Roadtrek
Electrical Systems

A User's Guide

I gave this presentation at the fall 2015 chapter Rally in Nashville. Several people asked for the slides. Please refer to the notes for each slide. While I made notes before hand, I did not stick to them, so if you where there, this version is different and more complete. I was not able to present every slide so there are several here that were not used during the talk.

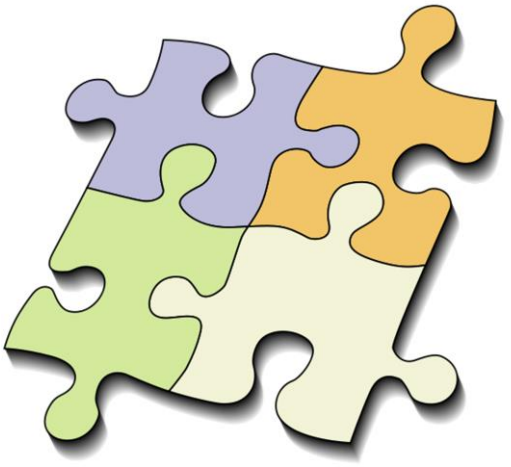
Introduction

- Who is John Slaughter?
  - Roadtrek Owner Since 2005
  - 124,000 Miles
  - More than 800 days and nights on the road.
  - Phyllis and John VP Region 7
  - Author of Electrical Simulator / Notes

Having said all this I will admit up front that the more you know the more you realize how much you don't know. I get reminded of this everyday. With 7 billion people on the planet, all thinking at once, the world is a really complicated place. Every situation is a little different and one needs to be careful not to simply apply a rule of thumb which might not apply.

I gave a talk in Branson in 2013 and after it was over I found that I managed to lose a few people along the way. This time I hope to do better, but you will have to help me by stopping me when something does not make sense. If it does not make sense to you, there are others who feel the same way. Please send me an email and ask for clarification. john@pochiro.com

Solving the Puzzle



How do you go about solving a puzzle?

1) Find the edge pieces first. (Start with what you know.)
2) Look for similarities in the colors of the pieces. (Have I seen this before.)
3) Look at the picture on the box. (Consult the documentation.)
4) Get others involved. (Ask for help.)
5) Take a break and come back later. (Always a good plan!)

It's Not Rocket Science or is it?

Think about it for a moment.

1) Self contained living unit.
2) On board Water Supply
3) On Board Sewage Treatment and Storage
4) Auxiliary Power Supply (generator, batteries inverter)
5) Environmental Control System (A/C and Heater)
6) Propulsion System (Vehicle Chassis with engine.)
7) Multi Mode operation. (Shore Power, Generator, Solar, Batteries)
8) Guidance System (GPS)
9) Communications, Terrestrial Radio and TV, Satellite Radio and TV and Cell phone.
10) The only thing we don't have is an oxygen supply!
11) It's complicated! But like that puzzle we can figure it out!

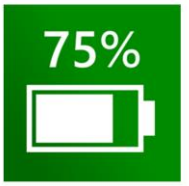
How Simple Things Work

(Or don't work the way we think.)

The lowly thermostat is often misunderstood. Most people understand if they think about it for a minute. Usually it's just a switch. If the temperature is below the set point the furnace come on and goes off when it reaches the set temperature. The furnace is either on or off. The furnace does not work any faster if you turn it up to 85. You will however eventually get too hot!

Many of the systems in our RV are like that thermostat, at first glance we might apply an incorrect understanding of how they work, but with a little thought, we will understand better the underlying function.
We are not going to get highly technical and the details can be very complicated.

Energy Management



This talk is about electrical systems and the story is all about managing energy. We know how our gasoline, cell phone battery, propane and even our usage of electricity when we get the bill at the end of the month. But in the RV world things are a little more complicated.

Start with What we Know

- All of us are familiar with power. We know that for example a 100 watt light bulb makes more light and gets hotter than a 40 watt bulb.
- If we think about it, we know that the longer you run the light, the more you will have to pay for the energy at the end of the month.

