BY GARY BUNZER

WIRING FOR SAFETY

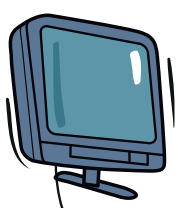
Understanding the operation and components of the motorhome's 120-volt-AC systems can help you avoid potentially dangerous electrical problems.

EFFECTS OF 120-VOLT (60-HERTZ) AC CURRENT ON THE BODY

CURRENT FLOW	EFFECT ON THE HUMAN BODY
1 milliamp (ma) or less	Not usually felt.
5 ma	Painful shock.
10 ma	Local muscle contractions. For 2.5 percent of the population, it will prohibit a person from letting go of the circuit.
15 ma	Local muscle contractions. For 50 percent of the population, it will prohibit a person from letting go of the circuit.
30 ma	Difficult to breathe. May cause unconsciousness.
50 – 100 ma	Possible ventricular fibrillation of the heart.
100 – 200 ma	Certain ventricular fibrillation of the heart.
Over 200 ma	Severe burns and major muscle contractions. The heart is apt to stop.
A few amps and above	Irreparable damage to body tissue.

Not many technical discussions within the motorhome community cause more consternation than those that involve understanding the nuances of the multiple electrical systems common to virtually every motorhome on the road. As author of the monthly "House Calls" column in *Family Motor Coaching*, I receive thousands of e-mails annually, and by far the majority of technical problems proffered by active motorhome owners fall within the scope of one of the onboard electrical systems. Though the 12-volt-direct current (DC) battery system does cause some issues, it's the higher-voltage, 120-volt-alternating current (AC) systems that seem to create the most anxiety and will be the focus of this three-part series.

Motorhome owners are accustomed to the conveniences of having 120-volt-AC electric in the coach. Many motorhomers wouldn't even consider venturing out on an excursion without their personal computer, cell phone chargers, hair dryer, curling iron, coffeemaker, electric razor, popcorn machine, toaster, etc. After all, the 120-volt-AC receptacles in the motorhome are



This three-part series examines the intricacies and safety issues that relate to a motorhome's 120-volt-AC electrical systems, and provides information about how to protect individuals and the motorhome when this electric source is being utilized.

PART 1

the same as those in our stationary home, right? Well, that's partly correct. Yes, you can plug anything into a motorhome's 120-volt-AC receptacle that you could plug into a residential 120-volt outlet, but the internal wiring of the motorhome is configured a little differently from a residential home. I addressed these differences last year in a "House Calls" column ("Air Conditioner Woes — Redux," page 24, June 2009) and we'll review that information in greater detail later in the article for those of you who may have missed it or overlooked its importance. The focus back then, as now, centers on personal and property safety — meaning you and your motorhome.

As a reminder, here's a quick RV "Fact of Life" I often cite in the seminars I present. Bluntly stated, electrical shocks can be lethal! The human body conducts electricity wonderfully. As you scrutinize the accompanying chart (opposite page), keep in mind that one milliamp is only 1/1000 of an amp (0.001 amp).

Yes, RV electricity should indeed be respected, but not feared. Always adhere to the following safety precautions while working on the 120-volt-AC systems in a motorhome:

- Unless properly measuring voltage or current flow, never work on live or "hot" circuits.
- Always use insulated tools and equipment.
- Always work in a clean, dry space. Never troubleshoot AC circuits while wet or damp.
- Wear appropriate clothing, such as long sleeves and insulated shoes.
- Remove all metallic jewelry.
- Always hold test meter probes by their insulators; never touch the metal test points.
- Inspect your diagnostic equipment regularly. Check for defects such as broken or cracked insulation on the test leads, frayed or exposed wires, etc.
- If you have any doubts, stop! Call a certified RV service technician or licensed electrician.

It is often stated to always check the AC voltage source before plugging a motorhome into any campground pedestal. In other words, make sure the voltage is in the acceptable range (107 volts to 130 volts) and that the polarity is correct. Subsequent to the discussions that resulted from that earlier "House Calls" column, it was discovered that some readers were unclear about how to actually go about verifying the polarity of a voltage source. We will get to testing voltage and polarity at the pedestal in Part 2 of this series, but first let's review what constitutes a motorhome's 120-volt-AC systems.

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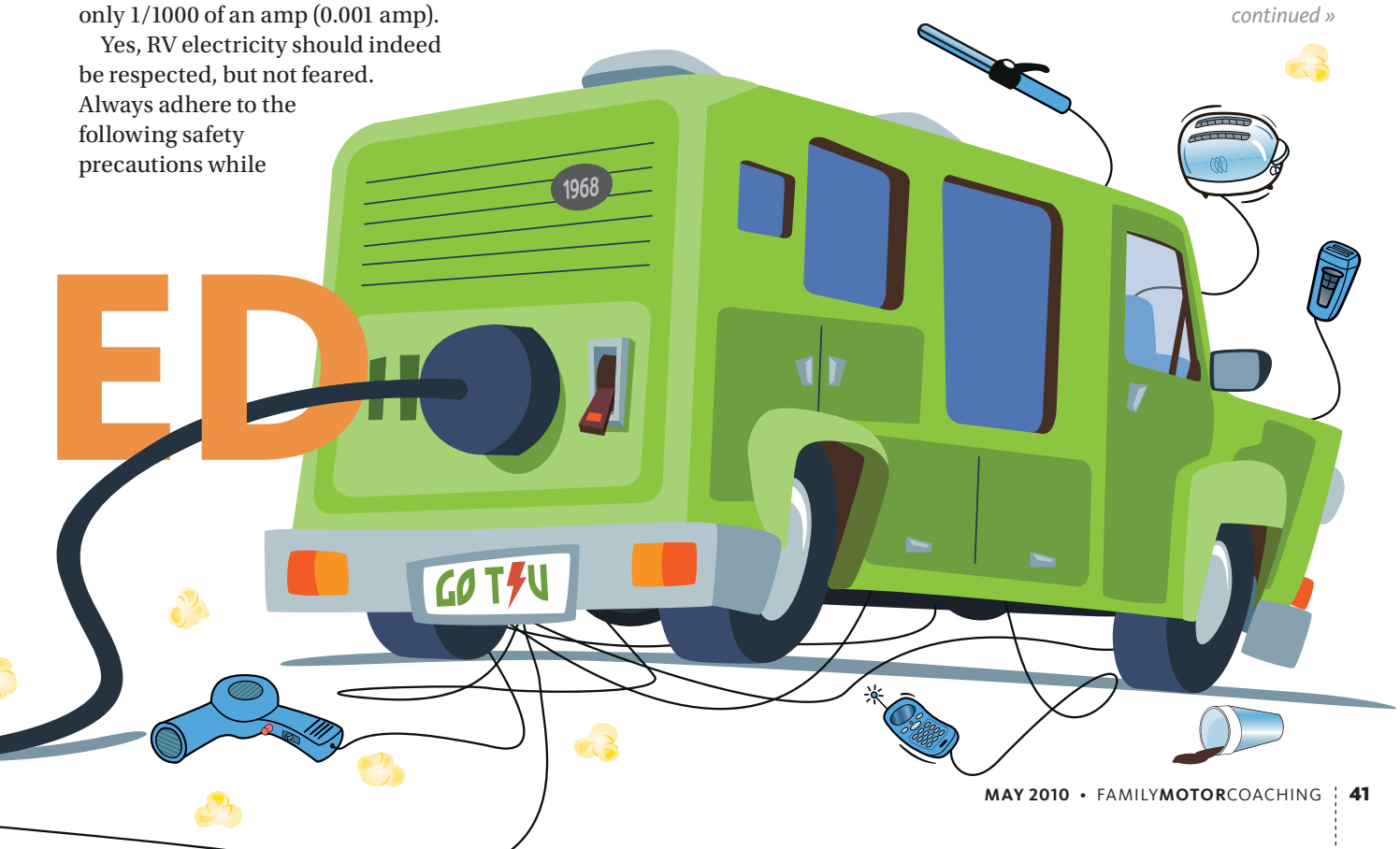

AC ELECTRICAL COMPONENTS

As denoted by the plural word "systems" above, it must be understood that virtually every motorhome has the capability to utilize and employ more than one AC source, albeit not at the same time. The most obvious source is when a motorhome owner connects the shoreline cord to a campground pedestal. A source of untethered AC power is the RV generator. An integrated power inverter can supply yet a third source of AC electricity for some motorhomes.

