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KNOW YOUR 12-VOLT DC POWER

A general discussion of the form of energy that affects the workings of all motorhomes today.

Direct current (DC) electrical power is one of the systems that enables motorhomes to be completely self-contained. DC power runs our lights, refrigerators, freezers, water pumps, fans, furnaces, and televisions.

A wide variety of DC electrical configurations exist, from the very simple to the very elaborate. Of course, more complex systems can pose more problems. Failure in the DC electrical system can cause inconvenience and, at its worst, danger and disaster. It is inconvenient to lose your lights or water, but a massive short without the protection of a high-capacity fuse or circuit breaker can lead to component meltdown or fire. We believe it is important for an RV owner to learn about his or her particular system and to understand how it functions. After you become comfortable with a system, you may want to perform your own maintenance and some repairs. It is important to accurately assess which procedures and tasks you can handle. Know your limits, and do not exceed them.

This article will discuss various components that can be part of a DC system. We've also provided a list of reference books that discuss DC electrical power in greater depth. If you want to develop your skills, you'll find these books to be very helpful. You should also seek advice from service personnel who work on your coach. With more knowledge, you will soon find your confidence level increasing.

A wiring diagram will help you to identify the components of your DC electrical system. Note the physical location of the components and where the wires are routed between the components. You may want to keep track of this in a notebook so you do not need to repeat a search. If you do not have a wiring diagram or cannot obtain one from your OEM builder, you can make your own as you identify parts and wires. Also, always ask technicians if they will make a wiring diagram of any components they may be servicing. Even if you do not plan to complete any service work yourself, this information may be useful to others for future repairs. This is especially true if your coach requires an emergency repair and you must rely on technicians who do not routinely work on recreational vehicles.

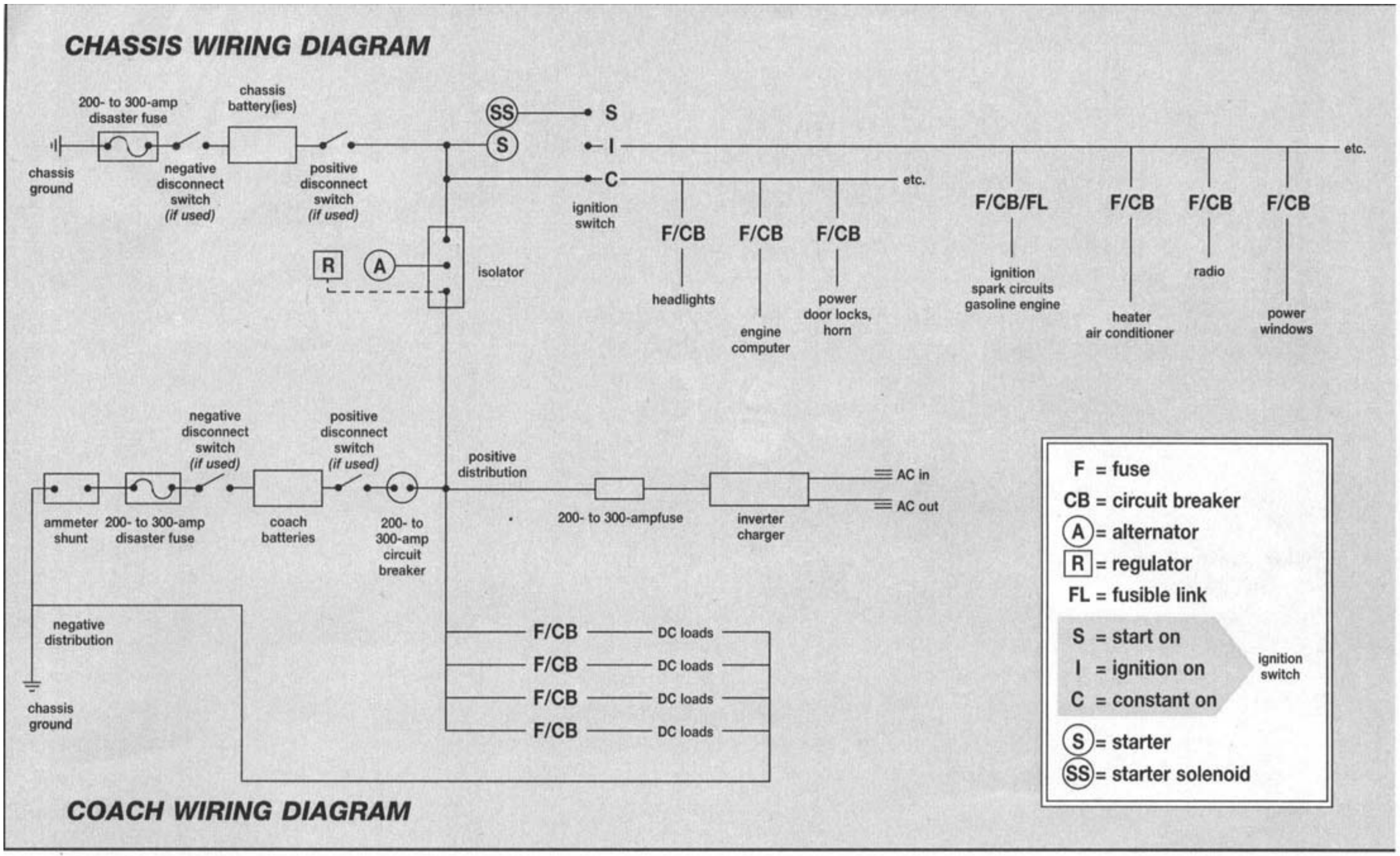
Batteries. Motorhomes usually contain two types of batteries: one type for the chassis and another type for the "house" or interior functions.