I am trying to clarify our understanding of some basic concepts we all know, but perhaps have not really thought about. Power is an example of a concept which seems obvious on the surface, but we might have an incorrect model in our mind about what it really means. It's describes a rate and without the second factor, time it does not have a lot of meaning. It does however give us an number to apply to the power handling capability of the equipment we are working with.

Power

- Power is a measure of the rate of using energy.
- A common unit is the watt.
- A salary of $10 per hour is a rate.
- A 100 watt bulb consumes energy at a 100 watt rate.

Before we get to the details we need to fill in some pieces of the puzzle. Let's start with the edges. We can relate to power, like that 100 watt bulb.

Energy

- Energy is a measure of the work done.
- A common unit is the watt-hour or joule.
- Your net pay after working 10 hours at $10/Hour rate is $100.
- Run a 100 watt bulb for 10 hours and you have used 1000 watt-hours or more commonly 1KWH. A KWH is the same as 1000 watt-hours.
- Run a 1200 watt air conditioner for 10 hours and you will consume 12,000 watt hours or 12KWH.
- It takes power and **time** to transfer energy.

Energy is a bit nebulous, however we are all familiar with the electric bill at he end of the month. 1000 watt hours or 1 Kilo-watt-hour costs about 10 cents. The reason this is important is that sometimes in our RV, just like the water in our tanks, we have to be aware of the amount of energy needed to perform a task. Making coffee, running lights, fan or the A/C these all take energy and we need to both have enough of it available and be able to deliver that energy at the rate it is needed. Sometimes we might have enough energy, but can't deliver it at the needed rate and other times we can deliver at the needed rate, but run out of energy before the job is done. An sometimes we fall short in both the amount and the needed rate.

Power Considerations

- At home, plug too many things into one outlet and you will trip a breaker.
- Low power devices might be televisions, computers, crock pots or phone chargers.
- High power would be things like coffee pots, hair dryers, microwaves and air conditioners.
- It's not surprising some devices might use all the available power. You can't plug two toasters into the same outlet!

If you think about it most of the things we use seem to fall at one end of the spectrum or the other. Lots of devices are 100 watts or less and then there are things which push the limit of the circuit. Air conditioners, space heaters, coffee pots etc. You want to get cold fast and you want coffee fast!
As a product designer if I'm making a hair dryer or a toaster I want as much power as possible. A computer I want to be as low power as possible so it can run off the battery for as long as possible. Most things seem to be at one end of the other of the spectrum of available power.

Abundance of Energy and Power

- At home we have an abundance of energy.
- Usually the only real limit is the bill at the end of the month. Ouch!
- We can usually use it as fast as we like. Our homes are designed to allow the operation of the air-conditioner, dryer, stove and microwave all at the same time!
- We might trip a breaker now and then, but its normally an unusual event.

Our mental model of electrical use is that it's easy and there is plenty of it. The reality is that we have built up tremendous infrastructure which makes this possible at home. It was not easily done and we've had 120 years to perfect it. At home we never run out of energy, the utility is happy to sell us all we want. The design of the electrical systems in our home is such that we rarely are unable to consume it as fast as we like!

Voltage

- Most of us are familiar voltage or volts.
- Most know for example that ordinary house electrical circuits operate at 120 volts and might also know that larger appliances like dryers and large air conditioners require 240 volts to operate.
- What you might not know is that voltage is a measure of electrical pressure or potential and by itself does not tell us the full story.
- We know that high voltage can be dangerous.

We've all heard of voltage, but it's a bit of a hard to visualize. Higher voltages generally make it easier to deliver more power. You can have high power at lower voltages, but you will need thicker conductors and generally are restricted to shorter distances.

