
- Perform GFCI test.
- Perform hot skin test.
- Perform polarity check.
- Verify neutral to ground separation.
- Measure branch/source voltage (static and loaded).
- Test, identify, and repair shorts and opens in 120 VAC wires.
- Measure amperage.
- Measure resistance/continuity.
- Use a VOM for troubleshooting procedures.
- Test 12 VDC motors.

4-8.1 Special Tools for Use in RVs

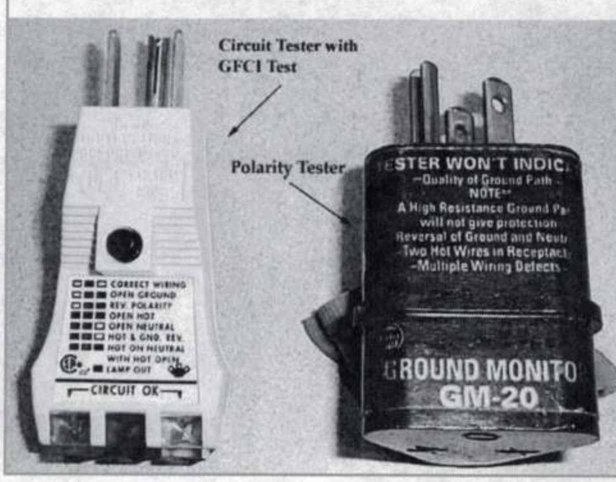
This section will cover some of the special tools used by an RV technician when servicing electrical systems.

The term "special tool" defines a piece of equipment or device that is used for troubleshooting, installing, or removing a specific component. Some examples of specialty electrical tools are:

1. Wire strippers
2. Circuit tester
3. Meters
    A. RMS voltmeter
    B. Multimeter or VOM
    C. DC and AC ammeter/clamp-on multimeter
4. 12 VDC test light
5. Diode tester
6. Board tester
7. Battery load tester
8. Hydrometer
9. Hi-pot tester

A CIRCUIT TESTER, as shown in *Figure* 4-77, is a device that plugs into a receptacle to analyze the circuit. These will commonly show many different types of defects in the circuit such as reverse polarity, open hot, open neutral, open ground, and so on. Some are also provided with a button that will create a fault for testing of GFCI receptacles or circuits. Use these devices according to the specific instructions for the device.

Figure 4-77 Circuit Tester and Polarity Tester

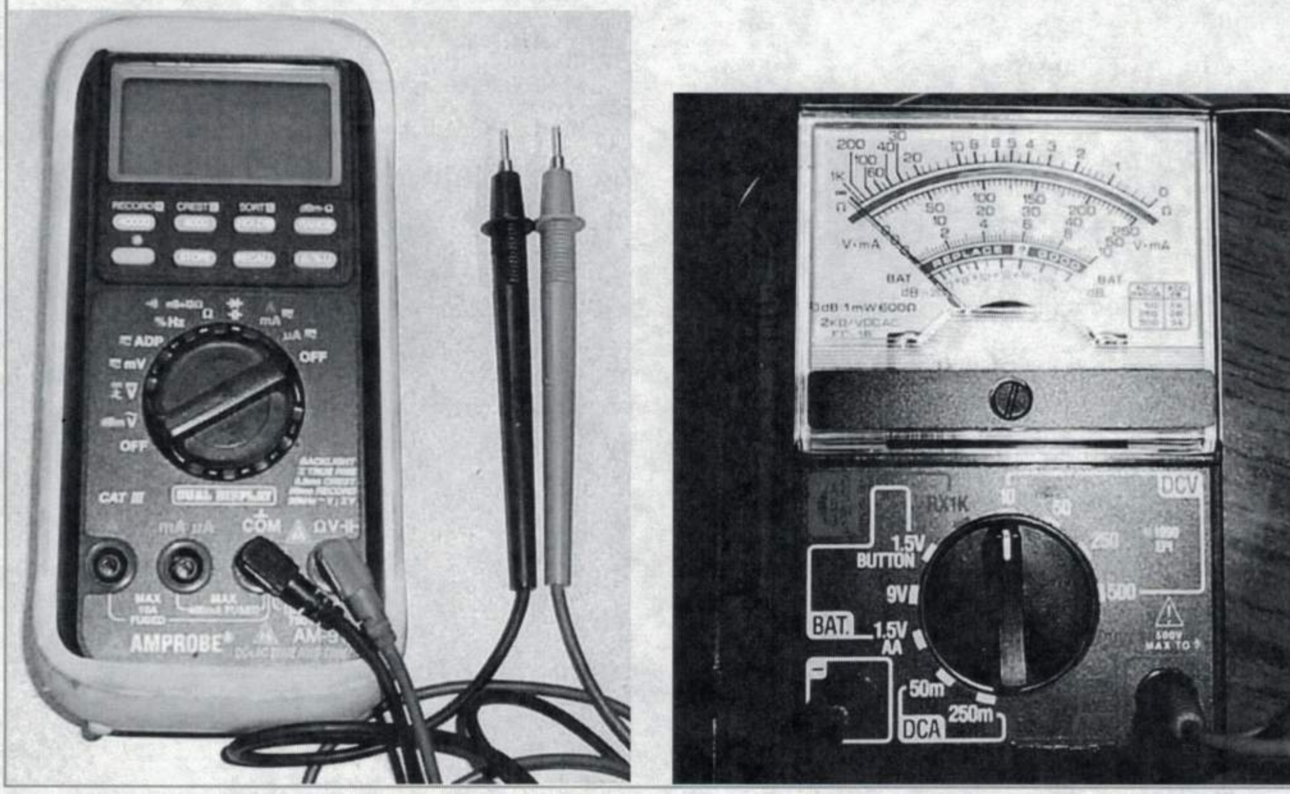


METERS are the most common pieces of equipment used in diagnosing problems with in the electrical system. The most common type of meter is the multimeter, as shown in *Figure 4-78*. A multimeter is a combination of several different types of meters. It provides a means for measuring voltage, amperage, resistance, and continuity. The use of meters will be discussed in detail in the paragraphs that follow.

The RMS VOLTMETER is required to obtain accurate readings from non-sine-wave AC sources (inverters and generators).

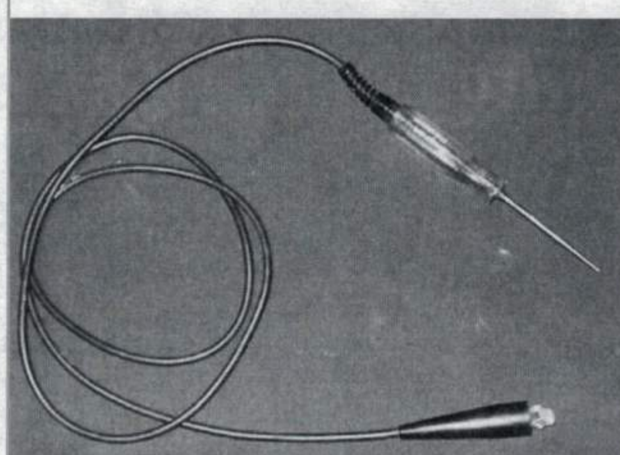
The VOM is a volt-ohm-multimeter of which examples are shown in *Figure 4-78*. It is used to measure voltage, resistance, and current (amperage). It is probably the most useful instrument an RV technician can own when troubleshooting electrical systems.

Figure 4-78 Multimeters



The 12 VDC TEST LIGHT, as shown in *Figure 4-79*, is a circuit tester designed for the 12 VDC system. It indicates the presence of voltage in a circuit.

Figure 4-79 12 VDC Test Light



The DC AND AC CLAMP-ON AMMETER, as shown in *Figure 4-80*, is designed to work on the principle of induction. There is no need to break into the circuit to measure current. Clamp around the DC wire or the AC conductor being measured to determine the current flow in that wire.

Figure 4-80 Clamp-on Multimeter

The DIODE TESTER is designed to test diodes found in battery isolators and converter systems (also found on many multimeters).

The BATTERY LOAD TESTER, as shown in *Figure 4-81*, allows the technician to apply a varying load to the battery. After a few seconds, the indicator is switched from amps to volts, and the resulting voltage will indicate whether the battery has the capacity to store amperage. The tester should be able to draw a maximum of 500 A DC from a battery. A carbon-pile battery load tester is recommended.

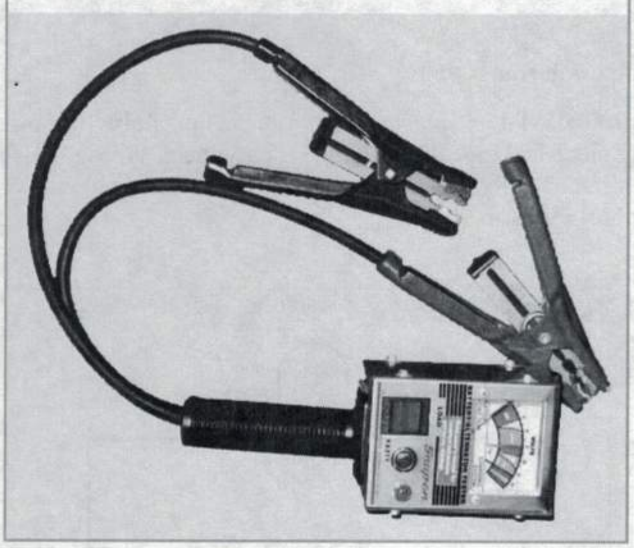


Figure 4-81 Battery Load Tester

The HYDROMETER, as shown in *Figure 4-82*, is used to measure the specific gravity of the electrolyte in a battery to determine the battery's state of charge or to find a bad cell. A temperature-compensated hydrometer is recommended.


Figure 4-82 Hydrometer

4-8.2 Use of Test Meters

Different rules and regulations are in effect for 12 VDC wiring versus 120 VAC. Although 12 VDC systems are allowed to use a single positive wire conductor with chassis ground for the return, two wires are usually run. Boxes are not required, and splices can be made with crimp connectors wherever needed. Larger wire sizes are normally used with the 12 VDC system, because 12 VDC draws approximately ten times more current than the same equipment on 120 VAC. Remember from earlier studies that the wire ampacity is the same with 12 VDC as it is with 120 VAC. Larger equipment such as motor loads (expandable rooms), furnaces, water pumps, lift jacks, electric steps, and refrigerators will have their own dedicated circuit. Coach lighting can usually be handled by circuits that may also include exhaust fans and auxiliary outlets.

Voltage, resistance, and current measurements are generally made with an analog volt-ohm meter (VOM) or a digital VOM multimeter. They both provide the same functions in measuring voltage, resistance, and current. Meters can be different, and meter operation should be explained in the meter's operator's manual. Always follow the manual's instructions. Typically, a switch on the front panel is used to set for setting the functions of testing voltage, resistance, and current.