Chassis batteries are used to supply power to the starter, ignition, and exterior lights, and are generally rated in cold cranking amps (cca). This is a measure of performance at 0 degrees Fahrenheit. Marine cold cranking amps (mca) is a measure of performance at 60 degrees Fahrenheit, and cranking amps (ca), is a measurement of performance at 32 degrees Fahrenheit.

It is important not to confuse "mca" and "ca" with the "cca" rating. The "cca" batteries achieve their high rating as a result of increased plate surface area. This is accomplished by increasing the number of plates per cell and decreasing the thickness of each individual plate. These thin plates will not tolerate repeated deep discharging, because each time a battery is cycled, some of the positive plate material is lost. Additionally, when they're over heated, these plates are susceptible to warping. The "cca" batteries are usually constructed of lead and calcium or lead and calcium/low antimony plates. These use less water than lead-antimony batteries, so manufacturers classify them as "low-maintenance" or "maintenance-free."

The Delco battery is completely sealed so that no water can be added, but it has a built-in hydrometer to indicate the level of charge. Other manufacturers produce batteries with removable vent plugs so service personnel can perform specific gravity measurements to check the state of charge and also to add any required water.

High-output alternators help to pro long the chassis battery life. After starting the engine, the battery is immediately recharged by the alternator, which also powers any accessories, such as the radio, lights, and air conditioner. Before the advent of high-output alternators, the high cca batteries did not have a particularly long service life. This was a result of the battery being cycled when energy demands exceeded the output of the alternator. Motorhome owners should



keep this phenomenon in mind even when their coach is equipped with a high-output alternator. The alternator can use a considerable portion of its output to charge house batteries, so the chassis battery may not be adequately recharged.

Another concern is that many motorhomes do not have a battery disconnect switch for the chassis battery. Because power is used for phantom loads (clocks, alarms, LEDs, or engine computer modules) even when the engine isn't running, the battery can be discharged during long periods of disuse. Suppose the battery supplies 1/4-amp for these purposes. Over 24 hours, 6 amp-hours would be used. If the vehicle were stored for three months, 540 amp-hours would be consumed. This results in a deeply discharged battery. After the engine is somehow started, an added insult occurs. The alternator says, "Wow, is that battery down! I'd better give it all I've got!" and then proceeds to hit the battery with 100 amps. This fast charge produces excessive heat, which can warp the thin plates inside the battery. If this abuse is repeated, the battery's life will be decreased significantly.