The informed coach owner will be able to switch from one voltage source to another (either manually or automatically); will know where to locate the distribution panelboard (breaker box) and be able to identify its components; can identify where individual circuit breakers are inside the coach; and will know the assorted AC voltage loads required by the electrical devices in the motorhome. Typical AC loads consist of "hardwired" devices such as the converter, air conditioners, inverter/charger, ground fault circuit interrupter (GFCI), water heater element, ceiling fans, mounted lamps, energy management systems (EMS), etc. Plug-in devices include the microwave oven, televisions, satellite systems, entertainment centers, washer/dryer, refrigerator, garbage disposal, vacuum cleaners, ice makers, etc. In addition, an assortment of standard, duplex receptacles are located throughout the coach, as well as those unseen, all-important wires that connect it all together — not to mention other ancillary equipment such as pigtail adapters, extension cords, voltage boosters, and surge protectors. Collectively, these compose the motorhome AC electrical system. One or more of these can become a problem if not cared for properly. The intent of this article, however, will be limited to the coach AC systems in general. It is not intended to be a troubleshooting guide for individual components.

Three common electrical testing devices (left to right): a clamp-around ammeter, a digital multimeter, and a plug-in circuit analyzer.

ELECTRICAL TEST DEVICES ALL COACH OWNERS SHOULD CARRY

It is a well-known fact that FMCA members are not typical RVers. The technical savvy of the membership continues to astound me. This section may seem elementary to some of you, but allow me to highlight the necessity of having a few quality-built testers on board.

The most important and most versatile test device is a volt-ohm-meter (VOM), also called a digital multimeter (DMM). I recommend the digital version for its accuracy and ease of use. Nice digital meters are available at very reasonable prices, so there's really no excuse for any coach owner not to have one. If you plan to measure output voltages produced by some inverters, look for a DMM that also measures true root mean square (RMS) voltage.

Another necessity when traveling in a motorhome is a plug-in circuit analyzer. These devices are quite useful for checking the polarity of the receptacles inside and outside the coach. They are inexpensive and readily available at any hardware, home improvement, or mass merchandise store. Some may even be equipped with a built-in GFCI test function.

A clamp-around AC ammeter, though more costly, is highly recommended for the do-it-yourselfer who gets into a deeper level of electrical troubleshooting and needs to measure current flow. The value of a clamp-around ammeter is that amperage can be measured without having to break into the circuit or disconnect any wiring. That safety factor alone is worth the cost to some. Some digital ammeters can measure both AC and DC current flow — a handy feature for checking battery charge and discharge rates, battery drains, and AC current usage.

Some of the folks I have worked with have found all these benefits, plus more, in a meter produced by Extech (www.extech.com). The EX830, for example, measures AC and DC voltages (true RMS); AC and DC current (amperage flow); resistance; capacitance; and continuity. It also contains an infrared (IR) thermometer and a type K thermometer (very handy for troubleshooting furnace output temperatures, refrigerator and air conditioner cooling effectiveness, and other tasks around the motorhome), and it can measure frequency (more on this later). These devices have a price around $200.

Another good AC test device is a proximity voltage tester, also known as a tic tracer. This device allows you to detect the presence of AC voltage without having to disconnect any wiring or expose the conductors. It also provides the added safety bonus of not requiring you to actually make physical contact with a "live" or "hot" wire. The more sophisticated models have an audible beep and flashing light that becomes more rapid and brighter the closer the device is to the actual wiring. As you trace the wiring, the beeping continues until you reach a break in the wire, and then it stops. Professional RV service

technicians use a proximity tester to quickly locate hidden wires and open circuits. Readily available in myriad sizes, quality, and price points, a very nice one can be purchased for approximately $75.

So for around $300, you can be equipped to measure or monitor just about anything involved with the motorhome's 120-volt-AC systems.

UNDERSTANDING THE MOTORHOME AC DISTRIBUTION SYSTEM

The two illustrations (right) depict a typical RV 30-amp AC and 50-amp AC circuit. Notice that in both illustrations the shoreline cord feeds directly into the distribution panelboard (breaker box). In reality, the cord will likely terminate first in a junction box before feeding the breaker box. Also notice that the white neutral conductors are secured to an insulated neutral buss inside each breaker box. This is important, since, in any recreation vehicle, the neutral wires must remain isolated from the ground conductors. The National Electrical Code (NEC) for recreation vehicles states that the ground circuit in the motorhome cannot be permitted to carry electrical current, and the neutral wire in a motorhome indeed carries current.

This is the major difference between motorhome wiring and common household wiring. This also was the point of contention that stemmed from that earlier "House Calls" column. I cannot say this more emphatically: because of the isolated neutral requirement, the motorhome AC system is indeed different from common household wiring. While the house wiring allows the neutral and ground wires to be interconnected at the service entrance, in the motorhome, they must be kept separated.

Here's a quote from the *RV Electrical Systems* textbook published by the Recreation Vehicle Industry Association (RVIA), the same

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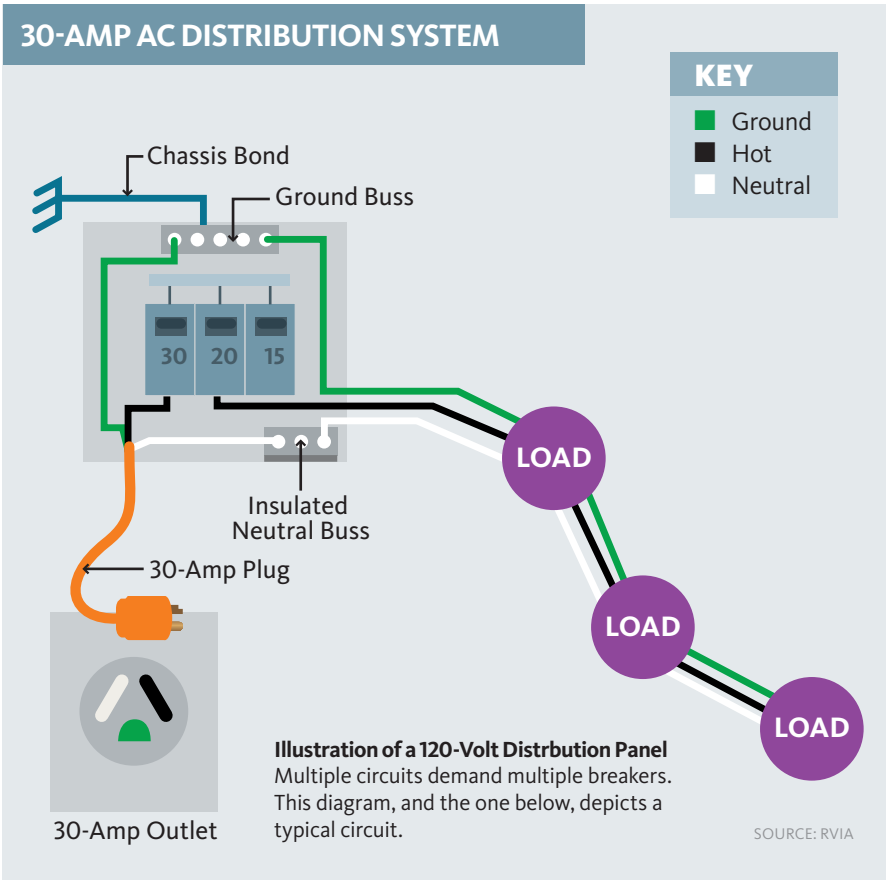
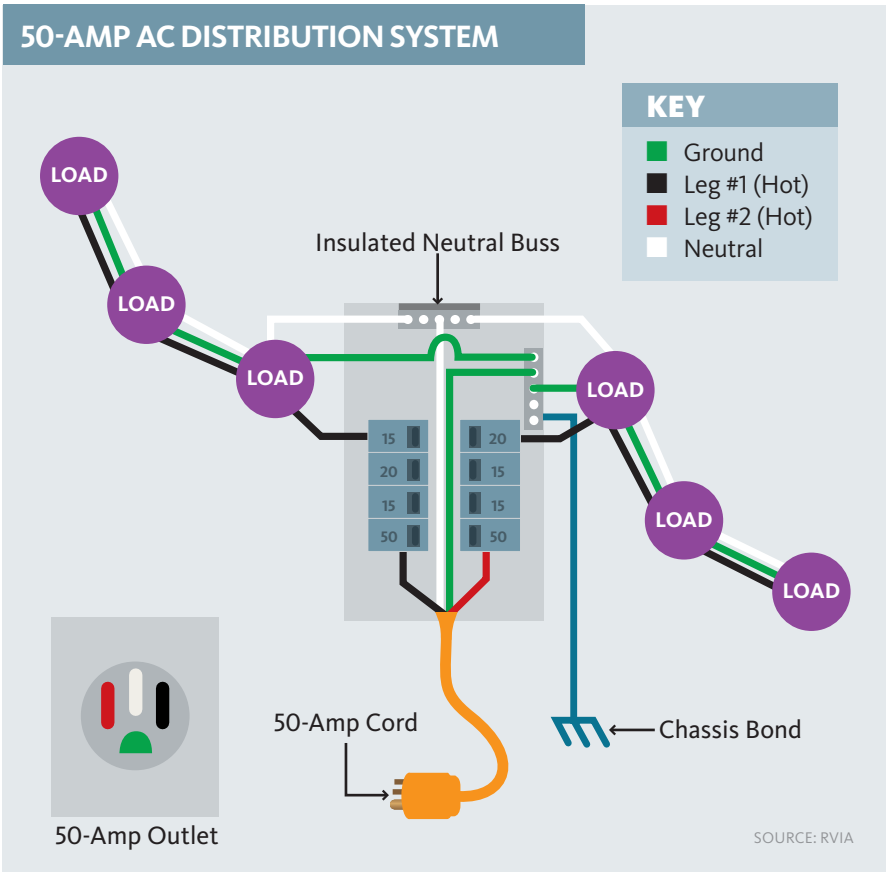


Illustration of a 120-Volt Distrbution Panel
Multiple circuits demand multiple breakers. This diagram, and the one below, depicts a typical circuit.