Meters that indicate values with a moving pointer over a printed scale are called *analog* meters. Meters with numerical readouts that indicate specific values are called *digital* meters. To measure voltage, the test leads of the voltmeter are connected in parallel across two points of potential difference. For DC voltages, observe the correct polarity. Otherwise, the pointer on the meter scale will move to the left instead of up the scale to the right.

Similarly, to measure resistance in ohms, the two leads of the ohmmeter are connected across the resistance to be measured. Typically, a circuit is tested for resistance to determine if an open exists in the circuit (e.g., whether there a break in the circuit). Resistance testing of a circuit can be misleading if the circuit contains diodes. Diodes in the circuit may produce a false reading.

AC components being tested for resistance (ohms) must be isolated from the circuit. No power is needed to the component being tested, because the ohmmeter has its own internal battery. To measure current in amps, milliamps, or microamps, the meter must be in series with the component in the circuit. For this reason, current measurements are not as convenient as testing voltage and resistance in troubleshooting, unless an induction meter is used.

NOTE: Power in the circuit when testing for resistance will ruin a meter!

A meter, like the VOM with all three functions, is also called a *multimeter*. This meter is probably the most important type of test equipment when troubleshooting electrical circuits, because it can check voltage, resistance, and current. The nondigital (analog) multimeters are basically DC meters. However, an internal rectifier is included to convert AC values to DC values for the meter measurement.

4-8.2.1 Range Scales

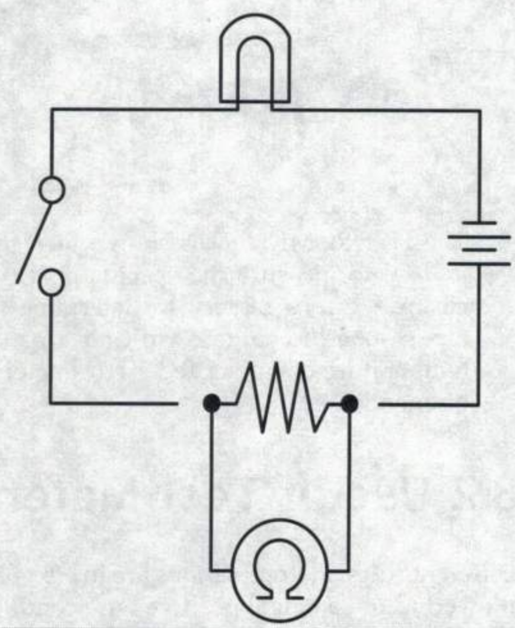
Range scales are adjustable by using a range switch on the meter. The AC-only scale indicates AC measurements with a full-scale reading. Sometimes the AC/DC function has more than one. Be sure to set the meter to read the applicable range.

4-8.2.2 Measuring Resistance

The steps for measuring resistance with an analog or digital meter are as follows:

1. Place the meter in a safe position.
2. Select the resistance mode, and select the middle range.
3. Zero the meter (analog only).
4. Turn off the power to the circuit.
5. Disconnect the component from the circuit.
6. Connect the meter to the component.

Figure 4-83 Measuring Resistance



7. Select the range that puts the pointer near the middle of the scale (analog only).
8. Disconnect the leads and check that the meter reads zero (analog only).
9. Reconnect the leads and read the indicated value.
10. Multiply the indicated value by the range to determine the component resistance (analog only).

4-8.2.3 Measuring Voltage

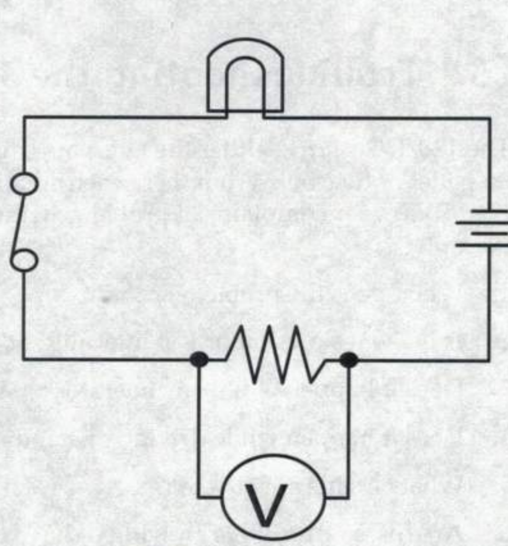
The steps for measuring voltage using an analog or digital meter are as follows:

1. Place the meter in a safe position.
2. Select the voltage mode, AC or DC.
3. Switch to the highest voltage range.
4. Ensure that the meter capacity is greater than the expected voltage.
5. Connect the leads of the meter as follows:

   Connect the black lead to the circuit ground.

   Connect the red lead to the live side of the circuit.
6. Switch down to the best range.
7. Read the indicated value.

Figure 4-84 Measuring Voltage

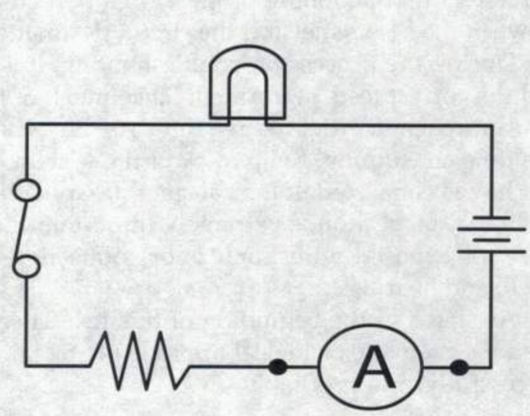


4-8.2.4 Measuring Current

The steps for measuring current on an analog or digital meter are as follows:

1. Place the meter in a safe position.
2. Select the current mode, AC or DC.
3. Switch to the highest current range.
4. Ensure that the meter capacity is greater than the expected amperage.
5. Turn off the power to the circuit.
6. Disconnect the circuit at the point where the current is to be measured (fixture leads of light, switch, or similar).
7. Connect the meter between the disconnected leads created in step 5 above (in series) to the meter (observe polarity in the DC mode).
8. Turn on the power to the circuit.
9. Switch to the lowest safe range.
10. Read the indicated value.
11. Turn off the power to the circuit.

Figure 4-85 Measuring Current



12. Return the circuit to its original condition.

Meters vary in their ability to measure circuit parameters. Manufacturers' specifications describe this ability in terms of accuracy, sensitivity, frequency response, and a variety of other characteristics. Even after all due care is taken to select the best meter for a specific test, the measurement ultimately depends on the meter user. Most of the time it is not the meter that makes the error, but the user.

4-8.3 Basic Methods for Troubleshooting

4-8.3.1 Troubleshooting the 12 VDC System

The 12 VDC source, either the alternator, battery group, converter, or solar array, is connected to a distribution panel or fuse box. From there each circuit is routed to its equipment destination.

If an RV owner complains of problems with the 12 VDC system, it is extremely important to ask questions. For example:

1. When does the problem occur?
2. Is it always present or is it intermittent?
3. Does it happen while on generator or supply power?
4. Does it happen while driving or standing still?
5. What circuits are effected?
6. Are fuses or breakers blowing or have they been blown?

The more questions asked, the better the chances are of isolating the problem. At the onset of the problem, the customer usually knows more about the symptoms than the technician. Be sure to take advantage of it.

Assume a converter is operational, the batteries are fully charged, and all AC voltage sources that feed the converter are functioning properly. If a particular circuit is not functioning, it is safe to assume the problem is between the fuse panel and the circuit destination.

During the process of troubleshooting, it is important that the proper tools and test equipment are used and the correct tests performed. Since much of the time is spent locating the trouble, there must be some suitable approach in order to save time. As the technician becomes more familiar with troubleshooting, it becomes less time consuming. Keep track of the system operations already tested. Make a list of the probable troubles that have been tested. If logical steps are followed, most problems will be able to be located.

Initial inspection is extremely important. Look for broken, burned, loose, or worn parts; chafed, broken, loose, or exposed wires; and poor connections. Initial inspection involves all of the senses of sight, touch, smell, and hearing.

As stated at the beginning of this text, successful technicians have "reasoning ability." They have developed a systematic or logical approach to isolating the failed circuit or component and repairing it efficiently, successfully, and profitably.

4-8.3.2 Troubleshooting the 120 VAC System

The most common problem with the 120 VAC system is a short or open. Shorts can be between hot and ground, hot and neutral, or neutral and ground. The most common cause of a short is that screws or staples have worked through into the wire or a sharp edge has damaged the conductor's insulation. There are times when objects will accidentally become lodged in the slots of the outlet socket. There will also be occasions when wires come loose or chafe together due to vibration. A short may trip a circuit breaker or make the chassis of the RV "hot." See *Figure 4-86* for illustrations of some common circuit problems.

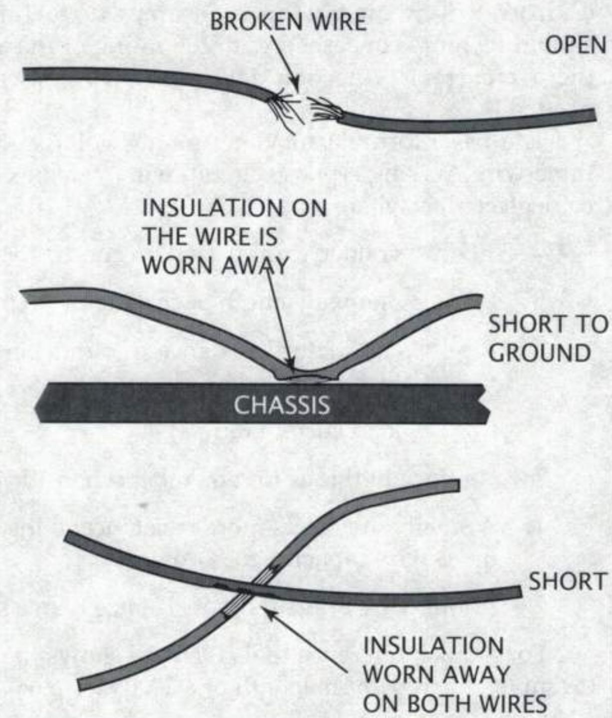


Figure 4-86 Common Circuit Problems

In the case of a circuit breaker tripping, check the wiring diagram or schematics, if available, to determine what system or devices are on the circuit that breaker is protecting. Then begin disconnecting each device one at a time until the circuit breaker stops tripping. In the event the problem continues, use the ohmmeter and read the resistance from the hot wire (black) to neutral (white) and between hot and ground (bare or green). A short would indicate a reading of zero resistance. An open would indicate a resistance reading of infinity. Another way to find a short is to use a circuit tracer. This is a device that injects a signal into the circuit, enabling the signal to be followed with a receiver directly to the short. The circuit tracer can also be used with DC circuits.