House batteries can be either wet or gel type. As mentioned previously, each time a battery is cycled, some of the positive plate material is lost. The deep-cycle house batteries can better tolerate repeated deep discharging and recharging, because they have thick positive plates and can accommodate several hundred cycles. These batteries are usually rated in amp hours. In multiple battery configurations with a high amp-hour capacity, best results will be achieved by using identical batteries. They should not only be of the same size and rating, but also of the same brand and carry the same manufacturing date.

Manufacturers of gel batteries claim several advantages. They say a gel battery has a longer shelf life and a lower self-discharge rate. It can tolerate a deeper discharge and accept a charge more readily. Although the gel battery is known to have a longer life than the wet battery, it is much more costly. The gel battery is sealed and requires no maintenance, but it is not entirely foolproof. It can be overcharged, which can lead to gassing of the electrolyte. Although the battery is sealed, the caps can vent if gassing increases the internal pressure. Once gassing has occurred, the loss is irreplaceable.

Generally speaking, size for size, gel batteries have lower amp-hour ratings than wet batteries. Wet batteries require some maintenance and have removable vent plugs so water can be replaced periodically. If properly cared for, a wet battery can provide an excellent service life, and its lower cost makes it the choice for many. The golf cart (GC 2) battery is the most economical when you calculate the cost per amp-hour for the service life of the battery. These batteries are also readily available at many discount stores. However, if you are uncomfortable with wet batteries or not willing to maintain one, then perhaps your best choice would be a gel type.

The battery is the heart of the DC system. It is a passive device that stores energy and releases it on demand. It is constantly being pushed and pulled by other components in the electrical system. When a battery dies prematurely, usually the manufacturer is blamed. However, in most cases batteries are actually the victims of either undercharging or overcharging. Chronic undercharging will cause sulfation (plates encrusted with lead sulfate crystals), which leads to irreversible damage. Normal aging results in progressive positive plate disintegration. Chronic overcharging, which causes excessive gassing and water loss, accelerates the aging process. This also results in a premature battery death. As discussed previously, different designs can better serve a variety of uses, but the longevity of all batteries is dependent upon the demands and performance of other system components.

Battery manufacturers do have some responsibility, however. Providing maximum charge voltage and float voltage recommendations would be very helpful when programming set points on multistage chargers. Recommendations vary among battery manufacturers, however. Trojan Battery Company, for instance, recommends charging 2.37 volts per cell (7.11 volts on a 6-volt battery and 14.22 volts on two 6-volt batteries wired in series). Some manufacturers publish little information, and some provide extensive instructions, but we have found none readily available. Sales personnel often have little knowledge concerning these levels, and charger manufacturers list only general information.

It should be understood that set points will change as batteries age, and that they also will fluctuate with temperature changes. As the batteries lose capacity, gassings will occur at preset voltage levels and water requirements will increase. We use an electrolyte level monitor ("Battery Electrolyte Level Monitor," FMC, October 1993, page 64) to track water requirements. This device is always triggered at the same level of water loss, so the variable is the frequency of water replacement. Increasing frequency of water loss indicates overcharging in a new battery, and decreasing ability to accept a charge in an older battery.

We have yet to have an expert tell us how to determine whether a gel battery is being overcharged. The best option is to have a regulator to control all charging systems and adjust charge voltages automatically for changes in temperature. Some inverter-chargers are capable of multistage charging and can be manually or automatically adjusted for temperature. Most convertors or convertor-chargers are not adjustable. If the voltage set points can be adjusted to a level that will provide as much charge as possible without excessive gassing, battery life can be extended. In small-capacity systems, the most economical option may be to simply replace batteries more frequently.