SOURCE: RVIA

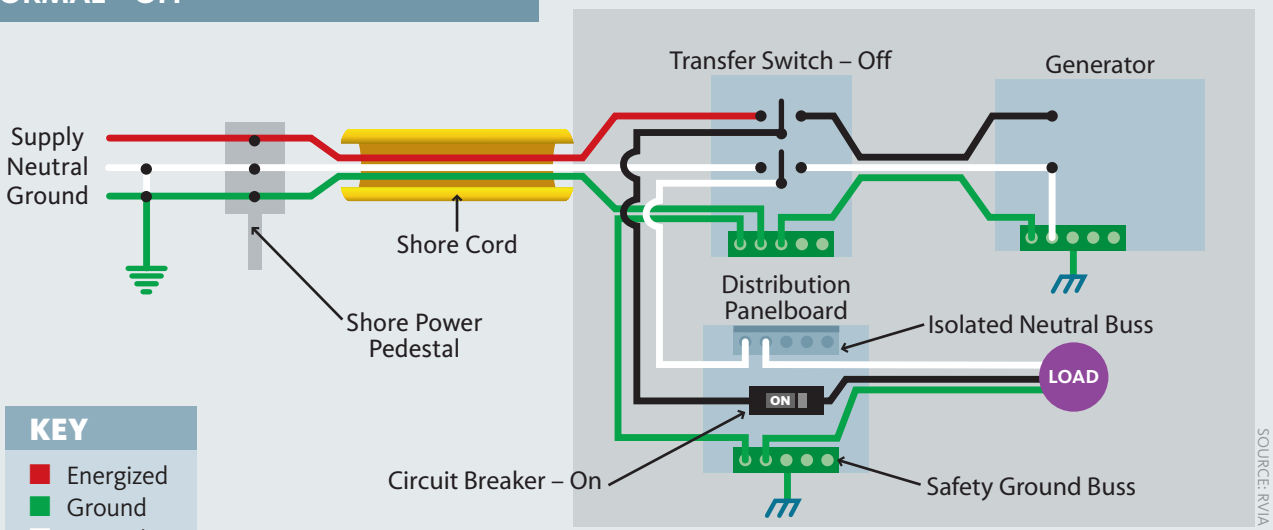


SOURCE: RVIA

textbook used to teach professional RV service technicians:

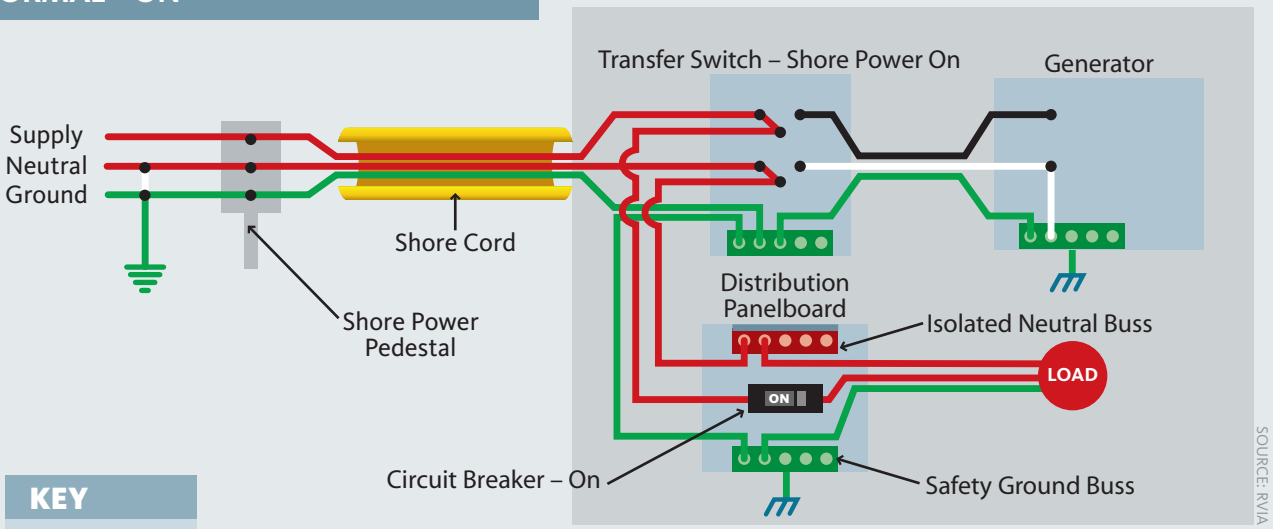
"In the distribution panelboard there are two terminal strips, or buss bars, for connecting wires. One buss bar (insulated from the box) is for the neutral and the other (screwed to the box) is for the grounds that are grounded to the vehicle chassis. In other words, the white and bare wires are isolated from each other. This ensures 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.' This condition is extremely dangerous. In a house, the white and ground wire can be connected to the same buss bar since the house electrical system is grounded from the panelboard to a steel ground rod that is driven into the earth.

NORMAL – OFF



The automatic transfer switch in this hypothetical motorhome is in the "off" or "open" position. Therefore, the incoming voltage stops at the transfer switch.

NORMAL – ON



The shoreline cord is now providing power from the pedestal, through the transfer switch and to the distribution panelboard inside the motorhome. From there, it proceeds through the circuit breaker and to the load. Note that both the "hot" (supply) and the neutral wires are energized all the way to the load and back. (Remember, the neutral wire is a current-carrying conductor.) This, too, demonstrates a normal electrical situation.

The RV does not have the grounding rod to insure the needed grounding. It depends on the grounding of the land-based supply system that is connected to the RV through the grounding wire of the power supply assembly (shore cord and panelboard)."

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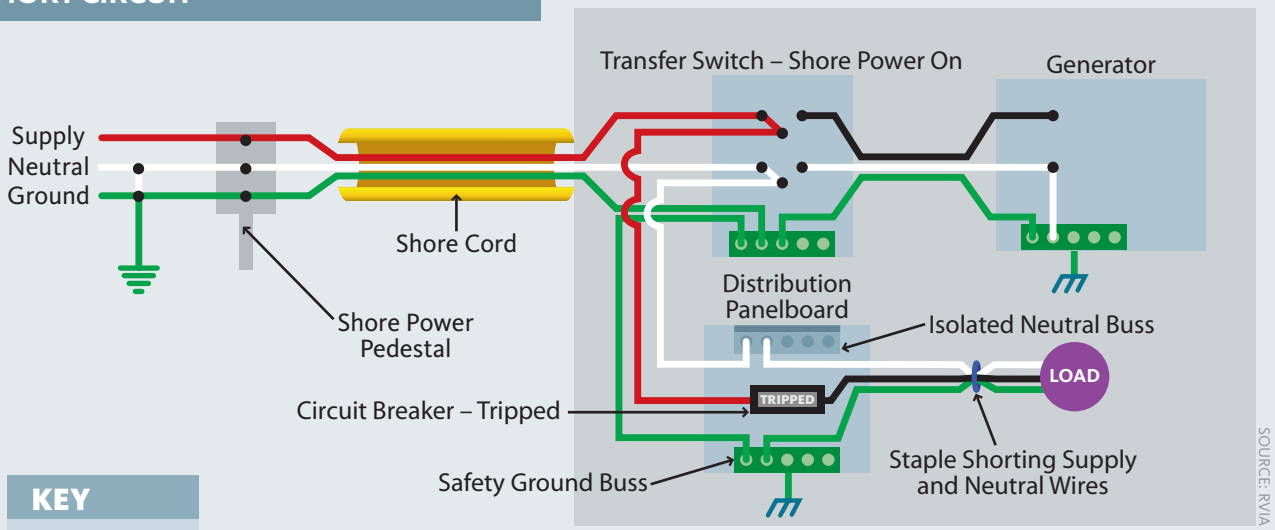
SHORT CIRCUIT