An open is usually a loose or broken wire or a bad connection. It can be isolated to a particular circuit almost in the same manner as a short. Use the wiring diagram again and determine what other systems or devices are on the same circuit as the device that is not receiving power. Working with 120 VAC means parallel circuits, and in most cases, each device receives its power from the one it follows in that circuit. This means the devices that make up the circuit in question are in parallel with each other and the 120 VAC is fed sequentially to each parallel branch. Now check continuity between the last parallel branch in the circuit that has power and the branch in question. A voltmeter can be used to locate a short or open as covered in a *Section 4-8.2*.

If a defective component, such as a circuit breaker or receptacle, or a bad connection is detected, replace or repair it according to specifications. If the problem is a broken or chaffed wire, replace the entire length of wire or make a splice inside a junction box or devices listed for this purpose (Molex®). Never splice AC wires without using a junction box or devices listed for this purpose (Molex®).

NOTE: Be sure the power is off when checking continuity.

4-8.3.3 Wire Size and Voltage Drops

When electrical accessories are added, it is important that the circuit in which they are connected be of sufficient capacity to take care of the increased load. Low voltage in a circuit can cause lights to dim, television pictures to "shrink," motors to run hot, and appliances to not operate properly.

Possible Causes:

1. Wire that is too small for the load being served
2. A circuit that is too long
1. Overloaded circuits at the campground
2. Poor connections at the terminals or ground
3. Conductors operating at higher temperatures
4. Anything in the circuit that causes additional resistance

Low voltage due to any of these causes can be checked with a voltmeter. Voltage drop in any circuit must be kept at a minimum. All connections must be clean and tight. Determining voltage drop is quite advanced for the RV service technician. There are times when voltage drop may need to be determined. This is particularly true when long runs of wire are used for higher loads. Calculations may be needed when adding electrical loads to a circuit, but this is generally done during the design process. Technicians adding loads to circuits should be more concerned with the rating of the added load, the size of the circuit conductor, and the size of the overcurrent protection device. Knowing how to calculate voltage drop is convenient but not generally needed.

The basic formula for determining voltage drop in a two-wire DC circuit, a two-wire AC circuit, or a three-wire AC single-phase circuit, with a balanced load at 100 percent power factor and where reactance can be neglected, is where:

VD = voltage drop (based on conductor temperature of 75°F)

L = one-way length of conductor (in feet) from beginning of circuit to the load

R = conductor resistance in ohms per thousand ft (from conductor properties tables in National Electrical Code)

I = load current (amps)

Two important things to remember when adding accessories to a circuit are:

1. A small wire offers more resistance to the flow of electrical current then a larger wire. Resistance goes up as wire capacity goes down.
2. A long wire offers more resistance than a short wire. Resistance goes up as length goes up.

For a quick reference tool, *Table 4-8* shows the maximum length of wire for each gauge size and load. For example; the maximum length of a 2000 W (16.66 A) circuit using #14 AWG wire is 27 ft.

Table 4-8 Wire Sizes for 120 VAC, 2% Voltage Drop

Wire Size		14	12	10	8	6	4	2
Watts	Amperes @ 120 Volt	Distance (Feet)						
100	0.84	550	880	1330	2080	3400	5500	8500
200	1.67	275	440	665	1060	1690	2750	4300
250	2.50	183	290	450	710	1130	1850	2840
400	3.33	137	220	330	530	840	1380	2150
500	4.16	110	175	265	430	680	1100	1700
750	6.25	73	115	177	285	450	740	1140
1000	8.33	55	83	130	214	340	550	850
1500	12.50	36	57	88	146	225	365	575
2000	16.66	27	42	68	104	166	275	430
2500	20.80	22	37	52	83	135	220	365
3000	25.00	18	26	42	68	115	188	285
3500	29.20	-	23	37	63	94	155	245

Table 4-8 Wire Sizes for 120 VAC, 2% Voltage Drop

Wire Size		14	12	10	8	6	4	2
Watts	Amperes @ 120 Volt	Distance (Feet)						
4000	33.30	–	21	31	52	83	134	217
4500	37.50	–	15	29	46	73	119	176
5000	41.80	–	–	26	42	67	108	166
6000	50.00	–	–	21	36	57	88	140
7000	58.30	–	–	–	29	46	78	119
8000	66.60	–	–	–	26	42	67	104
9000	75.00	–	–	–	–	36	57	93
10000	83.30	–	–	–	–	31	52	83

4-8.3.4 Locating Problems with a Voltmeter

A voltmeter is preferable in locating trouble in an electrical system, because it is not necessary to disconnect any wires when making voltage tests. A voltmeter must always be connected in parallel with the circuit or load, as shown in *Figure 4-87*. When a voltmeter is connected in this way, it will measure the voltage drop across the load. In this case, it would be the source voltage, since there is only one load in the circuit. When a voltmeter is connected to a circuit, as shown in *Figure 4-88* (on the negative or positive side of the load), there should be no reading on the voltmeter, because there is no potential difference in that part of the circuit. If, however, there is damage to the wire, such as a pinch that has caused some broken strands, as shown in *Figure 4-89*, the meter sees it as a resistance (second load) that will cause a second voltage drop. If the load is a light, it won't burn as bright until the bad wire is replaced. When using the voltmeter in this way, any reading along the wire is an indication of excessive resistance. Of course, with the parallel hook-up, if the voltmeter reads zero, it indicates that all connections are clean and tight, and the cable or wire is the correct size and is in good condition.

Figure 4-87 Voltmeter in Parallel

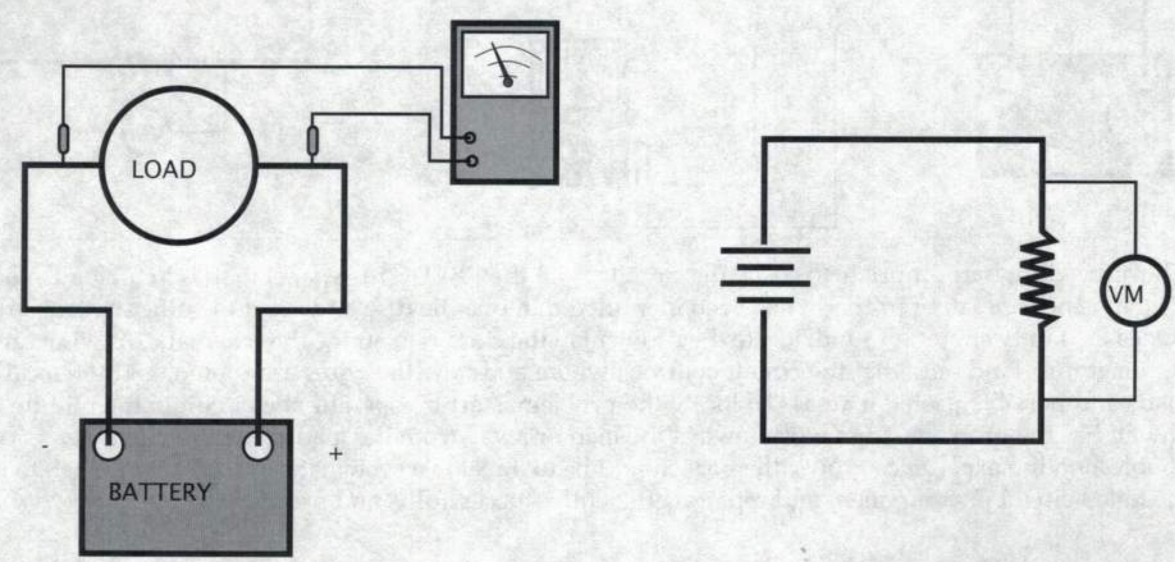


Figure 4-88 Voltmeter to Circuit

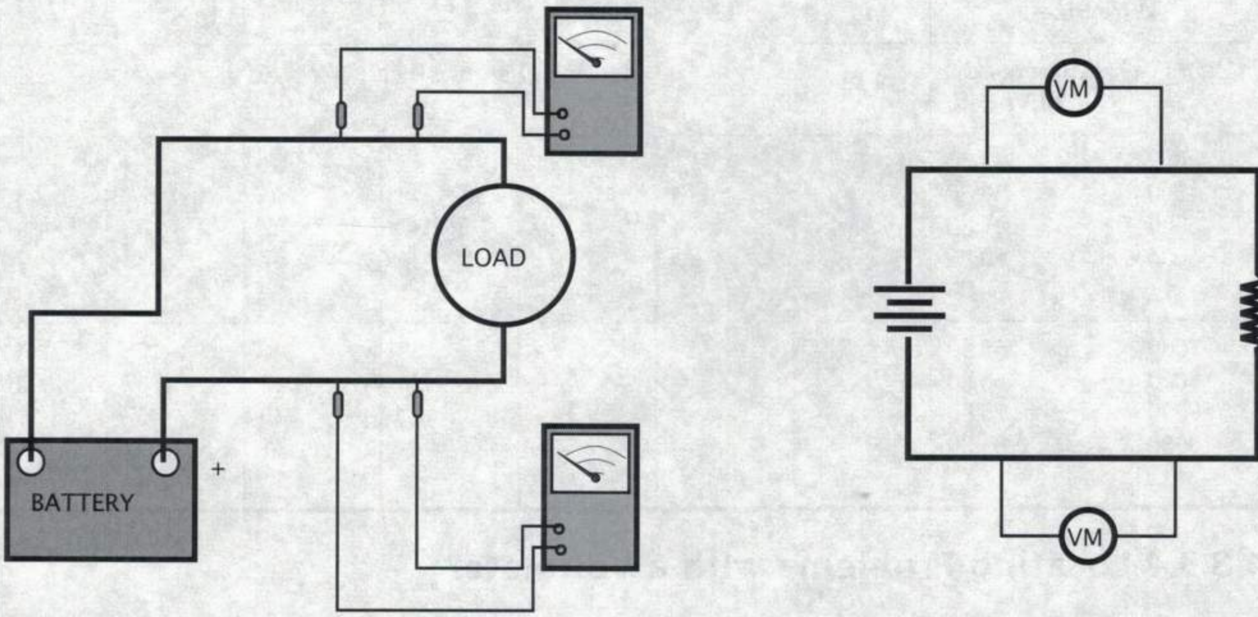
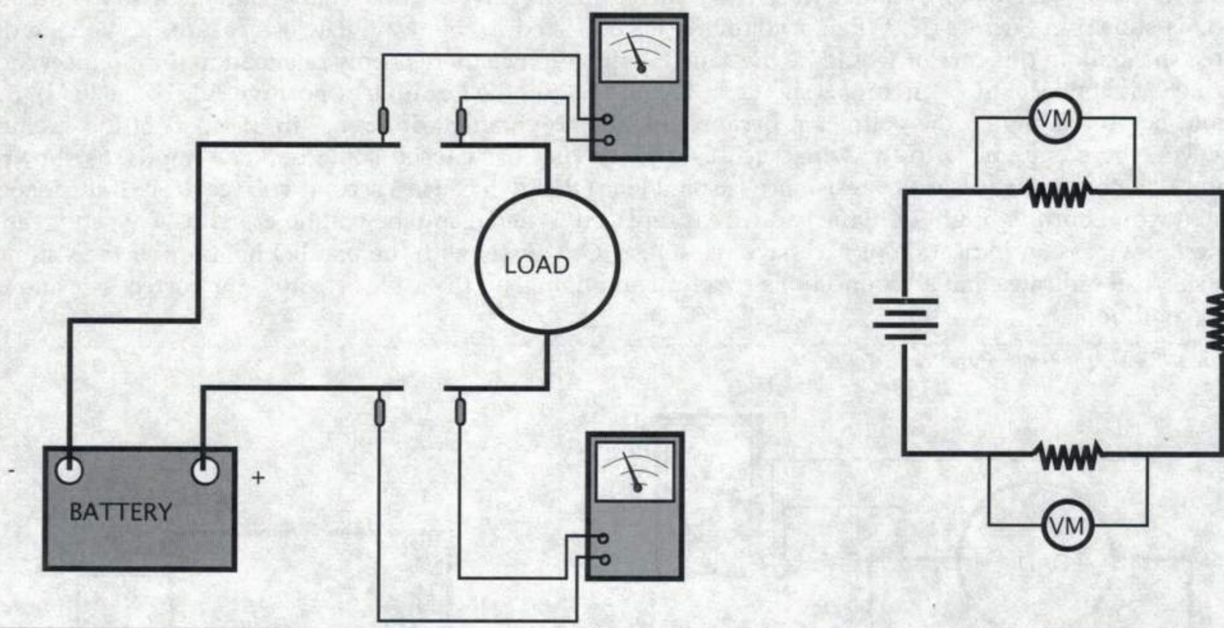