Isolators. A battery isolator is a device used to separate the chassis battery and its electrical system from the house battery and its electrical system when over-the-road charging is accomplished via a single-output alternator. Isolators are available with numerous amperage ratings. The isolator rating should always exceed the maximum cold alternator output rating. The isolator uses high-capacity diodes mounted on a heat sink to direct the independent flow of current to each system. This creates heat and a voltage drop of around .6 in high-quality isolators. It is important to adjust the alternator output to compensate for this voltage drop. Some regulators have a battery sense lead that should be attached directly to either the house or chassis battery. This connection will compensate for the voltage drop through the isolator, thereby eliminating the need for the alternator output to be adjusted. Several different regulator designs are commonly used, so always follow the manufacturer's recommendations.

Dual-output alternators that eliminate the need for an isolator are available. In this case, the isolating diodes are within the alternator, adding to the already high degree of heat that is intrinsic to the alternator output process.

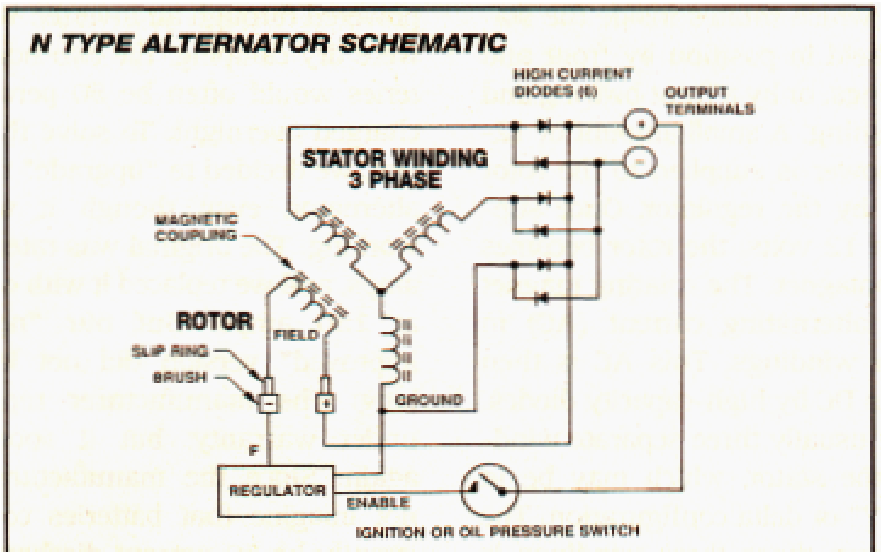
Relays. The original method of connecting the two batteries was with a continuous-duty relay. At this point the difference between a solenoid and relay should be discussed. A relay is a device that uses a small amount of current to control a large amount of current. A solenoid is a similar device but involves physical movement. Two examples are the solenoid on some luxury .vehicles that closes the trunk, and the solenoid on some GM starters. in these instances, a small amount of current controls a large amount of current, which in turn provides physical movement.

The device used to join the coach and chassis battery is called a relay. When the ignition switch is in the "on" position, current flows to the small terminal that activates the relay to join the two batteries, allowing them to be charged from a single alternator.

Early relays experienced some durability problems, and the isolator became the method of choice used by most motorhome manufacturers. In recent years the trend has been back to the relay, and most coaches are equipped with such a device. In large part this is because of work done by Intellitec, C3589. The company supplies a continuous-duty relay that is very dependable and lasts a long time. The relay is available from Intellitec (131 Eisenhower Lane N., Lombard, IL 60148; 630-268-0010) under part number 77-90000-000.

In addition, PowerTap Inc. (1513 N.W 46th St., Seattle, WA 98107; 800-54 1-7789) markets the Isolator Eliminator. This device is a regulator that incorporates a microcomputer that senses the condition of the second battery bank and sends a controlled charge to that bank.