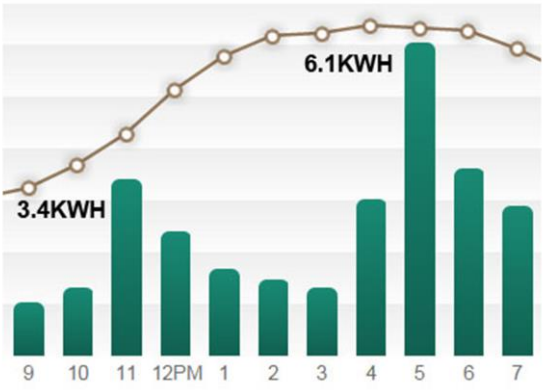
Current

- Current is a measure of the movement of electrical charge.
- You might for example know that an extension might be rated a 15 amps or that a circuit breaker is designed to trip at 30 amps.
- Multiplying the current times the voltage gives you the power in watts.
- Keep track of the power over a period of time and now you have energy or KWH.

I don't like the water flow and pressure analogy, but it can be useful. The important concept is the product of current and voltage tells you the power. More voltage requires less current and vice versa. So knowing the voltage, current and time, you can compute KWH of energy.

Technically one should consider reactive power in AC circuits, but for purposes of this discussion it is probably not relevant. The air conditioner will have less than unity power factor and the net effect of this is higher apparent current than would be expected for the actual energy required. The system must be able to support the current. The limited current capacity of the wiring is normally the limiting factor.

Typical Day at the Slaughters



Clearly we ran the electric dryer in the morning and the A/C in the afternoon. But we could have run the oven, stove, microwave at the same time and the electrical system would have just shrugged it off. It's no wonder that it's easy to get into trouble in our RV. It's just about impossible to get into trouble at home.

Review

- A Volt is the unit of electrical pressure.
- An Amp is the unit which describes the flow of electrical charge.
- Power is the rate of doing work and in the electrical world is measure in watts. A watt is the product of voltage and the current.
- Energy is the work done and it's is calculated by keeping track of the power over a period of time.
- At home we have the ability to use a energy at a enormous rate (power) and the amount of energy (KWH) is effectively only limited by our pocketbook!

Armed with this information, we can now address the impact of all this when we try and apply it to our Roadtreks.

12 Volt Electrical System

- You may know that your RV has a 12 volt DC system and a 120 volt AC system.
- Because our machines are portable and mains power is not always available, we'd like to operate using a battery. These batteries are typically 12 volts.
- The lights, water pump, macerator, exhaust fan, controls for the frig, water heater and furnace, all operate on this 12 DC volt power source.

Most of the electrical in your Roadtrek runs off of 12 volts DC to make it easy to run from a battery. The notable exceptions are the air conditioner, microwave and coffee pot. We usually add things like computers, cell phone chargers, hair dryers and crock pots.

120 Volt Electrical System

- The one or two batteries in our Roadtrek's can't deliver the power or energy needed to operate some devices. The Air Conditioner for example requires a lot of power and energy. In other words, it has a high rate of power over a long period of time.
- An electric coffee pot or a hair dryer on the other hand requires a lot of power for a short period of time. High power, but low energy!
- Computers, television sets and the like are low power and maybe low energy if we don't use them constantly!

Note that the batteries may not be able to deliver the power or the energy required. The power is the rate of energy usage and the total energy is the capacity of the battery. We are also hobbled by the fact that rapid discharge of the battery results in less total energy available. Some of our Roadtreks have differing numbers of batteries and with additional batteries, one can operate high power and energy devices.

What about AC and DC

- AC or alternating current power is easily transformed from one voltage to another.
- DC or direct current is naturally produced by a battery and is a bit more difficult to transform from one voltage to another.
- Conveniently by convention, the calculations for power and energy work the same way in both cases. So volts time amps will give you watts.
- Most devices today require both the correct type of power, AC or DC and the proper voltage.

There are exceptions. Today many phone and computer chargers will happily work with different voltages and frequencies. Incandescent lamps will work just fine on AC or DC of the proper voltage, but LED's may or may not. Yes it's a little more complicated for AC power, but for our purposes the rule holds.