Figure 4-89 Voltmeter to Damaged Wire



This procedure is appropriate to check the circuits from the 12 VDC fuse panel to the circuit load. Once the circuit that is not operating properly has been identified, remove the fuse and see if the other circuits are normal. Once the faulty circuit is found, locate the problem in the circuit. Examine the schematic drawings and the wiring diagrams. Find out what the circuit controls, where and how the wires are routed, and the location of the loads and possible problem areas. To locate the problem, start by opening the circuit in the middle to see which half has the problem. Then work toward the load or away from the load using the voltmeter as before. As troubleshooting experience grows, the goal should be to develop a systematic or logical approach to isolating the failed circuit or component and repair it efficiently, successfully, and profitably.

Some of the obvious things to look for are:

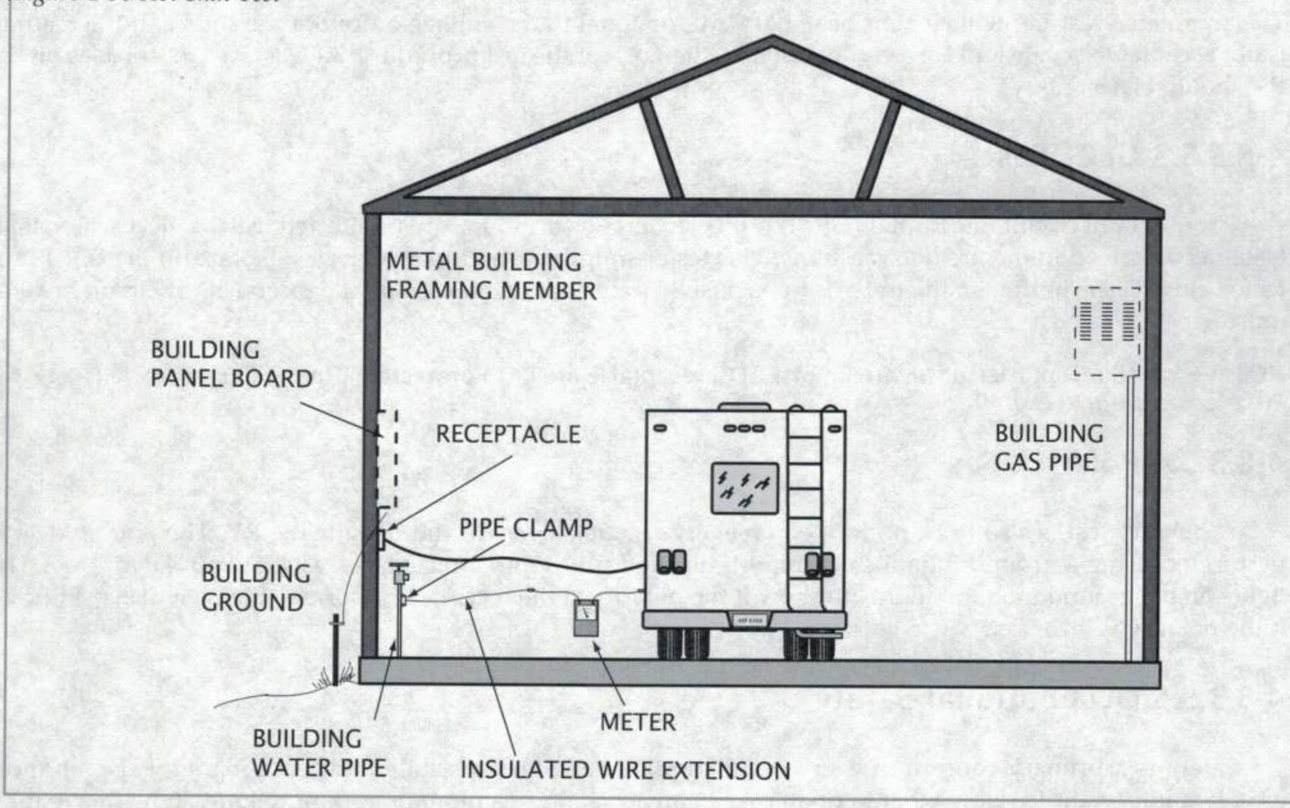
1. Loose or corroded ground connections
2. Open wires
3. Shorted wires
4. Dirty or bad connectors
5. Grounded wires or connections (to skin or frame)
6. Broken or cracked components
7. Overheated wires or components
8. Poor work done previously
9. Incorrect wire size
10. Too many devices on the circuit

As stated in the first section of this text, successful technicians have "reasoning ability."

4-8.3.5 Testing and Safety

4-8.3.5.1 Hot Skin Test

Figure 4-90 Hot Skin Test



1. Turn all circuit breakers ON. Plug the unit's power supply cord into an external 120 VAC receptacle.

2. Using a voltmeter set on the 250 VAC scale, test for an electrical short. Place one voltmeter probe on a bare metal surface of the RV (e.g., a door frame) and the other probe on an earth ground source (e.g., a water pipe). Repeat the test at least twice, changing the placement of the voltmeter probe on the RV's bare metal surface (e.g., window frame or door step).

   A. If there is a "0" reading on the voltmeter, the skin of the unit is not hot. Proceed with the AC voltage test.

   B. If the skin of the unit is hot, there will be a reading on the voltmeter above or below "0" depending on how the probes are attached. This reading indicates that there is an electrical short. Locate and correct the short, then repeat the hot skin test procedure.

Many technicians think that fiberglass and other nonmetal composite materials have eliminated the need for a hot skin test. This is not true! As long as the chassis, steps, or any other part of the RV is made of metal or some other conducting material, the hot skin test needs to be conducted.

Hot skin problems in RVs are typically high-resistance shorts. High-resistance shorts do not cause breakers to trip or fuses to blow. These types of shorts may result from the insulation on the wire(s) rubbing thin, where they can cause problems, but not a dead short. Another example would be where the white (neutral) wire is cross-connected with the ground. In this case, where there is also reverse polarity, the power would bypass the circuit breaker(s) and not be impacted by the overcurrent protection. Of all the tests that are conducted, this is one that should be conducted on every RV that is having service to the electrical system.

4-8.3.5.2 AC Voltage Test

Check all interior and exterior 120 VAC receptacles with a line voltage tester or a multimeter. The multimeter should be set on the AC voltage scale. Place the test probes into the two slotted openings of a receptacle. The acceptable reading will be at or near 120 VAC, or equal to the voltage output of the source. If the reading is not acceptable, locate and correct the problem, then repeat the test procedure. At least two receptacles on the RV should be tested.

4-8.3.5.3 GFCI Test

Ground fault circuit interrupter (GFCI) protected circuits on an RV are best tested using a electrical system tester as described in the previous sections. This tester simply plugs into receptacles that are on the GFCI protected circuit. The button on the tester is to be pushed to introduce a fault, and the receptacle or circuit breaker must trip.

NOTE: All receptacles downstream of a GFCI receptacle are GFCI protected if the GFCI receptacle is properly wired.

4-8.3.5.4 Polarity Test

A polarity test is also to be preformed on every receptacle inside and outside the RV. The polarity test is performed using a ground monitor or circuit tester that plugs into a receptacle, as shown in *Figure 4-77*. The lights on the ground monitor "light" to show if the polarity at the receptacle is correct. Lights will also indicate if the polarity is incorrect.

4-8.3.5.5 Occupational Safety

Safety is a primary concern in every occupation, because the possibility of being injured exists in most jobs. It is important to know what to do in case of an accident. It is more important to know how to avoid an accident. Accident prevention is key.

Electrical shock can kill. The amount of electricity that is fatal depends on many conditions, including how someone comes in contact with the circuit, the path the electricity takes through the body, how well an individual is insulated from the floor, and the person's general health. Many technicians have already had the unpleasant experience of being shocked by a 120 VAC outlet. Many people have died from this type of shock.

The body is a fairly good conductor of electricity, and when a person touches an electrically live point, current tries to flow through the body to ground. Depending on the body resistance, a severe electrical shock or even death can be the final result (see *Table 4-9*).

Table 4-9 The Effects of 60 Hertz Alternating Current on the Human Body

Current	Effect
1 milliamp (mA) or less	No sensation—not felt
5 mA	Painful shock
10 mA	Local muscle contractions, sufficient to prevent a person from being able to let go of the circuit for 2.5 percent of the population
15 mA	Local muscle contractions, sufficient to prevent a person from being able to let go of the circuit for 50 percent of the population
30 mA	Breathing difficult, can cause unconsciousness
50 to 100 mA	Possible ventricular fibrillation of the heart
100 to 200 mA	Certain ventricular fibrillation of the heart
Over 200 mA	Severe burns and muscular contractions, heart more apt to stop than fibrillate
Over a few amperes	Irreparable damage to body tissues

An RV technician can be shocked, burned, cut, or injured in some manner. Injury can result from the worker's action or the actions of someone near the worker. The degree of injury can range from a cut requiring a small bandage to death by electrocution. Most accidents are not accidents at all but are the results of negligence. When an accident occurs, it must be reported to the supervisor. Then all concerned should decide how to avoid a recurrence of the accident.