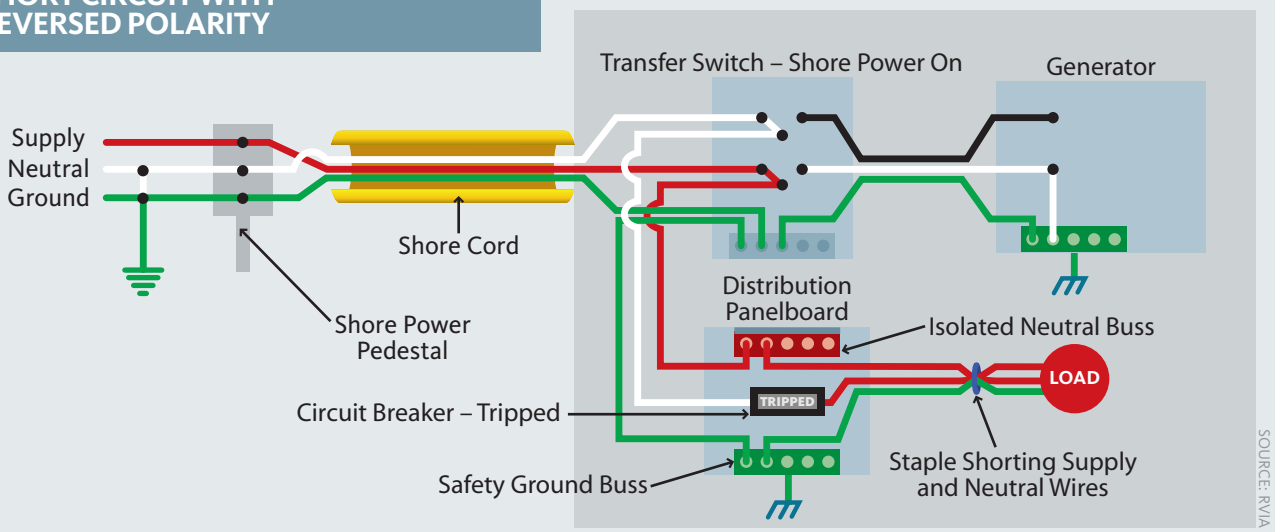


KEY

- Energized
- Ground
- Neutral
- Supply

This diagram shows a common type of short circuit — a staple was driven through the Romex wiring behind a wall, causing a direct short. The result is a tripped circuit breaker. This, too, is an expected situation in the event of a direct short. The protective circuit breaker did its job and prevented further damage or injury by stopping the current at the breaker. However, now the short must be located and rectified before that circuit can be energized again.

SHORT CIRCUIT WITH REVERSED POLARITY



KEY

- Energized
- Ground
- Neutral
- Supply

The same short circuit in the motorhome is shown, but this coach also suffers from reversed polarity. Notice the reversal at the shoreline cord connection at the park pedestal. As previously mentioned, this polarity reversal can occur anywhere within the power supply, the park pedestal, the pigtail adapter (not shown in the diagram), the shoreline cord, the transfer switch, the distribution panelboard, or in any section of the RV's wiring. Also notice that the circuit breaker will still trip and remain "open." This is a very dangerous situation. With the breaker in the tripped position, one would think the circuit downstream of the breaker is now "dead" or de-energized. But with the hot and neutral reversed, the circuit is still energized. Follow the RED wires!

The following is from the same textbook:

"RVs are wired differently than 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. Reverse polarity occurs when the white and black wires are crossed. In an RV, the power supply cord or power supply adaptor plug can provide reverse polarity. This is especially possible where someone cuts off the ground pin of the cord or uses an ungrounded (2-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, energizing the exterior skin or other metal parts leading to severe burns or possibly death."

Another section in the book states:

"An important factor to remember is when working on distribution panelboards, the RV is unlike a house! The RV has the neutral circuit isolated from ground. As explained earlier this is so that reverse polarity could not 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."

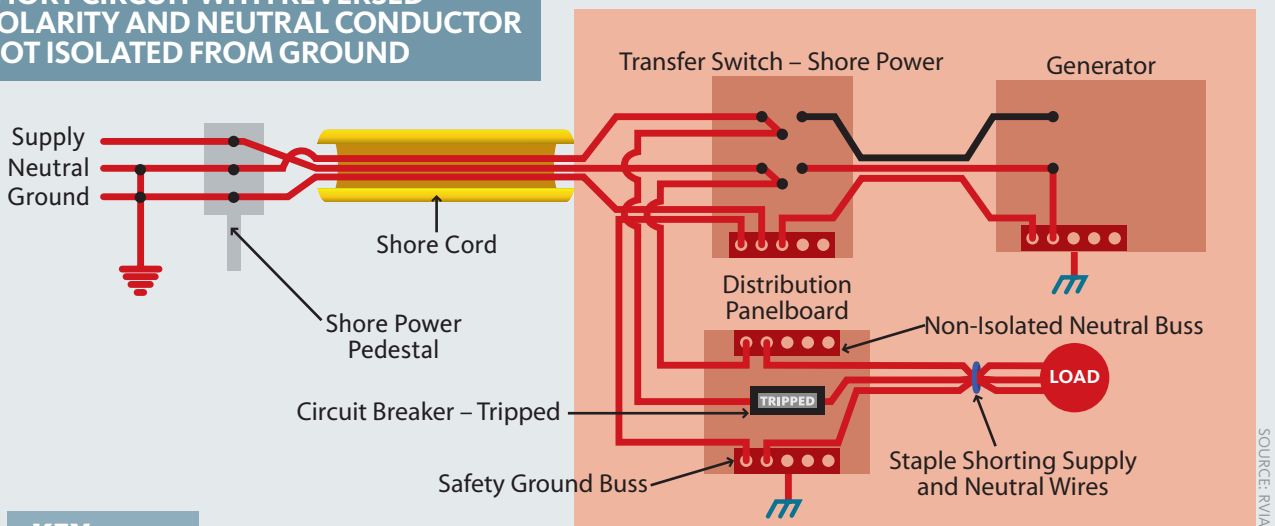
It is notable that in no less than three separate sections of the textbook, the point is made concerning the importance of the isolated neutral wire in a recreation vehicle.

Keep in mind, the reversed polarity mentioned in the textbook can be manifested within any motorhome circuit, within the pigtail adapter, or within any extension cord or motorhome shoreline cord. The same malady also can occur at any campground pedestal — hence, the importance of verifying the voltage and polarity of that voltage prior to plugging in the shoreline cord.

The importance of maintaining a safe and secure motorhome 120-volt-AC system should never be taken for granted! It's the proactive, informed coach owner who has the advantage. So, what's to do? Well, frequent inspections and specific electrical measurements and tests performed periodically will ensure your equipment is in safe operating condition. Also, never subject the motorhome to an improper voltage source.

Part 2 of the series will examine safety precautions and necessary tests along the route of electric from the pedestal to the distribution panelboard, along with generator and inverter output testing. FMC

SHORT CIRCUIT WITH REVERSED POLARITY AND NEUTRAL CONDUCTOR NOT ISOLATED FROM GROUND



KEY

- Energized
- Ground
- Neutral
- Supply

If nonisolated neutral conductors were used in a motorhome (meaning, the neutral and ground wires are interconnected inside the breaker box, such as you would find at the service entrance at a house), a short circuit with reversed polarity would result in all the metal components of the motorhome becoming energized. All chassis and frame members, electrical boxes, possibly the entry step, and, in some cases, the exterior skin would become "hot." Because of electrical bonding (another NEC requirement), virtually all metal parts, inside and outside the motorhome, are now lethally energized.

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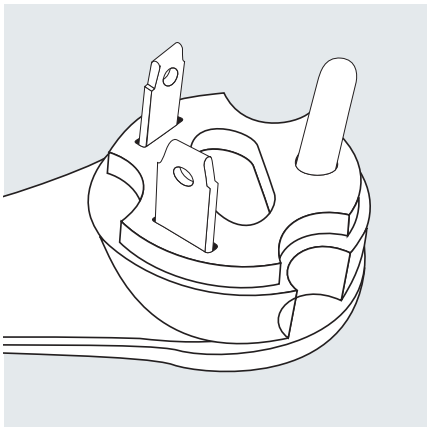
PART 2

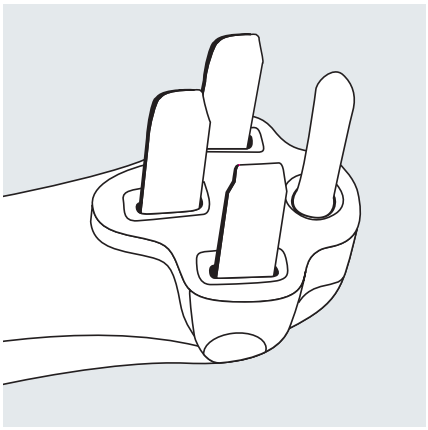
AC SHORELINE CORD

All motorhomes will have either a 30-amp (on left), or a 50-amp (on right) shoreline connection. The difference is obvious; three contacts and conductors for the 30-amp plug, four for the 50-amp plug.