Alternators. The alternator is a device that provides 12-volt DC to power accessories and to charge the batteries while the engine is running. The alternator pulley is connected to the rotor, which rotates inside the stator. It is held in position by front and



Adapted from *Living On 12-Volts With Ample Power* by David Smead & Ruth Ishihara

rear bearings, or by a front bearing and a rear bushing. A small amount of 12-volt-DC power is supplied to the rotor windings by the regulator. Once supplied with 12 volts, the rotor becomes an electromagnet. The rotating magnet produces alternating current (AC) in the stator windings. This AC is then rectified to DC by high-capacity diodes. There are usually three separate windings on the stator, which may be in either a "Y" or delta configuration. The current from these three windings is rectified into 6 pulses per revolution. The result is 12-volt DC, with some ripple effect. As the alternator reaches operating rpm, the ripple effect is minimized. The output of the alternator is controlled by a regulator, which may be internal or external to the alternator. An alternator is designated as either a "P" or "N" type, depending upon whether the regulator is connected to the positive or negative side of the rotor.

When shopping for a replacement alternator, it is important to know whether it is rated in cold or hot amps. A cold amp rating may be higher than a hot amp rating, but the performance will be lowered once the alternator is up to operating temperature. Because of the charge demand encountered in motorhomes, the alternator usually operates at a high temperature. This makes the cold amp rating unrealistic in motorhome applications. After an overnight stop, the house batteries can be significantly discharged the next morning. As we start down the highway again, we expect the alternator to power our radio, air conditioning, and other accessories while it is also attempting to recharge the depleted house batteries. Some alternator manufacturers do not understand how deeply motorhome batteries can be discharged and that the alternator will have to run at maximum output for a significant period of time. This can create very high temperatures.

We have experienced four alternator failures in two coaches because of excessive charge demand. In 1986 we had a new Holiday Rambler Imperial. Among many other features, it was equipped with an icemaker that was powered through an inverter. When we were dry camping, the two house batteries would often be 50 percent discharged overnight. To solve this problem, we decided to "upgrade" the OEM alternator, even though it was still working. The original was rated at 105 amps, and we replaced it with one rated at 130 amps. But our "new and improved" version did not last very long. The manufacturer repaired it under warranty, but it soon failed again. Since the manufacturer could not imagine that batteries could frequently be 50 percent discharged, the company accused us of trying to charge sulfated batteries.

We learned two things from this experience. First, the high output replacement alternator was rated in cold amps and was meant to produce maximum output only intermittently. Second, the original alternator's 105 amps was a conservative hot rating. We reinstalled the original device, and it was still working when we sold the coach four years later.

We do admit that our current coach, a Prevost conversion, uses plenty of 12-volt power, and we have experienced two alternator failures, most likely due to excessive heat. The first alternator had a bearing failure, and the second showed evidence of a massive meltdown of both the rotor and stator windings. The last time, we traveled 1,755 miles over two weeks without an alternator. The solar panels kept us going. David Smead of Ample Technology, C6485, suggested that we install the heaviest alternator with an adequate output that would fit our coach's mounting bracket and space. Because of its increased mass, a heavier alternator can dissipate heat better and more easily maintain an appropriate operating temperature. We were surprised to find that the replacement alternator had the same amperage output (probably very conservatively rated) but weighed twice as much as the previous unit, it has been performing well for the past three years.

Delco manufactures a gear-driven, high-output alternator that is externally lubricated and oil-cooled. This is a 24-volt, 250-amp unit. A similar belt driven unit is available on the Series 60 Detroit Diesel engine. Although we have no experience with either of these alternators, we have heard that they have a long service life. The high capacity, plus engine oil lubrication and cooling, most likely contributes to the longevity.

Convertor-chargers. Most Class A and Class C motorhomes have a convertor-charger that runs 12-volt-DC house loads from an AC input A convertor-charger can also charge or maintain the charge of the batteries.

The *linear, unregulated convertor-charger* type is the least expensive, but it is sensitive to variations in AC input. If AC voltage is low, the output will be less than 12 volts; if AC voltage is high, the output will be greater than 12 volts. It can cause radio frequency interference (RFI), which results in a hum in radios, televisions, and communication equipment. The charge capabilities of linear, unregulated convertors vary with the manufacturer, and their capacity is 50 amps or less. Because these convertors are unregulated, they will overcharge batteries if left on for prolonged periods.