Limited Power

- Unlike sitting at home, the available power is limited in our RV.
- When connected to the mains power we are restricted because of the limited power handling capability of the 120 volt wiring. We might be limited due to park wiring as well.
- The 30 amp wiring essentially limits us to 2 high power devices like the air conditioner and the microwave. The good news is that you have plenty of energy.

The good news is that you won't run out of energy. You can run those high power devices as long a you like!

Generator

- Because we'd like to run the AC and the microwave while not connected to mains power many of our machines are equipped with a gasoline or propane powered generator.
- The generator can provide energy at a 2,800 watt rate and do that for as long as there is fuel in the tank! Sprinters are a bit less at a 2,500 watt rate.
- Unlike mains power, the generator can sometimes struggle to start the AC!
- Once the AC is running you can usually run the microwave!

Propane has less energy per gallon than gasoline. The air conditioner requires a very large inrush of current to start. This inrush of current falls off quickly as the compressor gets up to speed. Lower voltage means that the compressor is slower to get up to speed and the inrush is longer in duration. Starting is tough. When you are mains connected, the system usually shrugs this off, but the generator has very little "inertia" and will struggle to get the compressor started.

Batteries

- Most of our machines are equipped with either two 12 volt batteries in parallel or two 6 volt batteries in series.
- The energy stored in the batteries can be expressed in a number of ways. Amp-hours or KWH. A 12 volt 85 amp-hour battery is about 1KWH. Two batteries gets you 2KWH. It's a really bad idea to go lower than about ½ the charge so effectively you have about 1KWH of available energy.

For this discussion we are only talking about lead acid batteries. Other battery chemistries are being used in RVs, but these are far less common. There seems to be a lot of opinions about the depth of discharge possible with a lead acid battery. Some contend that up to 90% is acceptable for flooded cell batteries. In any event, deep discharge reduces the life of any battery more than a shallow discharge. While amp-hours is a convenient way to talk about energy storage, one needs to consider the voltage as well. A 6 volt 200 amp-hour battery has the same amount of energy as a 100 amp-hour 12 volt battery. So two 100 amp hour 12 volt batteries in parallel can store the same amount of energy as two 6 volt 200 amp-hour batteries in series.

It is usually argued that two 6 volt batteries wired in series will stay balanced better than two 12 volt batteries in parallel. Having said this I don't think there is any reason to convert existing 12 volt batteries to 6 volt batteries.

How Does a Battery Work

- Flooded cell, AGM and Gel Cell batteries are all based on same basic chemistry.
- Sulfuric acid, water, Lead and Lead oxide
- A chemical reaction runs one way and converts the acid, lead, lead oxide into water, lead sulfate and energy in the form of electrical current.
- When you charge it up you force the reaction to run backwards by forcing a current through the battery which converts the lead sulfate and water back into acid, lead and lead oxide.
- You are literally taking battery apart and putting it back together again.
- The details of the structures vary but the fundamentals are the same.

While we can't visualize electricity, the chemistry in the battery means that the battery will wear out! Both age and use enter into the mix.

Inverter

- An inverter converts the 12 volt DC battery voltage into 120 volt AC. The power required to run the inverter will exceed the power delivered by the inverter.
- Unlike operating from mains power, the energy available in the battery is limited.
- The rate of energy delivery by the battery is also limited. High rates will decrease the total available energy.
- The inverter has a power rating as well.

Even if you have a 3KW inverter, unless you have enough batteries the inverter cannot deliver energy at that rate safely. Note that the measured voltage from an inverter may read “low” on a voltmeter even though it is correct. This is a result of the modified sine wave output. Most meters make the assumption that AC voltages are like mains line voltage. In the case of the inverter this is not normally the case. Some inverters are “true sine wave.” The reality is that most things will work just fine on these modified sine wave inverters. Electric motors may not run as efficiently. It’s largely a myth that electronics need pure sine wave inverters. In the past this was true, but most modern electronics will work properly.