Begin by closely inspecting the entire length of the cord from the point it enters the motorhome, all the way back to the plug. Look for cuts, abrasions or any damage. At the plug cap end, be sure the molded plug is intact. Look for any sign of melted rubber near where the metallic prongs emerge from the plug. Molten rubber is a sign of overheating and should be investigated further. Try to wiggle each prong with your fingers. If they appear loose, pitted, wobbly or otherwise burned or damaged, replace the cord.

If the plug cap has pulled away from the remainder of the cord exposing the individual conductors, (such that might happen when forgetting to unplug the cord before pulling away from the campsite), it will be necessary to replace the entire cord. Yes, I know retail outlets sell individual plug caps that can be easily installed should such an occurrence happen, but… Actually there are two "buts." In order to remain code compliant, the plug cap must be molded onto the shore cord in order to safely guard against water intrusion (important). And secondly, replacement plug caps usually necessitate attaching the stranded conductors with a screw and clamp-type, mechanical device. Screw connections have a propensity to vibrate loose causing an unnecessary arcing situation. Arcing causes overheating and problems become accentuated.





While at the shoreline plug, take the time to clean and brighten the prongs. Corrosion and oxidation on the metallic contacts can cause improper conductivity of the AC electricity (notice the corrosion on the 50-amp plug above). Use 0000 steel wool or fine sandpaper to remove the corrosion, leaving each prong bright and shiny. Add an electrical contact preservative to aid in maintaining the cleanliness of the plug contacts. Perform this maintenance task two or

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three times per year or as necessary.

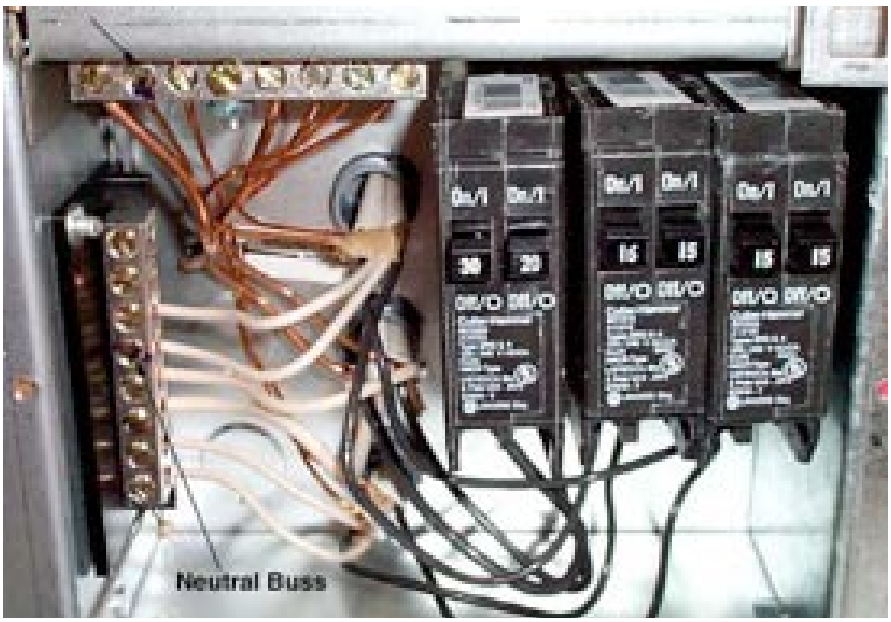
For a video explanation regarding shoreline plug maintenance, check out this You Tube tip: http://www.youtube.com/watch?v=QoVUozvu5IU

AC SHORELINE CORD TESTS

As discussed earlier, having an electrically sound ground connection is crucial to the safety of the motorhome and you. The integrity of the ground wire must include a complete metallic path from the shoreline cord ground pin, through the cord, the transition to Romex cable, through every connection via the internal wiring through the distribution panelboard, through the bonding wire to the chassis of the motorhome. Here's how to verify the integrity of the ground path.

At the shoreline plug, with your versatile VOM on the Ohm's scale, measure the resistance between the ground pin and a clean, bare metallic portion of the motorhome chassis. Note: it may be necessary to scrape away some paint or undercoating on the frame in order to obtain a valid measurement. If the measurement is anything less than 1-Ohm, the ground connection is secure and proper. Typically you'll measure less than .5-Ohm indicating continuity. As a redundant check using a digital VOM, reverse the test probes and measure again.

Before continuing to the next test, turn on all circuit breakers inside the motorhome. Then measure the resistance between the ground pin on the shoreline cord to each of the current-carrying flat blades on the shoreline cord. On 30-amp cords, there will be two flat blades (hot and neutral). On 50-amp cords, there will be three flat blades (hot-black, hot-red and neutral). If the resistance measurements between the ground pin and the flat blades are higher than 1-Mega Ohm (one million Ohms), the wiring is correct. Typically it will measure "infinity" (∞). If the measurement is less than 1-Ohm, there is a direct short between ground and that conductor somewhere in the system and further troubleshooting is in order. If it measures less than 1-Mega Ohm, there exists a high resistance leakage somewhere on that wire and again, further troubleshooting is required.



Occasionally, you'll see a large, uninsulated solid conductor attached to the steel chassis. This too is a code requirement for metallic electrical boxes such as the AC to DC converter, the inverter, the generator and the breaker box itself. This is the "bonding" conductor mentioned earlier and not really a "ground" wire as it relates to the AC circuitry in the coach. Bonding conductors will always be uninsulated and typically 8-gauge or larger. The ground wire is a return path for the electron flow while the bonding conductor protects and bonds the metal case of electrical devices to the chassis. Still, those connections, as with all electrical connections, must remain clean, dry and tight as well.

Once you are satisfied the shoreline cord is in good shape, next take a look inside that first junction box (J box). In the J box, the stranded conductors of the shoreline cord usually transition to the solid conductors in the Romex cable. Wire nuts are typically used to make this connection. During travel, wire nuts can vibrate loose so it's the wise coach owner who verifies that all wire nuts in the AC system are wrapped with electrical tape as a precaution. Roof top air conditioners on older motorhomes will often have a J box located in the ceiling, next to the air conditioner. Be sure to check the wire nuts at all J boxes throughout the entire coach.

Speaking of generators; specific code requirements apply to every generator installation as well. As an example, it is required that the conductors coming from the generator be stranded wires sheathed inside a flexible conduit. This is because vibrations, caused by the running generator, coupled with heat accumulation may cause solid conductors (like in Romex), to fatigue and break over time. Therefore, check the wiring connections at the generator J box also.

DISTRIBUTION PANELBOARD INSPECTION

At the panelboard distribution box, remove the cover and gain access to the breakers, the buss bars and all the wiring. Begin by inspecting the neutral buss bar. Is it indeed insulated and isolated from the metallic components inside the box? Only white wires should be attached to the neutral buss. Take the time to tighten all

the setscrews for all the white wires attached to the buss, making sure the screws are indeed contacting the copper conductor rather than clamping down on just the white insulation. Same thing for all the bare copper ground wires. They should be securely attached to their respective buss bar. Likewise, tighten all the black wires where they are attached to the "load" side of each circuit breaker, again making sure the copper conductor is firmly attached to the circuit breaker, not just the insulation. Give a little tug on each black wire to ensure they are secure.

While inside the breaker box, look intently at everything. Look for burned or scorched insulation or any evidence of arcing and sparking. Remember, this is a motorhome. Rolling and bouncing along down the highway causes setscrews to work loose and connections to deteriorate over time. Also inspect the Romex connectors, those clamp-like devices that protect the Romex where it passes through the metallic walls of the enclosure. Today, the majority are made of plastic, but check to make sure each section of Romex that enters and leaves the enclosure of the panelboard distribution box is protected against rubbing and chaffing. If cuts or abrasions are noticed, it may be necessary to replace that section of Romex. Any break in the outer casing of the Romex cable or in the insulation of any individual conductor inside is cause for concern within the 120-volt AC system.