Ferro-resonant convertor chargers use a special resonating circuit in the transformer. This creates an electromagnetic field that is intended to keep the output constant, even with AC input variations. They are usually rated at 50 amps or less, and manufacturers claim that they produce less RFI than other convertor-chargers. Because of their lack of regulation, however, these chargers often provide only 5 percent of their rated output at 13.6 volts (desirable float voltage). Any DC demand exceeding this output will be drawn from the batteries. This effect causes the batteries to be undercharged. During periods of disuse, a ferro-resonant convertor-charger can overcharge the batteries. It is imperative to check battery electrolyte levels regularly.

A *phase-controlled convertor charger* uses silicone-controlled rectifiers (SCRs) to regulate the DC output and has the potential to allow multistage charging. SCR chargers can be used with some of the linear unregulated convertors via a transfer switch and can cause RFI. They also can be subject to diminished output when the incoming voltage is low. This is aggravated by high-consumption appliances such as air conditioners or heaters, which reduce the line voltage. DC lights may appear dimmer than usual. Under these conditions, the charger may not reach its rated output. With ample AC input, the charge voltage is set at a constant rate. Since optimal charging is dependent upon the age and temperature of the battery, a constant set voltage may not always be the proper charge rate. Again, battery water levels should be checked regularly.

A modified version of the SCR phase-controlled charger with multistage charging capabilities and adjustable voltage set points is used by some inverter-charger manufacturers.

At approximately 45,000 cycles per second (45 Khz), high-frequency switch-mode chargers can produce a nearly pulse-free direct current. FETs (field effect transistors) or MOSFETs (metal oxide semiconductor field effect transistors) incorporated into the charger are capable of switching at this high rate of speed. The pure direct current diminishes battery heat during charging. Although the pure DC does not cause noise in stereos and other equipment, the high-frequency techniques that produce the pure DC may cause some radio and TV interference. If the charger is properly shielded, this can be minimized. The high-frequency switch-mode chargers can produce full output current even with low AC line voltages and can be protected from high temperatures. Of the three coaches we have owned, one had a linear, unregulated convertor-charger, and the other two were delivered with ferro-resonant convertor-chargers. The last two also had inverters without chargers. No problems were experienced in the first coach, because it didn't have much optional equipment and, therefore, had low electrical demands. The other two coaches were filled with options and had much higher electrical demands. Because of the higher usage, it was impossible to recharge the batteries with the convertor-charger. Only when we switched to inverters equipped with high-output (120 to 130 amps) multistage charging did we solve our charging problems.

12-volt circuit protection. Circuits must be protected to prevent damage from excessive current flow caused by shorts, etc. Three main methods of circuit protection exist — fuses, circuit breakers, and fusible links.

A fuse is an electrical safety device that has a metal wire or strip that melts and interrupts the circuit when the current becomes too high. Most motorhomes have one fuse box for the chassis and one or more fuse boxes for the house. Some chassis use fusible links, a section of smaller-gauge wire inserted in a line that will melt under a high load and act like a fuse.

Most RV owners know the location of their fuse boxes. The boxes may use blade or barrel-type fuses, which will have ratings ranging from a few amps to 30 amps. Radios and other equipment may have individual in-line fuses. It is important to determine the location of all fuses. As mentioned in the introduction, a manufacturer's wiring diagram will help you to identify the circuits protected by each fuse, as well as the location of the wires.

Fuses may be rated to protect the component or to provide overall disaster protection. The end component is best protected by having specific fuses with as low a rating as possible that still will perform. Disaster fuses are designed to protect the wiring in case of a dead short. Most inverter-charger manufacturers recommend the use of a 200- to 300-amp fuse on the positive lead between the batteries and the inverter-charger. Both the house and chassis systems should be protected with either high-output circuit breakers on the positive lead from the batteries, or a fuse sized for the system on the negative battery lead. Make sure fuses for battery overload protection and inverter-charger uses are DC-rated. These protection features may be absent in some coaches.