Proper emergency response is critical. Know where the fire extinguishers and alarms are located and what to do if someone gets shocked. This knowledge is part of a technician's responsibilities. Think before turning on a switch. Determine if anyone is working on another part of a circuit before energizing it. Don't leave things around for other people to fall over. Check to be sure that power supply cords are not frayed, exposing bare wire. Keep work areas clean.

Remember, each technician is responsible for the products and systems being processed. To be safe, operate the equipment according to the instructions. Listed below are some of the safety practices that should be followed at all times when working on 120 VAC electrical systems.

4-8.3.5.6 Special 120 VAC Safety Precautions

The following special precautions should always be taken when working on the 120 VAC electrical system:

1. Turn off the power to circuits when working on 120 VAC systems. This is the most basic safety rule for 120 VAC system work. Turn off the circuit breaker servicing the circuit or unplug the RV altogether. When turning off the circuit breaker, as opposed to unplugging the RV, test the circuit with a meter to ensure it is de-energized before beginning work.
2. When working on or near circuits that must be energized, always use insulated tools.
3. In the event it is necessary to probe live circuits or work on a plugged-in distribution panelboard, keep one hand behind your back. This is something all professional electricians are taught to do. By using only one hand for the probing, the chances of electric current passing through the heart are minimized. Even if a person were grounded at the feet, the current would still pass mostly through the right side of the body, passing from the right hand down through the legs. If both hands were used, current could pass from one hand to the other, passing directly through the heart. Also, if the right hand is used, a better chance of current passing through the right side of the body exists. The most common cause of electrocution death is defibrillation of the heart. The large electric shock stops the heartbeat.
4. Work in a dry area, and always wear properly insulated footwear. This is to prevent the technician being grounded while working on the RV. Also, always be very careful about kneeling or laying on the ground while working on live 120 VAC current. Any time any part of the body is grounded through contact with the floor (especially concrete, asphalt, or bare ground), a much greater electrical hazard exists. Therefore, technicians should always try to prevent any situation in which they are grounded and working on the RV from the outside. There is generally a much slighter chance of being grounded when the technician is working inside the RV.
5. When using meters and other test equipment, check the test leads for such defects as broken or cracked insulation and broken or cracked probes. If broken or cracked, replace or repair before using.
6. Always hold test leads by the insulating sleeves (solid sleeves on end of leads) when making tests. Never hold leads by the metal test points, as this may cause false readings and possible injury.

When installing or maintaining electrical components on an RV, it is very important to remember some basic safety issues. All devices and appliances within the 120 VAC system must be listed. Therefore, when replacing components such as outlet boxes, junction boxes, light fixtures, and so forth, the technician should always be sure to use a listed fixture. Another very important electrical concept is grounding. Grounding of electrical equipment is provided so a low-resistance path to ground from any electrical device is provided in the event of a fault current. In this way, in the event of a fault where current is available to a human being, a lower-resistance path to ground is available for the current. Since current will always take the path of least resistance, there will then be a better chance of current flowing through the grounding system rather than the human body being shocked. Grounding also ensures that overcurrent protection devices will function. All metal electrical equipment in the 120 VAC electrical system must always be grounded. A main #8 gauge ground conductor is always provided to bond the distribution panelboard to the chassis of the recreation vehicle. In this way, all electrical and metal components of the RV are picked up in the grounding system and then grounded through the connection of the power supply cord to the grounded receptacle of the power source.

4-8.3.5.7 Repairing Electrical Systems

As in all repair work, the technician must be safety conscious at all times. In addition, the technician must also have pride in the work performed, confidence in the use of knowledge learned, and satisfaction knowing that the job is completed at the highest professional level possible. All repair work must be checked for safety, accuracy of measurements, and tolerances as per manufacturer's specifications. When a repair job is completed, answer the following questions:

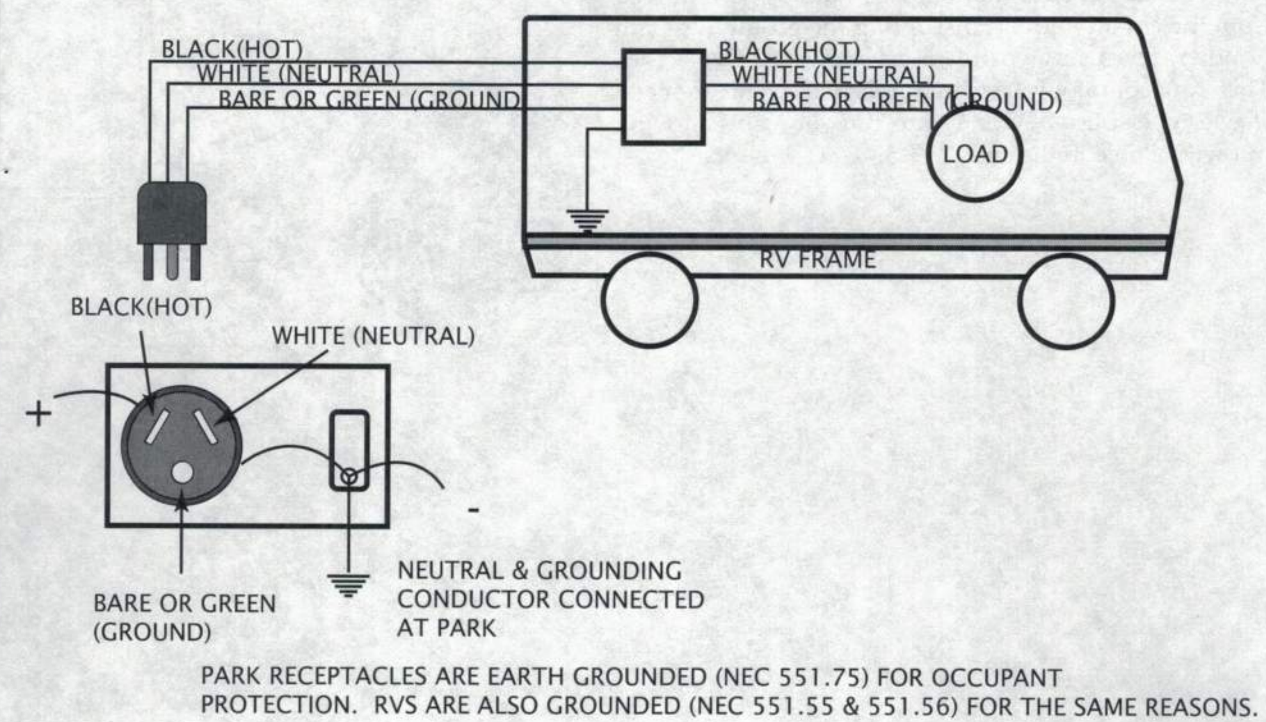
1. Was polarity observed when making wire and cable connections?
2. Were any cables or wires pinched while working on system?
3. Were all cables and wires secured away from any heat source?

4. Were the correct connectors used?
5. Were all connections clean and tight?
6. Are all solder connections made properly?
7. Were any wires burned while soldering?
8. Did any solder fall into other areas of the system?
9. Was the correct specification used for measurements and values?
10. Were all parts reinstalled properly?
11. Was the last area worked in left cleaner then it was before the work started?
12. Is the work satisfactory?

4-8.3.5.8 Grounding Electrical Equipment

All outlets and other metal equipment in the electrical system must be grounded.

Figure 4-91 Grounding Electrical Equipment



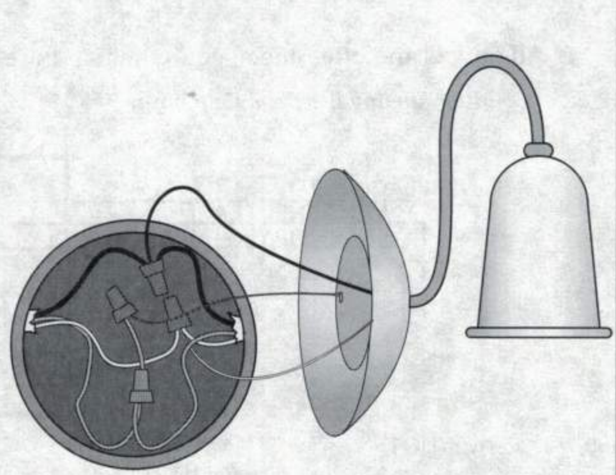
When replacing electrical components, the technician should always ensure that the grounding connection is made. The grounding connection in a light will normally be a braided wire coming off the 120 VAC light fixture that must be interconnected with the grounding conductor in the nonmetallic sheath cable servicing that fixture. When grounding a metal electrical device such as a junction box, listed grounding means must be employed. The two most common listed grounding means are a ground clip that attaches the grounding conductor from the nonmetallic sheath cable to the edge of the junction box or a grounding screw in the bottom of the junction box to which the grounding conductor is attached. Technicians should always ensure that a listed grounding means has been employed for any device installed in the electrical system.

Figure 4-92 Grounding to Frame

4-8.3.5.9 Grounding Continuity

All devices in the 120 VAC electrical system must be installed to provide grounding continuity to other devices downstream. This means that if a device is removed for service, it should be able to be removed from the circuit without disrupting the grounding path of other devices downstream, as shown in *Figure 4-93*. This can commonly be accomplished using a metal sleeve-type splice device, crimp ring, or a special wing nut with a hole in the end.

Figure 4-93 Ground Continuity/Light



4-8 Review

1. What are the two most common faults found with a 120 VAC system?

   A.

   B.

2. A reading of zero resistance indicates a/an ________________.
3. A reading of infinity indicates a/an ________________.
4. A loose or broken wire or a bad connection will cause a/an ________________.
5. 120 VAC circuits are wired in

   A. series

   B. parallel

6. Because of item 5 above, power is fed to each device

   A. sequentially

   B. simultaneously

7. When splicing a 120 VAC wire, always ________________

   A. use listed electrical tape

   B. use a junction box

   C. both A and B

   D. 120 VAC wires are not to be spliced.

8. A major concern when adding accessories to a circuit is to determine that the circuit will have sufficient current to take care of the increased ________________.
9. A Hot skin test is an electrical test of the RV that determines if the vehicle has a/an ________________

   A. open

   B. short

10. ________________ milliamps is sufficient AC current to cause painful shock.