Inside the distribution panelboard is where you can truly see the quality and expertise of the installer and perhaps extrapolate the attitude of the coach maker. When I evaluate the quality of a coach manufacturer, inside the distribution panelboard is one of my key inspection areas. True electrical craftspeople will ensure all the wiring is neat and tidy inside this box. All the insulation will be precisely and evenly trimmed and each conductor will be routed in an organized manner guaranteeing that when a circuit breaker is removed, there is enough slack in the black wire that will enable the breaker to be pulled clear of the enclosure for inspection and testing. Pride in workmanship evident in the hidden areas indicates a quality mindset that typically endures throughout the rig.

Now that the entire shoreline cord, the plug, its attaching points and connections, etc., have been inspected and all the measurements indicate a sound system so far, next, plug the coach into a landline source of AC voltage. Ah, but how do we know the value and the safety of that voltage source? Good question!

Here's the rule again: never plug the motorhome into any AC source of voltage without first checking the amount of voltage and the polarity of that voltage. By following this precept, you can be guaranteed you are doing the most you can to protect your recreational investment. Plugging into an unknown source of voltage is akin to filling your fresh water tank without first, at least tasting the source water. It's doubtful you'd want to fill the water tank with brackish, stale water, right? Have the same mindset with the incoming AC voltage.

First, make sure all AC devices are in the "Off" position or remember to turn off the main breaker(s) at the coach distribution panelboard. As with the generator, never plug into an AC source with a load applied. Doing so may cause arcing at the contacts and subsequent damage to the blades on the plug cap.

MEASURING PEDESTAL VOLTAGE

At the park pedestal, or any power source for that matter, begin by performing a cursory inspection. Look closely for evidence of water intrusion, abnormal oxidation, dirt, leaves, wasp's nests, etc. If you have any doubt as to its condition and safety, before or after the following tests, do not plug in. Inform the park manager or maintenance department immediately. It may be necessary to move to a different site. This is especially true concerning older RV parks that have not upgraded the AC service and campsite pedestals to accommodate the more popular, 50-amp coaches.

30-AMP RECEPTACLE

Next, turn on the main breaker in the pedestal, but don't plug in yet! Measure the voltage first. Make sure the VOM is set to the AC Voltage scale. Insert the black test probe from the VOM into the neutral slot in the pedestal receptacle. On a 30-amp receptacle with the ground pin at the top, the neutral slot will be on the lower right. Insert the red test probe from the meter into the "hot" slot on the park pedestal receptacle (the slanted slot on the left). The voltage measurement should be approximately 120-volts AC. Voltage measurements below 107-volts AC and above 130-volts AC should be avoided.

Next, insert the black test probe from the VOM into the round, ground contact in the pedestal receptacle and measure the voltage to the hot slot again. This voltage measurement should be within 5-volts of the previous measurement. If so, all is well.... so far.

50-AMP RECEPTACLE

If the motorhome will be connected to 50-amp, 120/240-volt service, mea-

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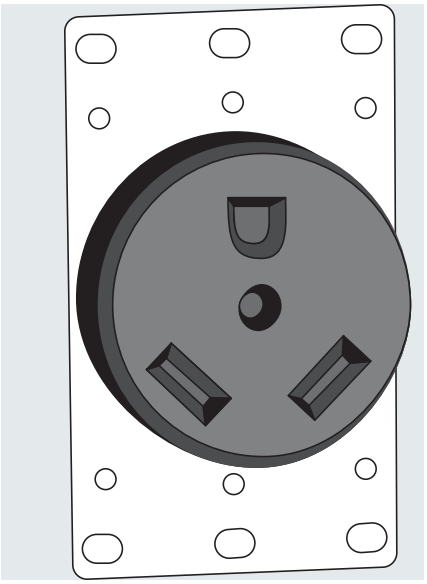
sure the voltage between the neutral vertical slot (the bottommost slot in the photo) and each leg of the 120-volt power at the two vertical side slots on the pedestal receptacle.

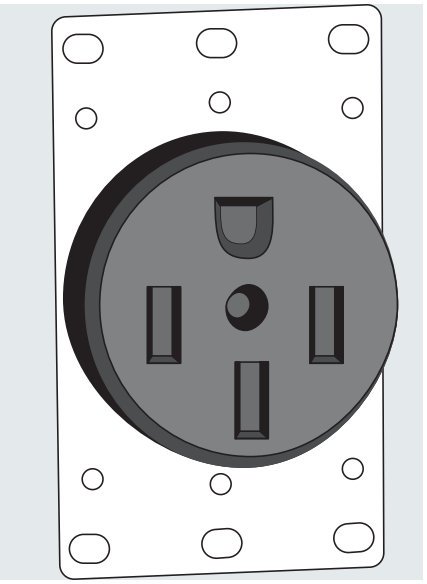
Then measure the voltage at both hot legs again, but with the black test probe of the meter inserted into the top, rounded, ground connection in the receptacle. Again, a 5-volt difference or less, is acceptable.

VERIFYING PEDESTAL VOLTAGE POLARITY

Once the incoming voltage has been measured at the pedestal and it falls safely within the limits required by the motorhome, continue the testing and perform the additional measurements as indicated in the following table to verify the proper AC polarity of the incoming voltage. Remember, have the VOM set to the proper AC voltage scale. All told, you'll be making the following measurements:

- Measure from the hot slot(s) to the neutral slot in the same receptacle.
- Measure from the hot slot(s) in the receptacle to the ground location in the same receptacle.
- Measure from the neutral slot to the ground location in the same receptacle.
- On a 50-amp receptacle, measure from one hot slot to the other hot slot.





Compare your results to the following table:

If the results are anything other than correct at the pedestal receptacle being measured, by all means, do not connect the motorhome to that voltage source. If this happens at a campground, immediately notify the park manager and ask to be moved to a different site. Be sure to verify the voltage and polarity at the new site too!

If it happens at home, call an electrician. It is recommended that if you connect the coach to your house AC system often, have a licensed electrician, familiar with RV wiring, install a dedicated 30 or 50-amp circuit, complete with the appropriate sub-

TESTING ALTERNATING CURRENT (AC) POLARITY

120-VOLT, 30-AMP RECEPTACLE

Hot to Neutral	Hot to Ground	Neutral to Ground	Status
120-volts	120-volts	0-volts	Correct Wiring
120-volts	0-volts	120-volts	Hot & Neutral Reversed
0-volts	120-volts	120-volts	Hot & Ground Reversed
0-volts	0-volts	0-volts	Open Hot
120-volts	0-volts	0-volts	Open Ground
0-volts	120-volts	0-volts	Open Neutral
120-volts	120-volts	120-volts[1]	Neutral to Ground bonding connection may be missing at the inverter or generator.

120/240-VOLT, 50-AMP RECEPTACLE

Same as above as measured from either hot blade to ground and to neutral and from neutral to ground. Hot (black) to Hot (red), however, will measure 240-volts

FOOTNOTE: [1] *Reading may be caused by capacitance. Voltage measurement may actually be less than 120-volts.*

SOURCE: BILL TRIMMER

panel and protective devices. If it's only temporary, be sure to use the correct adapter and extension cord (more on this later). Note: 50-amp coach owners should never plug into a 240-volt clothes dryer or range circuit. Some 240-volt house circuits do not contain a neutral conductor. Therefore, it's simply not worth the risk. Temporarily reduce down to a 30, 20 or 15-amp house circuit and be judicious in the devices you employ on the motorhome. The optimum is to have the correct branch circuit and receptacle installed by a licensed electrician so that an adapter is not needed.

If the voltage measures around 120-volts AC and the polarity of that voltage has been verified, it is safe to power up the motorhome. But first, turn off the main breaker on the pedestal. Remember, it's best to avoid any rapid transfer to any load that may be activated in the coach.

With the main breakers off on the site pedestal and inside the motorhome, plug the shoreline cord in a couple of times. You previously removed the corrosion and oxidation on the contacts of the plug cap, but don't assume the campground pedestal will have clean contacts. In fact, assume they will not. By plugging in, unplugging and plugging in repetitively with the circuit breakers off, the male plug cap will help scrape away any oxidation on the female connections inside the park pedestal. At the very least, it cannot hurt and it just may help.

Once the shoreline is firmly connected at the pedestal, turn on the pedestal breaker. Inside the motorhome, turn on the main breaker at the distribution panelboard. Then turn on each individual breaker one at a time until all are in the "On" position.

Switch on all the AC loads inside the motorhome one at a time. Be sure the water heater is filled with water prior to activating its 120-volt AC heating element. And be sure the absorption refrigerator is adequately leveled prior to activating the AC mode on it.

Note: if two roof air conditioners are installed on a 30-amp motorhome, it will be necessary to first check the operation of one air conditioner, and then switch to the second unit by the means supplied on that motorhome. Two air conditioners cannot be powered from a single 30-amp shoreline connection.