Review

- Our machines have a 12 volt DC system which operates most of the systems, lights, controls and pumps.
- The 120 volt electrical system provides for the Air conditioner, microwave other appliances.
- The vehicle wiring and park wiring limit the rate of energy usage while connected to mains power.
- The generator can deliver energy at almost the rate possible when connected to mains power.
- Two batteries have about 1KWH of energy available.
- The inverter energy rate is limited by the battery energy rate and the total amount of energy stored in the battery. The inverter power rating limits the rate.

Our machines are designed for boon docking, everything runs on 12 volts! Well almost everything. My motto is to go places where I don't need air-conditioning!

The basic rule is with a 30 amp park connections, you can run two "high power" devices at once. Most everything else is not significant. With a 15 or 20 amp circuit you can run 1 high power device. Don't cheat!

Keep in mind that unlike mains power, the generator is less able to cope with the large starting current required by the air conditioner. The generator is just barely capable of starting the air conditioner. Once running additional loads can be added.

There is not a lot of energy in the batteries, think green!

Inverters are great for running TVs, computers and even a crock pot. You might run a coffee pot, but with 2 batteries, you are abusing the batteries and with 4 batteries you are working them very hard.

High Power Devices

Device	Power Watts	Hrs/Day	Energy KWH/Day
Coffee Pot	1025	6 min	0.103
Hair Dryer	1600	10 min	0.270
Microwave	1300	15 min	0.325
Toaster Oven	1500	30 min	0.750
A/C / Space heater	1400	8 hrs	11.2
Frig on DC	175	12	2.1

Note how much energy is required and how much is in your batteries. In the case of the coffee pot we have plenty of energy, KWH available in the battery, but the power is beyond what two batteries can safely deliver. So the coffee pot is a high power low energy device. Remember the batteries have about 1KWH of usable energy and the coffee pot only needs about 10% of that. The power demand goes beyond what the batteries can safely deliver.

The Air conditioner on the other hand is a high power high energy device. You can't get there from here!

Running the Dometic refrigerator on the battery is never a good idea, particularly when you consider that the unit will operate very poorly on battery. It will do much better on DC when the vehicle engine is running because the voltage will be higher. Power goes with the square of the voltage. With the vehicle running the voltage will be 13.8 volts or higher and on battery the voltage will be 12 or less. 13.8^2/12^2 = 1.32 so the heater will have 32% more power in this mode.

Low Power Devices

Device	Power Watts	Hrs/Day	Energy KWH/Day
Computer/TV	50	2 hrs	0.100
Cell Phone Charger	<5	8 hrs	< 0.040
Exhaust Fan Hi	18	8 hrs	0.216
4 Lights (18w each)	72	10 hrs	0.720
4 LED (1w each)	4	10 hrs	0.040

There is a world of difference between the high power devices and the low power devices with very little in the middle. The biggest takeaway on this chart is that LED lights make a huge difference taking a major energy device and making it quite insignificant. Lots of bang for the buck!

Managing Batteries

- Batteries have limited energy capacity.
- Rapid discharge shortens battery life.
- Discharged batteries will freeze in cold weather.
- Every Cycle uses up your battery!
- Deep discharges are very damaging.
- Most batteries are killed by neglect and expensive batteries are not exempt.

Think about it. When you charge and discharge a battery you are literally converting lead dioxide and lead into lead sulfate and back again.
If you notice the lights getting really dim, you are over working your batteries.
Do the math, is it really worth buying batteries all the time just to get a little more run time? Charge them up!

Charging Batteries

- Drive somewhere! The vehicle engine will charge the battery at a high rate.
- Plug in to mains power. Depending on your charger, it might take 8 hours or more to charge your battery this way. Many of the Trip-Lites are set to a low charge rate.
- Remember when you drive you charge and should arrive fully charged!
- When your are connected to mains power your battery should not discharge. (Maybe!)