    A. 1

    B. 5

    C. 10

    D. 15

11. List at least four special 120 VAC safety precautions to which all technicians should always adhere.

    A.

    B.

    C.

    D.

12. Explain the purpose of a ground.

13. Match the following:

________	Multimeter	A. Allows technician to apply a varying load to a battery
________	Load tester	B. A volt, ohm, ammeter
________	Hydrometer	C. Used in troubleshooting, tuning, or setting up a generator
		D. Designed to test printed circuit boards
		E. Designed to test diode type battery isolators
		F. Used to measure specific gravity in electrolyte

14. Larger wires are normally used with the 12 VDC system because 12 VDC draws approximately ________________ times more current than the same equipment on 120 VAC.

    A. 5

    B. 10

    C. 15

    D. 20

15. ________________ is the same with 12 VDC as it is with 120 VAC.

    A. Voltage

    B. Wattage

    C. Ampacity

    D. Resistance

16. List five obvious things a technician should look for when troubleshooting an electrical system.

    A.

    B.

    C.

    D.

    E.

17. List six things a technician should answer after completing repairs on an electrical system.

    A.

    B.

    C.

    D.

    E.

    F.

Chapter
4-9 RV Electrical Codes and Standards

4-9.1 Industry Codes and Standards

Industry codes and standards have been developed to ensure safety and to reduce liability. The major sources of RV standards are the *NFPA 1192* and *CSA Z240*. These standards outline requirements for plumbing, heating (propane system), fire and life safety, and electrical.

The RVIA (Recreation Vehicle Industry Association) requires that member manufacturers agree to in-plant visits by the RVIA inspectors. If members refuse or fail to comply, they can be expelled and, therefore, lose the right to bear the association's seal of membership.

To help everyone better understand the requirements of the standard, an industry handbook is maintained by RVIA. Industry stakeholders work with RVIA to document the enforcement positions, which explains the standards in detail. Although standards are primarily designed for RV manufacturers, it is important from a liability standpoint that RV service technicians strive to follow these standards wherever possible when modifying, servicing, or installing RV systems or their components.

Agencies, state and private, involved with RV safety training use and follow the NFPA and CSA Standards for recreation vehicles. This NFPA standard is revised every three years, with dates being 2002, 2005, 2008, 2011, and so on. Industry always begins using the new edition of the NFPA requirements on or near May 1 of the revision year, and manufacturers must comply with requirements by September 1 of the new code edition year.

4-9.2 Code Summary

Table 4-10 and *Table 4-11* are summaries of the current RV standard that pertains to the normal duties of the RV service technician. This summary is provided as a quick reference, NOT AS A SUBSTITUTE FOR THE ACTUAL STANDARDS. Once the reference in these tables has been found, go to the referenced standard for the exact wording and use the handbook for the detailed explanation.

The *NFPA 1192 Standard for Recreational Vehicles*, RVIA's NFPA 1192 Handbook, *A Guide to NFPA 1192*, and *ANSI/RVIA 12V Standard for Low Voltage Systems in Conversion and Recreational Vehicles* are available at www.rvia.org. The *National Electrical Code* is available from NFPA at www.nfpa.org/catalog/ or by calling 1-800-334-3555.

Information on CSA Standards can be obtained by going to their website at www.shopcsa.ca.

Table 4-10 DC Electrical—Requirements Applicable to RV Service Technicians

Service Technician's Task	2008 CSA Z240	ANSI 12V 2011	Summary of Requirement
Service/maintain/replace batteries	5.13.1 to 5.13.3	2-3	This paragraph has the following requirements: • Battery compartments shall have a minimum of 1.7 in^2 of venting at the top and bottom of the compartments. • Batteries shall be secured to the vehicle. • Battery compartments shall not contain spark- or flame-producing equipment. • Battery compartments shall be vapor tight to the interior of the unit.

Table 4-10 DC Electrical—Requirements Applicable to RV Service Technicians

Service Technician's Task	2008 CSA Z240	ANSI 12V 2011	Summary of Requirement
Service converters	5.10	2-5	Converters shall be listed for RV use. The formula for converter ratings is as follows: • First 20 A of load at 100%; plus. • Second 20 A of load at 50%; plus. • All load above 40 A at 25%.
	5.14	2-5.1	Converters shall be bonded to chassis with a minimum 8 ga copper conductor.
Service DC wiring/ distribution system	5.12.11	3-2	DC circuits must be protected by overcurrent protective devices rated not in excess of the ampacity of conductor.
		3-3	Metal-capped mini breakers shall be wired correctly; the "BAT" leg of a breaker is for the load; the "AUX" leg is for the protected circuits.
	5.12.13	3-3	Fuse holders and circuit breakers shall be protected against shorting and physical damage.
	5.12.12	3-3	Replacement size for fuses must be identified.
	5.13.3	3-3	Open-bottom blade fuses are considered spark producers and shall not be installed in battery compartments.
	5.12.1	4-2	Low-voltage conductors shall conform to SAE J1127 or J1128 or have insulation in accordance with NEC table 310.13 or equal
	5.12.1	4-4	Conductors shall be surface marked at maximum 4-ft intervals with temperature rating, type, and size or as required by the listing agency.
	5.12.1	5-1	Conductors shall be protected against physical damage and be secured.
	5.12.1	5-1	Conductors shall be routed away from sharp edges, moving parts, and heat sources (including potable hot water lines).
	5.12.7	6-1.3	Terminals used must be identified for the proper wire size used.
	5.12.7	6-1.8	All splices, joints, and free ends of conductors shall be wrapped a minimum of three times with listed electrical tape.
		7-2.1	Switches require a DC rating not less than connected load.

Table 4-10 DC Electrical—Requirements Applicable to RV Service Technicians

Service Technician's Task	2008 CSA Z240	ANSI 12V 2011	Summary of Requirement
	5.12.13	3-5	Overcurrent protection shall be accessible and located within 18 in. of where the power supply connects to vehicle circuits.
	5.12.10	5-2	DC and AC circuits shall be separated by a minimum of 1/2 in.
	5.14.6	6-1.14	No more than four terminals shall be secured to one terminal stud
	5.14.1	6-2.5	Ground terminals shall be accessible and made mechanically secure to a clean surface using a self-tapping screw or internal-external starwasher or other approved means.
Service DC devices	5.1.2	7-3.1	Interior light fixtures shall be listed (exception: fixtures with bulbs rated 4W or less).

Table 4-11 AC Electrical—Requirements Applicable to RV Service Technicians

Service Technician's Task	2008 CSA Z240	NEC 2011	Summary of Requirement
120/240V test		551.60	**NOTE**: The dielectric test for the low-voltage system was removed beginning with the 1999 NEC. This test information is included as this test could be determined to be of value to some technicians. The requirement of the NEC is to provide an operational test of the low-voltage system to be sure all circuits and equipment are in working order.
Service A/C distribution panel	5.3.1 Table 1	551.42(C) 5 Max unless EMS	RVs have limitations on number of branch circuits provided.
	5.4.2	551.45(B)	Readily accessible and a minimum of 24 × 30 in. of working clearance directly in front of the distribution panel.
Service A/C distribution panel	5.4.1	551.45(C)	Any distribution panelboard with three or more branch circuits shall have a main circuit breaker provided.
	5.14.8	551.56(B)	Any distribution panelboard shall be bonded to the chassis with a minimum 8 ga conductor.

Table 4-11 AC Electrical—Requirements Applicable to RV Service Technicians

Service Technician's Task	2008 CSA Z240	NEC 2011	Summary of Requirement
120 VAC service power supply cord	5.1	551.40(B)	All components of the 120 VAC electrical system shall be listed.
	5.3.3.1 Table 1	551.46(C)	Power cord plugs shall have the proper plug configurations.
Replacing power cord		551.43(A)	If the power cord terminates in a j-box, the conductor from the j-box to the distribution panelboard shall be sized according to the main disconnect breaker.
	5.3.2.3	551.46	Permanently attached power cords shall have strain relief so that the cord is not pulling directly on the first point of connection.
	5.3.2.7	551.46(A) (1)	Male motor-base attachment plugs shall be in a listed enclosure.
	5.3.2.2	551.46(B)	When the point of entrance for a power cord is on the side of unit, a minimum of 25 ft of exposed cord is needed. When the point of entrance is on rear of unit, a minimum of 30 ft is needed.
Service 120 VAC wiring/distribution system	5.1.3	551.40(B)/551.50	All terminals shall be installed according to their listing.
	5.1.3 5.6.1	551.43(A)	Circuit breakers shall be sized not more than the circuit conductors (50 A, 6 ga; 30 A, 10 ga; 20 A, 12 ga; 15 A, 14 ga).
	5.1.3	551.47(F)	Sheathing of Romex® or cable shall enter enclosures a minimum of 1/4 in.
	5.5.1.14	551.47(G)	Romex® shall be protected when passing within 1-1/4 in. of the inside or outside of studs or framing.
	5.5.1.13	551.47(K)	Where subject to physical damage, conductors shall be protected.
	5.1.3	551.47(N)	Conductors routed outside the vehicle envelope and subject to the elements shall be in a listed direct burial-type conduit.

Table 4-11 AC Electrical—Requirements Applicable to RV Service Technicians

Service Technician's Task	2008 CSA Z240	NEC 2011	Summary of Requirement
	5.5.2.1	551.47(P)	The slideout room flexible 120 VAC cord shall be listed for hard use, and the cord must be routed to prevent chaffing during movement and protected from physical damage.
	5.1.3	551.48	All boxes in the 120 VAC system shall be sized according to this paragraph's calculation method.
	5.1.3 5.5.1	551.51(A)	Switches shall not be rated less than the connected load.
	5.14.1	551.55(A)	All exposed metal parts (j-boxes, frames, fixture canopies, etc.) shall be effectively grounded (listed ground screw or clip).
	5.1.3	551.55(E)	Grounding connections between multiple conductors shall be made in a manner that disconnection or removal of a device will not interrupt grounding continuity.
	5.14.6	551.56(B)	Ground terminals must be accessible. Also, the grounding conductor for the distribution panelboard must be permanent and continuous (no splices).
Service 120 VAC receptacles	5.8.1	551.52	All receptacles shall be of the grounding type.
	5.8.3	551.41(C)(2)	GFI protection is required for all receptacles within 6 ft of any sink.
	5.8.5	551.41(C)(4)	Exterior receptacles shall be GFI protected.
120 VAC system testing	7.3.1	551.60(A)	The requirements of this dielectric strength test are as follows: • Minimum test settings are 900 volts for 1 minute or 1080 volts for 1 second. • Maximum test setting is 1250 volts. • Switches shall be in the "ON" position. • Fixtures and permanently installed appliances shall be disconnected. • Generator/inverter circuit shall be tested. • Circuits downstream of transfer switches shall be tested. • Conduct continuity and polarity tests. • Test equipment shall be in proper working condition and recalibrated a maximum of 12 months. • Test equipment must be used according to its written instructions.