Using the plug-in circuit analyzer mentioned earlier, check for the proper polarity at each receptacle in the coach. You already know you have the proper polarity coming in through the shoreline cord, right? If the plug-in analyzer finds an electrical anomaly such as reversed wiring at any given receptacle, you'll know the problem is located within the motorhome.

Be sure to locate all the standard duplex receptacles in and outside the motorhome. Some may be hidden beside cupboards, under cabinets or inside storage compartments. Check them all! A problem could exist at just one that could affect others on that same circuit.

Though it's possible to make these same checks with the VOM, it's much easier with the plug-in analyzer. Since there is no need to actually measure the voltage (barring an unknown issue with any of the onboard AC devices), the three LEDs on the tester will suffice for quickly checking for the proper polarity at the receptacles.

GROUND FAULT CIRCUIT INTERRUPTION

Most coaches will be equipped with a special GFCI receptacle located in the lavatory area (some motorhomes may be equipped with a GFCI breaker inside the distribution panelboard). This receptacle can be used just like any other receptacle, but it also contains special circuitry that monitors the current balance between the hot and neutral wires on that specific circuit. The GFCI is another code requirement for circuits at or near water receptacles (sinks) and exterior receptacles on the motorhome.

It is a common misconception that the GFCI is itself a circuit breaker or an overcurrent device. It is not. While circuit breakers obviously do protect against overcurrent, they cannot sense or protect against the potentially lethal low-level ground faults. Additionally, most GFCIs will not sense a direct short to ground. The exception, of course, would be the breaker-type GFCI, which does both.

The benefit of the GFCI is evident in the fact that it will indeed sense the low-level current leakage that might occur in an AC system, lethal current that the circuit breaker may overlook. Low-level current leakage can occur as the result of oxidation, burned wiring or insulation, water intrusion or a simple loose connection. (See the importance of my three key words: clean, dry and tight?). The GFCI employed in the motorhome will sense and monitor current leakage up to 5-milliamp (.005 of one amp), then it will "interrupt" that circuit by tripping. Here is how it works:

AC current from the power source flows through the hot wire to a load and back to the power source through the neutral wire. In most cases this current flow to and from the load is always equal. Remember, the current alternates between the hot and neutral wires in any given AC circuit. If the current to and from the device is equal, it is said to be balanced. If the GFCI senses an imbalance between the two measurements that approaches 4 to 6-milliamps, the GFCI will trip, interrupting the current at that point. All receptacles downstream of the GFCI on that same circuit (including the GFCI), will now be dead.

All GFCIs contain a test function that is user-invoked. This test function allows testing of the internal electronic components of the GFCI. It also verifies the integrity of all receptacles on that same branch circuit. The GFCI should be tested at least Mayly. Simply push the test button on the GFCI and watch the reset button. It should pop out with

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an audible click. While in this tripped condition, use the plug-in analyzer to determine what other receptacles are on that same circuit. If you ever find that any plug-in load will not operate when plugged into a galley receptacle or exterior receptacle, chances are the GFCI is tripped. Simply reset the GFCI to restore voltage to that circuit. Note: the test function will only work when the coach is connected to an AC power source.

There are three ways to test the integrity of any GFCI circuit. The first is by using the integral test function on the device itself. Second, purchase a plug-in circuit analyzer equipped with a GFCI test function (as shown previously). Finally, some pro RV service technicians have a specific stand-alone polarity/GFCI test device that creates an incremental series of amperage imbalances until the GFCI trips at the desired level (see photo).

AC PIGTAIL ADAPTERS AND EXTENSION CORDS

Not all campgrounds will be equipped with 50-amp service at every site. When plugging in a motorhome rated higher than the service provided, it's necessary to use a common pigtail reducing adapter; sometimes referred to as a "dog bone" adapter. Caution: all pigtail adapters are not created equal! Only purchase high quality adapters. I've inspected lesser quality adapters and have found undersized internal connections that can lead to overheating. I've also seen 50 to 30-amp pigtail adapters with undersized conductors. Overheating at the adapter connection can lead to melted insulation, loosened contacts and open circuits amid a plethora of other electrical ailments.

Never use a modified or homemade adapter. Always check the polarity of any adapter to be sure the hot is hot and the neutral is indeed neutral. It's not uncommon to find reversed polarity in the cheaply made or homemade pigtail adapters. Also check the continuity through the adapter for all three or four conductors.

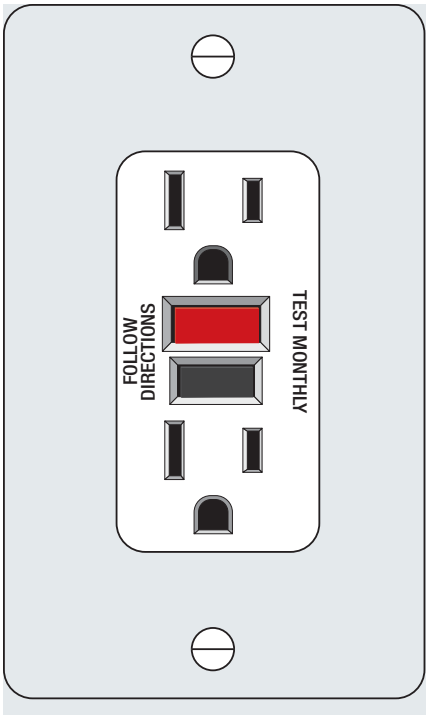
The two most common adapters reduce a 50-amp shoreline to a 30-amp receptacle and a 30-amp shoreline to a 15 or 20-amp receptacle. Reverse adapters are also available whereby it's possible to plug a 30-amp motorhome into a 50-amp receptacle, but usually if a campground has a 50-amp pedestal, it will most likely be equipped with 30-amp receptacle anyway. The campground pedestal shown in the accompanying photo provides three separate circuits (50, 30 and 20-amp); enough to accommodate any motorhome without the need for an adapter.

If it's necessary to employ an extension cord, be sure to use one rated for the same ampacity as the shoreline cord itself in order to eliminate an overheated situation. Be sure it contains the same number of conductors as the shoreline cord (three for 30-amp, four for 50-amp). Never use an extension cord without a ground conductor! Also, try to use the shortest extension cord as possible. Extra length in any conductor increases the resistance in that circuit. Only use an approved extension cord and pigtail adapter when necessary and only purchase quality components.

GENERATOR AC OUTPUT

Though it's impossible to correctly adjust the RV generator's AC output without employing specialty equipment, it is prudent to at least measure the voltage periodically to be sure it remains within the safe operating parameters. This can be accomplished by measuring the voltage at any receptacle inside the motorhome from time to time while the generator is powering the coach. Perform the same voltage measurement for inverter AC output as well.

Another RV Fact of Life is that RV generators require periodic tune-ups and set-ups. RV generators cannot be tuned by ear! Every mechanical adjustment on the generator has an electrical consequence! It's doubtful many coach owners carry a generator load bank around with them, so do leave generator adjustments to the certified techs.



However, aside from monitoring the generator output voltage from time to time, there's one more periodic measurement I would recommend; the output frequency. Every electrical device in North America is manufactured to operate at 60-Hertz (cycles) per second; meaning that the current alternates above and below a time line, sixty times per second. In contrast European countries operate electrically at a frequency of 50-Hertz. (That's why every airport sells those International AC adapters). While electricity from the grid remains stable at the 60-Hertz frequency, oftentimes the generator output frequency needs tweaking. Though the Extech VOM mentioned earlier can safely measure AC frequency, most meters cannot. But an aftermarket device called the Kill A Watt™, produced by P3 International Corporation, can measure AC frequency as well as true RMS voltage, current and watts among a few other handy measurements. It's a simple way to monitor the voltage and frequency when operating the motorhome on shore power or via the

generator or inverter.

Remember, the safe AC voltage range is 107 – 130-volts AC. The safe operating range for the generator output frequency is 59 – 62-Hertz per second. If you measure high or low voltage or frequency at any time from the RV generator, contact your local RV service center and make an appointment with them at your earliest convenience and do not utilize the generator until it has been rectified.

Keep in mind, the generator output voltage will fluctuate as individual AC loads are applied. It's best to measure the voltage and frequency of the generator when it is carrying about a 50% load. You'll have to do some basic math to determine how much current that will be for your particular generator. Professional RV service techs will actually measure the no-load voltage and frequency, then the full-load voltage and frequency by using a load bank, but a happy medium can be obtained if you apply a 50% load or slightly higher.

Indeed, AC electrical safety is paramount! Diligent and thorough inspections, periodic maintenance and quick resolutions when problems are located will keep your 120-volt AC systems in top condition.

continued »

BY GARY BUNZER

This three-part series examines the intricacies and safety issues that relate to a motorhome's 120-volt-AC electrical systems, and provides information about how to protect individuals and the motorhome when this electric source is being utilized.