Whenever electrical components are added to a coach, they should be protected with proper circuit protection. More sensitive equipment will benefit from individual fuse protection. For example, rather than using one 20-amp fuse for four 5-amp loads, it would be better to use four individual 5-amp fuses at each load. The 20-amp fuse could be left in place to protect the wiring from the main source to the accessories. In addition, wires must be adequately sized to carry the load.

Some circuits use circuit breakers rather than fuses. Generally, circuits that pose safety or severe inconvenience issues incorporate circuit breakers. Power windows, power seats, and windshield wipers represent a few examples. Circuits using circuit breakers also are tolerant of overloading for a brief period of time before creating an open circuit. Fuses, on the other hand, will "blow" instantly, thereby creating an open circuit. Using a circuit breaker in a circuit designed for a fuse is not a good idea. Let's say, for example, that you installed a circuit breaker in a radio circuit and a short developed. Internal damage to the radio could be done before the circuit breaker tripped. The fuse, on the other hand, would open immediately.

Two types of circuit breakers exist —recycling and non-recycling. The recycling type will reset after being tripped, even with the voltage still applied. The non-recycling circuit breaker will not recycle until the voltage to the breaker is shut off.

Fusible links generally are used in heavy-current circuits coming from the starter relay. A fusible link is simply a wire one size smaller than the wire in the system. When the current flow becomes excessive, the smaller wire becomes hot and "open."

Equipment upgrades. If your electrical system is performing to your expectations and requirements, you may not want to change anything. However, if your system does not have battery-disconnect switches, you may want to add them for both the chassis and house batteries, especially if you experience chassis battery discharging after several months of storage.

Intellitec makes a disconnect switch with a digital voltmeter that can monitor both the chassis and house batteries. Low-cost battery-disconnect switches that attach directly to the battery are also available. If your electrical system does not have either high-amperage circuit breakers or protection fuses, you should consider installing them for safety reasons.

RVers who are frustrated with their coach's electrical systems may want to consider some modifications. Some motorhomers have given up dry camping, because they are not able to remain off shore power for 24 hours. In order to solve the problem, you must identify the deficiencies. Is the battery capacity high enough? Is the capacity adequate but not the charging ability? Do excessive loads, such as a high-wattage inverter, exist? The answers to these questions will lead you to the required modifications.

Evaluating a system requires accurate instruments. Many coaches have an analog voltmeter, but these devices have several drawbacks. They may monitor only one system, not both the chassis and house systems, and they do not have adequate resolution. A digital voltmeter is much more accurate, but it still does not truly reflect the battery's state of charge. While the battery is in use, its terminal voltage does not measure its remaining capacity. Voltage is related to the state of charge only when the battery has been neither charged nor discharged within 24 hours. A rested, fully charged battery will show a voltage of approximately 12.8 volts. One that is 50 percent discharged will show approximately 12.2 volts. Because the difference between the two is merely .6 volt, only amp-hour instruments can accurately evaluate the state of charge of a 12-volt system. Amp-hour instruments continuously measure the flow of current into and out of a bank of batteries and compute the amp-hours used. Before purchasing an amp-hour gauge, review its specifications thoroughly.

This article is intended to be only an overview and does not have the scope to address all issues. Each and every coach electrical system must be evaluated individually. Before making major changes to your motorhome, thoroughly research your project.

Although many books about RV electrical systems exist, we are familiar with those listed below. We recommend them as a way of gaining a better understanding of the DC system.

W*iring 12 Volts For Ample Power* by David Smead and Ruth Ishihara, $20.

L*iving On 12 Volts with Ample Power* by David Smead and Ruth Ishihara, $25.

T*he Ample Power Primer* by Ample Power Inc., $4.95.

All of the above three books are available from PowerTap Inc., 1513 NW 46th St., Seattle, WA 98107; (800) 541-7789 (phone orders with VISA, MasterCard, Discover), (206) 789-1138.

• *RV Electrical Systems* by Bill and Jan Moeller, $19.95, plus approximately $4 shipping and handling. This book is available from TAB Books, a Division of McGraw-Hill, P.O. Box 548, Black Lick, OH 43004; (800) 262-4729.