NOTE: There is no review for this chapter.

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4 Answer Keys

Chapter 4-1

1. Decreases, increase *(page 4-1)*

   However, the reverse is also correct. As troubleshooting time increases, profits decrease. The axiom is equally applicable to the technician, especially one on flat rate. "As troubleshooting time increases, take-home pay decreases."

2. A. Know ohm's law and how and when to use it. *(page 4-1)*

   B. Know how to use electrical test equipment. *(page 4-1)*

   C. Read and understand electrical diagrams and schematics. *(page 4-1)*

   D. Have and know how to use the correct tools and equipment for a specific task. *(page 4-1)*

   E. Use available documentation and reference materials. *(page 4-1)*

Chapter 4-2

1. 12 VDC *(page 4-3)*

2. A. Current flows in one direction. *(page 4-3)*

   B. The fixed polarity of applied voltage *(page 4-3)*

3. lead-sulfuric acid cell (secondary cell) *(page 4-4)*

4. Carbon-zinc dry cell battery (primary cell) *(page 4-4)*

5. False. The electrolyte is a moist paste. *(page 4-4)*

6. Any of the following:

   B. No need to check liquid levels *(page 4-5)*

   C. Cannot sulfate *(page 4-5)*

   D. Can be easily installed in hard-to-reach places *(page 4-5)*

   E. No terminal corrosion under normal use *(page 4-5)*

   F. Will accept full charge after being discharged for up to 30 days *(page 4-5)*

   G. Can be stored for up to two years *(page 4-5)*

7. The deep-cycle battery will supply continuous DC power for long durations during discharge. There are also other advantages, such as the ability to withstand repetitive charging and discharging. *(page 4-7)*

8. False. They are available in both automotive and deep-cycle batteries. *(page 4-7)*

9. The power converter transforms 120 VAC to 12 VDC through use of a circuit, called a rectifier, consisting of a transformer, diodes, and filter capacitors. *(page 4-8)*

10. B Isolator—prevents tow-vehicle battery discharge *(page 4-26)*

    C Diode—converts AC to DC *(page 4-26)*

    A Type III circuit breaker—external reset button *(page 4-28)*

11. A. Linear converter *(page 4-8)*

    B. Ferroresonant converter *(page 4-8)*

    C. Switchmode electronic converter *(page 4-8)*

12. Ferroresonant converter *(page 4-9)*

13. Switchmode electronic converter *(page 4-10)*

14. Linear converter *(page 4-8)*

15. Alternator *(page 4-13)*

16. A. Batteries *(page 4-14)*

    B. Converters *(page 4-14)*

    C. Solar panels *(page 4-14)*

    D. Alternators *(page 4-14)*

17. False. A converter only has no method to smooth out the pulsating DC current which could damage devices. *(page 4-14)*

18. True *(page 4-14)*

19. True *(page 4-15)*

20. False. Solar power can both recharge batteries and operate devices directly with sufficient solar panels and sunlight. *(page 4-15)*

21. Diodes *(page 4-26)*

22. True *(page 4-26)*

23. False. Voltage drop, if forgotten, can make diagnosis of an electrical system very difficult. *(page 4-26)*

24. True *(page 4-25)*

25. False. Replace overcurrent protection devices with ones rated the same or LOWER. Higher rated devices can cause serious damage to equipment AND PEOPLE. *(page 4-18)*

26. False. Circuit breakers can also be used in RVs. *(page 4-18)*
27. True *(page 4-28)*
28. True *(page 4-28)*
29. True *(page 4-19)*
30. False. A multimeter or an milliammeter can be used to measure the amperage (load) if it is not otherwise known. *(page 4-19)*
31. True *(page 4-19)*
32. D *(page 4-28)*

Chapter 4-3

1. Higher voltage *(page 4-35)*
2. Higher current capacity (amperage) *(page 4-35)*
3. B *(page 4-35)*
4. C *(page 4-36)*
5. B *(page 4-37)*
6. False. Series is positive to negative. Parallel is positive to positive and negative to negative. *(page 4-35)*
7. A. Solenoid relay *(page 4-38)*
   B. Dual battery isolators *(page 4-38)*
8. C *(page 4-37)*
9. False. Disconnect negative first and reconnect negative LAST. *(page 4-39)*
10. True *(page 4-38)*
11. True *(page 4-38)*
12. False. Electrolyte is sulfuric acid diluted by water and will cause injury or damage if it comes into contact with eyes, skin, clothing, etc. *(page 4-38)*
13. B *(page 4-39)*
14. True *(page 4-40)*
15. D *(page 4-41)*

Chapter 4-4

1. A. An isolation switch and/or *(page 4-52)*
   B. Energy management system *(page 4-52)*
2. A. Manual plug-in *(page 4-56)*
   B. Manual transfer switch *(page 4-56)*
   C. Automatic relay *(page 4-56)*
3. True *(page 4-58)*
4. False. Higher gauge numbers indicate thinner wire sizes. *(page 4-58)*
5. True *(page 4-58)*
6. True *(page 4-58)*
7. False. The amount of voltage drop that will occur within a wire decreases as the copper area increases. *(page 4-58)*
8. False. Closed is ON position. Think of a switch as a door (remember the symbol). When the door is closed, there is a connection across the doorway. In electricity, this means the circuit is completed and current can flow. If the door is open, there is no connection and the circuit is broken. *(page 4-58)*
9. False. Open is OFF position. Think of a switch as a door (remember the symbol). When the door is closed, there is a connection across the doorway. In electricity, this means the circuit is completed and current can flow. If the door is open, there is no connection and the circuit is broken. *(page 4-58)*
10. Infinity, zero resistance *(page 4-58)*
11. Relays *(page 4-58)*
12. GFCI (ground fault circuit interrupter) *(page 4-60)*
13. Start capacitor *(page 4-61)*
14. B *(page 4-62)*
15. B *(page 4-51)*
16. A. Power supply cord *(page 4-52)*
    B. On-board generator *(page 4-52)*
    C. Inverter *(page 4-52)*
17. A. Black = hot *(page 4-53)*
    B. White = neutral *(page 4-53)*
    C. Bare or green = ground *(page 4-53)*
18. A. The silver terminal, wide prong or slot *(page 4-53)*
    B. The brass terminal *(page 4-53)*
    C. The green screw *(page 4-53)*

Chapter 4-5

1. 2.5 A, 300 W divided by 120 VAC *(page 4-67)*

2. 180 W, 120 VAC × 1.5 A *(page 4-67)*
3. 48-3/4 ± 10 percent *(page 4-68)*

Chapter 4-6

1. Neutral *(page 4-72)*
2. Ground monitor (polarity tester) *(page 4-72)*
3. Isolated from ground *(page 4-73)*
4. E *(page 4-73)*
5. A. 20 A *(page 4-74)*
   B. 30 A *(page 4-74)*
6. False. All transfer switches must be listed for RV use. *(page 4-73)*
7. True *(page 4-74)*
8. True *(page 4-74)*
9. Direct current (DC) to alternating current (AC) *(page 4-74)*
10. False. Do not twist the wires together. Simply strip the two wires to an equal length and then attach the wire nut. The wire nut twists the wires together while making a good connection. *(page 4-75)*
11. Polarity, polarity tester *(page 4-75)*

Chapter 4-7

1. F, E, A, C, B, D *(page 4-79)*
2. A. Pictorial drawings *(page 4-77)*
   B. Ladder diagrams *(page 4-77)*
   C. Schematics *(page 4-77)*
3. Sequential *(page 4-78)*
4. Schematic *(page 4-78)*
5. Pictorial drawing *(page 4-77)*

Chapter 4-8

1. A. Short *(page 4-90)*
   B. Open *(page 4-90)*
2. Short *(page 4-91)*
3. Open *(page 4-91)*
4. Open *(page 4-91)*
5. B *(page 4-91)*
6. A *(page 4-91)*
7. B *(page 4-91)*
8. Capacity, load *(page 4-91)*
9. Short *(page 4-96)*
10. B *(page 4-97)*
11. Any of the following: *(page 4-97)*
    A. Turn off the power to circuits when working on the 120 VAC system.
    B. Always use insulated tools when working on or near circuits that are energized.
    C. Keep one hand behind your back when probing live circuits or working on a plugged in distribution panelboard.
    D. Work in a dry area and always wear proper insulated footwear.
    E. Check meter and test equipment test leads for defects prior to using.
    F. Always hold test leads by the insulating sleeves.
12. Grounding of electrical equipment and circuits provides a lower resistance path to ground than a human being, thereby protecting the human from shock in the event of a fault circuit. *(page 4-98)*
13. B. Multimeter *(page 4-86)*
    A. Load tester *(page 4-87)*
    G. Hydrometer *(page 4-87)*
14. B *(page 4-87)*
15. C *(page 4-87)*
16. Any of the following: *(page 4-95)*
    A. Open wires
    B. Shorted wires
    C. Dirty or bad connections
    D. Grounded wires or connections to skin or frame.
    E. Loose or corroded ground connections.
    F. Broken or cracked components.
    G. Overheated wires or connections.
    H. Poor work done previously.
    I. Incorrect wire size.
    J. Too many devices on a circuit.
17. Any of the following:

A. Was polarity observed when making wire and cable connections?

B. Were any cables or wires pinched while working on the system?

C. Were all cables and wires secured away from any heat source?

D. Were the correct connectors used?

E. Were all connections clean and tight?

F. Are all solder connections made properly?

G. Were any wires burned while soldering?

H. Did any solder fall into other areas of the system?

I. Was the correct specification used for measurements and values?

J. Were all parts reinstalled properly?

K. Was the area worked in left clean?

L. Satisfied with work?

Chapter 4-9

There is no review for this chapter.

4 Glossary of Electrical Terms

Absorbed Glass Mat Battery (AGM) A type of lead-acid battery that has the electrolyte absorbed and held in place by microfibrous silica glass mats that are sandwiched between the plates.

Alternating Current (AC) Electrical current that reveres polarity at a regular rate (frequency).

Alternator An electromechanical device that produces alternating current (AC).

Alternator, Chassis An alternator typically driven by the chassis engine that has the output rectified to produce direct current (DC).

Alternator, Genset An alternator driven by a dedicated engine. The electrical producing component of a genset or power plant.

Ammeter An instrument used for measuring electric current.

Ampere (I) Basic unit of measure electric current. Value of one-ampere flows when one volt of potential difference is applied across one ohm of resistance.

Armature The part of a generator in which the voltage is produced. In a motor, it is commonly the rotating member. Also, the movable part of a relay.