PART 3

We've all heard the stories; an air conditioner hums to a stop and trips the breaker; a television monitor is suddenly reduced to a thumbnail image; a neighbor plugs his coach into the campground pedestal and your microwave oven quits in mid-cycle; reports of a lightning storm in the next county are followed by the lights inside your coach all of a sudden become very, very bright. I could go on, but I think most of you get the idea.

There are a multitude of electrical problems available to all RVers, in virtually every corner of North America, at any given time, in any season. Collectively known as "power line problems," individually they create frustrating dilemmas that we must be aware of and hopefully protect against. Why? Quantum leaps in motorhome electrical technology over the years has resulted in many components in our coaches now being controlled by electronic boards and microprocessors. Additionally, computers, email and Web browsing have well permeated the general RVing public. We are firmly entrenched in the microprocessor and electronic age of motorhome travel. Power line problems are no longer just a concern for the computer industry.

The AC shoreline, manifested at the campground pedestal is the tethered lifeblood for all things AC and many items DC in the motorhome. But it can also be the pathway for a mystifying menace that can render useless many components found in the coach. Let's take a detailed look at some of these power line enigmas.

STEADY-STATE VOLTAGE: normal voltage planned for a system that stays constant for ten seconds or longer. RV applications require 120-volts AC at a frequency of 60-Hertz, usually providing 30-amps of service for many smaller and mid-sized motorhomes. 50-amp service for the larger coaches simply includes another leg, or phase, of 120-volts AC also at 60-Hertz.

POWER FAILURE: a zero voltage condition lasting for more than one cycle (1/60 of a second). From a power grid standpoint, it could happen on any of the three phases being delivered.

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DROPOUT: a portion of the sine wave that has a lower value or is missing altogether, but only for a small portion of any given cycle.

BLACKOUT: a total power failure lasting several seconds to many hours.

BROWNOUT: a planned and usually announced region-wide reduction of available steady-state voltage. Typically associated with an impending expectation for heavy electrical consumption.

SAG: a cycle-to-cycle reduction of power line voltage of at least 10% of the average voltage for half of one cycle or longer. A sag might occur when your RVing neighbor first turns on his roof top air conditioner. Sags are detrimental to electronically controlled devices such as microwave ovens, television sets, DVD players and computers.

DIP: a faster sag. Dips are short decreases in the nominal line voltage, but are much quicker than a sag. Usually only visible in an incandescent light bulb.

TYPICAL CAUSES OF TRANSIENTS

OSCILLATORY TRANSIENTS

- **Lightning strikes –** the most common cause of spikes and surges. Lightning is most common and most severe during the summer Mays, though lightning has even been observed during snow storms! Lightning strikes can render sophisticated electronics in the motorhome useless or operationally intermittent. In either case, costly. Surprisingly, lightning does not need to strike nearby to reap havoc. A storm miles away could induce spikes that can ultimately reach your campsite pedestal. Lightning between clouds, never directly striking power lines or phone lines, will create large magnetic fields that can also cause surges and spikes in on-board equipment.
- **Utility grid switching –** your friendly power utility company can be responsible for creating spikes and surges simply by switching high power distribution lines. Power lines can also pick up transients from power company operating equipment.
- **Campground pedestal hook-ups –** even the power pedestal located in your favorite campground can be the source of transients. Many RV campgrounds and destinations sites were constructed some time ago when demand for current was not as prevalent as today. With today's larger RVs demanding more power to operate the modern conveniences we have come to expect, many older campgrounds are simply electrically undersized and outdated. When demand is high for current in an overloaded campground, the power sags or dips drastically. Power line transformers on the grid try to compensate when low voltage is sensed by raising the delivered voltage. When the demand for power sufficiently loads that transformer, all is well, but when the load is slight, the voltage could remain at dangerously high levels.

IMPULSE TRANSIENTS

- **Faulty wiring, (loose connections) –** common in campground connections and from within a motorhome.
- **Motor load switching**
- **Improper grounding or bonding of power lines**

NOTCH: similar to a dropout though typically too fast to see. They can be up to several milliseconds in duration and usually come in pairs. For every notch there is usually an immediate spike following behind. A notch is simply an out-of-phase impulse, (see impulse below).

SURGE: the opposite of a sag, surges are cycle-to-cycle increases in the voltage on any of the three phases above the normal voltage but typically below 500 total volts. The lasting time of a surge is equal to its duration for the number of 60-Hertz cycles that the power line disturbance is above normal.

SWELL: basically a series of long term surges that lasts form a few seconds to several minutes.

IMPULSE: a very short disturbance of either polarity, (up or down), superimposed on the AC sine wave that lasts between .5 and 100 microseconds. In-phase impulses that instantaneously increase the voltage are called spikes. Out-of-phase impulses that decrease the voltage are notches.

SPIKE: an in-phase, over-voltage impulse ranging from 400 volts to well over 5,600 volts! Such an impulse is superimposed on top of the AC sine wave and typically lasts for less than 1/000th of a second, (one millisecond). Any spike over 600-volts can be very damaging. Spikes contain high amounts of energy and are most detrimental to sensitive circuitry.

TRANSIENT: any short-term power disturbance on the power line. All the above disturbances are transient by definition. Transients can either be oscillatory, varying consistently with the frequency, or they can be of the impulse variety.

According to some electrical idustry studies, voltage transients represent 12 to 15% of all AC power line problems with only about 35% of those problems originating from outside on the utility grid. As mentioned above, problems can originate from within the campground itself or from within our very own coach. In the campground or at a home base,

transients can occur simply from a ground voltage differential between improperly bonded grounds during electrical faults. It is important to understand that given the state of the art of the technology we now employ in motorhomes, all AC power lines, campground phone, cable TV and data communication lines must all be commonly grounded or bonded together to prevent transients voltages from entering sensitive equipment.

One study shows that surges and impulse spikes can occur as frequently as twice per hour in any typical location; some with peak values at 1,500 to 2,500 volts. In industrial applications, such as in a large campground, they can be more frequent and more severe with spikes as high as 5,600 volts as recorded during lightning storms. An earlier study by IBM in various locations across the United States revealed an average of 50.7 voltage spikes per May. Another study showed that many locales will experience approximately twenty-five power line disturbances per year, 87% of which will probably be sags below 96-volts AC.

The bottom line is that electrical disturbances, the so-called "power line problems" may be severe, they occur often and the damage can be substantial, which usually equates to expensive. What goes mostly unnoticed is the accumulative effect on sensitive equipment in the coach after enduring spikes, surges, dips, notches, etc. The long-term performance deterioration of some delicate components may not surface until later; all the while the equipment performs at a sub-standard level until failure occurs. Unless, of course, the suggested AC inspections mentioned in the accompanying article become a habit.

So what can be done? One of the best solutions is to install a spike suppressor/surge protector in the motorhome. A number of suppliers now provide such protective devices for the RV industry. Surge protectors act like an electrical sponge of sorts, absorbing excess voltage, thereby protecting the entire coach. The surge protective device should include the ability to completely shut off the incoming power before damaging transients can reach sensitive on-board equipment. Additionally, they should have the capability to monitor and detect both high and low voltage conditions and to interrupt the incoming power until the system has returned to safer levels over a period of time.

Many surge protectors utilize a component called a MOV, (Metal Oxide Varistor) to protect against transients voltages. The quality devices usually have a minimum of three MOVs in the circuitry. More sophisticated protectors, such that might be used in the computer industry, have what is called sine wave tracking which actually tracks the incoming AC signal and literally cuts off the top portion of the wave. It provides better protection for highly sensitive equipment. The key to this technology is determined by the "clamping voltage rating" also called the "let-through voltage rating." The lower the rating, the better the protection. Sine wave tracking protectors have a remarkably tight clamping voltage surrounding the incoming power line sine wave.

Some companies extol the Joule Rating of their surge protection device. A "joule" is a measurement of energy that indicates the amount of energy that a device is capable of absorbing. The total number of MOVs in a device primarily determines its joule rating. Unfortunately, there is no standard for measuring the joule rating of surge suppressors, but generally those with a higher rating are considered better. It is felt by many in the surge protection business that the joule rating of a surge suppressor is less important than the "let-through voltage" rating. Underwriters Laboratories, (UL), has, however, developed a minimum standard for spike suppressors. The surge protector you choose to install in your motorhome should meet or exceed the requirements of UL 1449.

You are encouraged to investigate the feasibility of adding transient voltage protection to your electrical system. If you truly value the electrical equipment in your motorhome and are well aware of the consequences, it can be considered cheap insurance at the very least.

And remember, RVing is more than a hobby, it's a lifestyle! **FMC**