You can usually start your vehicle in no generator campgrounds and charge your batteries without anyone complaining. Modern alternators will produce a high charging current even while idling.

You might notice that even when plugged in your are losing ground. If the battery charger is running at 11 amps and your load is 15 amps, you are losing ground. You might want to go on an energy diet!

My Batteries Run Down too Fast!

- Old and/or abused batteries and don't work as well as well cared for and newer batteries.
- Think green
  - Run only the devices you need.
  - Convert to LED bulbs
  - Turn off your inverter unless you are using it.
  - Track down things which are pulling down your battery.
- Charge your batteries before they get really low.
- Have the batteries tested.
- Care for them when not in use!

You may not know that you have two! Most Roadtreks have two batteries and sometimes users are not aware of this. Some people erroneously think they should occasionally discharge the batteries completely. This is totally false and very damaging to batteries. Also it does not matter if a battery is placed on concrete or any other surface.

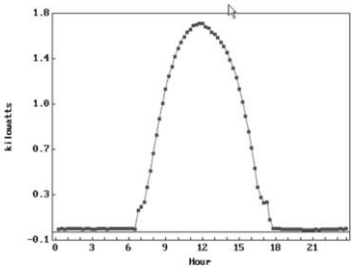
Why do my batteries die so soon?

- You only get so many charge discharge cycles
- Deep discharges shorten the life more than shallow discharges.
- Bad luck, even the same brand can vary.
- Overcharging, not as common as people think.

Have your system checked out and make sure the batteries are charging properly. You may think they are getting charged when if fact they are not.

Solar Power

- A very large, 250 watt solar panel on a sunny day will produce about 1KWH. The actual output is highly variable.



Solar panels produce about 10 watts / square foot on a sunny day when aligned properly. They get dirty and a shaded cell will impact the entire array. Yes a solar cell will produce output in low light, but will not produce much usable energy! This is an actual plot from a real array over a 24 hour day. When the sun goes down, the output falls to a trickle!

Solar Power

- Solar power is great, the energy is free, but the amount is limited and you must have a place to store the energy you can't use. Once your battery is fully charged, any surplus energy is lost.
- While it can supplement energy needs when boondocking, the real value is keeping your batteries charged while in storage.

The equipment cost is high and for many of us it's difficult to justify the expense. The E-trek has 8 batteries. Killing 8 batteries because the batteries went flat is a huge expense. Solar panels can prevent this from happening! Of course if you park in a garage, you might not do so well!

How can I tell if my Batteries are Charged?

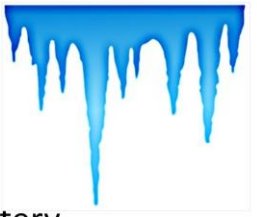
- There are really only three ways.
- Accurately measure the voltage after the batteries have been idle for several hours and consult a voltage chart.
- Measure the specific gravity with a hydrometer
- Install a battery condition monitor which keeps track of the energy which goes in and out of the battery.
- Experience! (Okay that's 4)

Your monitor panel does not tell you very much. Battery condition monitors have complex algorithms and estimate the condition. Rapid discharge reduces the total available energy! You never get back as much as you put in! Just like our water tanks, you can easily estimate how long you can run on batteries. Avoid high power and high energy devices and you will be in great shape!

Extra Credit

- What about winter storage
- Phantom Loads
- Is it a bad charger or a bad battery
- Chargers are not all created equal
- Fast vs Slow Charging
- Flooded Cell, AGM or Gel

Winter storage



- The bad news
  - Phantom loads can drain your battery
  - Discharged batteries can freeze and burst
- The good news
  - A healthy fully disconnected battery discharges at a very low rate between 1 % and 15% per month. 15% is unusual.
  - Charged batteries won't freeze

Phantom Loads

- Automotive electronics can drain your battery quickly. Some report on the order of a week. It varies greatly. More than a month you need to take action.
- The disconnect should be off!
- The inverter should be off!
- Leaving it on a charger can help, but disconnected is more reliable!