Battery A direct-current voltage storage device made up of one or more cells that convert chemical energy into electrical energy.

Bonding The permanent joining of metallic parts to form an electrically conductive path that will ensure electrical continuity and the capacity to conduct safely any current likely to be imposed.

Branch A portion of a wiring system in the RV that extends from an overcurrent protection device to an outlet or load such as a lighting fixture, motor, or heater.

Brushes In a motor or generator, devices that provide stationary connections to the rotor.

Capacitor An electrical device consisting basically of two or more conducting surfaces separated by an insulating material called a *dielectric*. It can store electrical energy, block the flow of DC current, and act as a conductor of AC current.

Capacitance The ability to store electric charge.

Chassis ground Common return for all electronic circuits mounted on one metal chassis or printed circuit board. Usually connects to one side of DC supply voltage.

Circuit An arrangement of conductors and devices connected together for the purpose of carrying an electrical current.

Circuit Breaker A device designed to open and close a circuit by (non)automatic means and to open the circuit automatically on a predetermined overload of current, without injury to itself when properly applied within its rating.

Conductor A material that can serve as a carrier of electrical current.

Continuity Continuous path for current. Reading of 0-3/4 with an ohmmeter.

Converter Component that is used to change 120 VAC to 12 VDC. Available in linear, ferroresonant, and switchmode types.

Current The movement of electrons through a conductor, similar to the flow of water in a plumbing system. Current is measured in amperes, milliamperes and microamperes. Expressed by the letter "I."

Cycles In electricity, the number of times per second an alternating current changes direction. It is measured in hertz (Hz).

D/A Converter A device that converts digital input to analog output.

Deep Cycle Battery A type of battery that has plates fabricated of high-density materials that will withstand repetitive cycling without loss of composition

Dielectric Insulating material separating the conducting surfaces in a capacitor. Typical dielectrics include mica, air, plastic, paper, and ceramic.

Diode A solid-state device that allows current flow in only one direction.

Direct Current (DC) Electrical current that flows in only one direction (polarity does not reverse as does alternating current).

DPDT Double-pole, double-throw switch. A six-terminal switch that simultaneously connects one pair of terminals to either of two other pairs of terminals.

DPST Double-pole, single-throw switch. A four-terminal switch that simultaneously opens or closes two separate circuits or both sides of the same circuit.

Dry Cell A chemical cell source of DC electricity that converts chemical energy into electrical energy. It uses different electrode materials from a wet cell, and a paste-type electrolyte rather than a liquid one.

Electrolyte A substance used in dry and wet cells in which conduction of electricity is accompanied by chemical action.

Electromagnet A temporary magnet consisting of a coil of wire wrapped around an iron core. As long as an electrical current flows in the wire, the iron core is magnetized.

Electron Basic particle of negative charge, in orbital rings around the nucleus in an atom.

Energy Management System (EMS) A system that automatically removes loads in a preset priority to keep a generator or shore power from being overloaded. Also known as a *shed system*.

Energy The capacity for doing work.

Field Coil A coil of insulated wire wrapped around an iron core. A magnetic field is produced by current flowing in the coil. Used in such devices as motors.

Frequency (f) Number of cycles per second for a waveform with periodic variations. The unit of frequency is hertz (Hz). See "Hertz."

Fuse Metal link that melts from excessive current and opens circuit.

Fusible Link A wire made of alloy that melts at a relatively low temperature and overheats to melt at a designed temperature when carrying a particular value of overload current.

Gel Cell A type of wet cell battery with electrolyte that is permanently locked in a thixotropic (a substance that becomes a fluid when stirred or agitated) gel.

Generator (Electrical) A device that produces electrical energy. Commonly used to describe a rotating machine that converts mechanical energy into electrical energy.

Germanium (Ge) Semiconductor element used for transistors and diodes.

Ground To connect electrical equipment to the earth or to some conducting body that serves in place of the earth (chassis).

Grounded Intentionally connected to earth through a ground connection or connections to something that serves in place of ground (chassis).

Grounding A conducting path between an electric circuit or equipment and the earth, or some conducting body serving in place of the earth (chassis)

Ground Fault Circuit Interrupter (GFCI) An extremely sensitive circuit breaker connected to exterior, bath, and kitchen outlets. The GFCI helps to protect against severe shock (electrical) if a ground fault develops by opening the circuit and stopping the flow of current.

HACR Stands for heating, air conditioning, and refrigeration. The name given to a time-delay circuit breaker installed in RVs to handle these appliances.

Hertz (Hz) An electrical unit of frequency (see "Frequency"). Normal current in the U.S.A. and Canada is 60 Hz.

Hydrometer A float-type instrument used to determine the state of charge of a battery by measuring the specific gravity of the electrolyte (i.e., the concentration of sulfuric acid in the electrolyte).

Inductance (L) The property in a circuit that opposes any change in the electric current. Inductance is present only when the current is changing.

Inductor Coil of wire with inductance.

Integrated Circuit Contains transistor, diodes, resistors, and capacitors in one miniaturized package.

Inverter A device for changing direct current into alternating current.

Jumper Temporary wiring used for checking electrical systems.

LCD Liquid-crystal display.

LED Light-emitting diode.

Line Voltage The voltage level of the main power supply. In an RV, this is 120 VAC.

Load (Electrical) The device that consumes power in an electrical circuit.

Mega (M) Metric prefix (ten to the sixth power).

Milli (m) Metric prefix (ten to the negative third power).

Motor A device that produces mechanical motion from electric energy.

Multimeter A device that combines the functions of an ammeter, an ohmmeter, and a voltmeter into one instrument.

National Electrical Code (NEC) Regulations governing electrical installations in the U.S.A.

Normally Closed (NC) Pertains to electrical switches that are in the closed position when not energized or activated. Current can flow through a normally closed switch.

Normally Open (NO) Pertains to electrical switches that are normally in the open position when not energized or activated. Current cannot flow through a normally open switch until it is energized or activated to be closed.

Ohm The basic unit of measurement of resistance. It is the resistance that will allow one ampere of current flow when the voltage across the resistance is one volt.

Ohm's Law (E = IR) The three basic quantities in an electrical circuit are voltage, current, and resistance. Ohm's law relates these three variables to each other. By using Ohm's law, any one of the three variables can be determined if the other two are known.

Open Circuit An electric circuit through which current will not flow because of an open switch, break in the wire, or poor connection.

Overcurrent Protection Device A device to cause and maintain the interruption of current flow to the device governed.

Polarity A condition in an electrical circuit that determines in which direction current will flow in that circuit.

Power (P) Rate of doing work. The unit of electric power is the watt.

Power Supply Cord Part of the power supply assembly that connects the RV to a power source independent of the RV such as the electrical outlet provided by a campground, sometimes called the *shore power supply cord*.

Power Supply A source of AC or DC electrical power, usually a converter, inverter, or battery.

Primary Cell (Battery) A type of battery with a single cell that delivers direct current as a result of an electrochemical reaction.

Primary Winding Transformer coil connected to the source voltage.

Printed Circuit Board A flat board printed with predetermined patterns on an insulating base that contains various electronic components.

Rectifier A device that allows current to flow through it in only one direction. Used to convert AC current to DC current.

Relay An electromagnetic device used to activate a component in one part of an electrical circuit from a signal in another part of the circuit.

Resistance (R) The property of a material to resist the flow of electric current through it. Designated as R and is expressed in units of ohms.

Resistor A device that acts to limit current flow in a circuit by virtue of its electrical resistance.

Rotor The rotating member of an electrical device, such as the rotating armature of a motor.

Secondary Cell (Battery) A type of battery with an electrolytic cell for generating electric energy in which the cell, after being discharged, may be restored to a charged condition by sending a current through it in a direction opposite to that of the discharging current.

Secondary Winding (Transformer) A transformer winding that receives energy by electromagnetic induction from the primary winding; a transformer may have several secondary windings and may provide AC voltages that are higher, lower, or the same as that applied to the primary winding.

Series Circuit A circuit in which all parts are connected end to end to provide a single path to current.

Shed System See "Energy Management System."

Short Circuit A low-resistance connection across a voltage source or between both sides of a circuit or line usually accidental and usually resulting in excessive current flow that may cause damage.

Silicon (Si) Semiconductor chemical element used for transistors, diodes, and integrated circuits.

Single-Pole, Double Throw (SPDT) An electrical switch that, when set in one position, energizes one circuit. When moved to opposite position, it energizes a different circuit. Center position may be neutral, energizing neither circuit.

Solar Panel A semiconductor device used to convert sunlight into electrical energy.

Solder Alloy of tin and lead used for fusing wire connections.

Solenoid An electrically energized coil of insulated wire that produces a magnetic field within the coil.

Solid State Electric circuitry based on semiconductors with no moving parts.

Spade Lug A type of wire connector.

SPDT Single-pole, double-throw switch or relay contacts.

Specific Gravity Ratio of the weight of a substance with that of an equal volume of water.

SPST Single-pole, single-throw switch or relay contacts.

Start Capacitor A device that is used to provide a power surge to produce a high torque for starting a motor. The capacitor is disengaged when the motor achieves a predetermined percentage of its rated speed.

Static Electricity Electric charges not in motion.

Stator The portion of a rotating machine that contains the stationary parts of the magnetic circuit and their associated windings.

Sulfating Formation of lead sulfate on the plates of a lead-acid storage battery reducing the energy-storing ability of the battery and eventually causing failure.

Switch Device used to open or close connections of a voltage source to a load circuit.

Transfer Switch An automatic or manual switch for transferring one or more conductor connections from one circuit to another.

Transformer Device for reducing AC voltage.

Transistor Semiconductor device having at least three electrical contacts, used for amplifiers or switches.

Volt (E) The unit of voltage measurement of the potential difference between two points. One volt will produce a flow of one ampere through a one ohm resistance (Ohm's law).

Voltage The relative amount of electric charge at one point in an electric circuit compared with that at another point in the circuit, which causes a current flow through a continuous path between the two points. Also referred to as *electromotive force* and *potential difference*.

Voltage Drop Voltage across each component in a series circuit. The proportional part of total applied voltage.

Voltage Regulator A device that maintains a constant output voltage with changes of input voltage or output load current.

Voltage Source Supplies potential difference across two terminals.

Voltmeter An instrument for measuring voltage.

VOM Volt-ohm-milliamp meter.

Watt (W) Unit of measurement of electrical power. Rate at which one volt can push one amp through an electrical system.

Watt's Law Power (watts) = I (amp) × E (voltage)

Wet Cell A primary cell with a liquid electrolyte.

Wire Gauge A system of wire sizes based on the diameter of the wire. Also, the tool used to measure wire size.

Z240 The Canadian equivalent of *NFPA 1192*.

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4 Index