For some of us the phantom loads on the vehicle battery is a real pain. I wish there was a great solution, but none of the solutions are perfect. One needs to work out a strategy and watch carefully. Leaving the inverter on continues to be a common mistake. The performance varies greatly.

Bad charger or Bad battery

- If a battery has a bad cell, any charger will overcharge the remaining 5 cells! Open circuit voltage below about 10 volts.
- Sophisticated battery maintainers are great, but if they get unplugged or fail they are not much help. You have to pay attention.
- High rate chargers are fine, but they are hard on the battery and not usually necessary.
- Working properly, the Trip-Lite or converter will not damage a good battery.

Many people blame the charger for their dead battery and sometimes this is the case. To often the battery has failed and then it looks like a bad charger. If the electrolyte in a battery boils or "spits" electrolyte, immediately remove the power from the charger and get the system checked out. Something is wrong. I would be very hesitant to plug in a charger and go off and leave the unit for months without periodic inspections. You are probably better off fully charging your batteries and then disconnect them from the circuit. Always disconnect the negative terminal. This is safer and you are less likely to short circuit the battery. More than one person has had a wrench touch a grounded part of the vehicle and got a shower of sparks!

Chargers are not all created equal

- Most of the time folks want their battery charged as quickly as possible.
- Fast charging is a dance where you push energy as fast as possible without damaging the battery. You have to push “HARD” to charge a battery fast.
- A low rate charger will bring a battery to full charge and keep it there.
- Don’t leave a battery on charge for months using a cheap charger. You a better off disconnecting the battery. Check up on it periodically.

A low rate charger works fine, it just takes longer! Check up on your machine and make sure everything is working as expected.

Fast vs Slow Charging

- High rate sustained charging generates heat and is rarely necessary.
- A partially discharged battery will rapidly return to a more normal charge rate.
- Rapid charging is tough on a battery.
- Avoid deep discharge. You will automatically avoid rapid sustained charging.

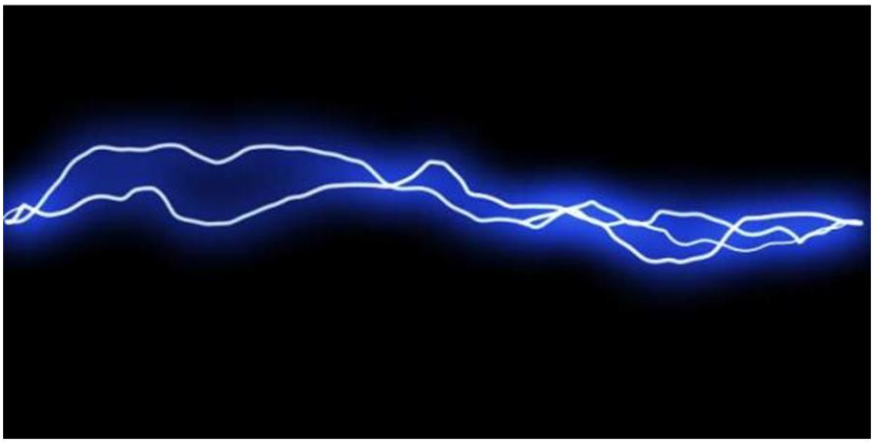
If nothing else, avoid deep discharge!

Flooded Cell, AGM or Gel

- I'm not taking sides!
- Flooded cell batteries are less expensive.
- Flooded cell batteries tolerate abuse better than other types.
- Flooded cell batteries outgas and can cause corrosion around the battery terminals.
- Flooded cell batteries must be vented to the outside due to outgassing.
- AGM batteries last longer

Do your research and make your own decision. However there is little point in buying a high dollar battery and have it die and early death due to uncorrected problems or abuse.

Want more?



Fuses and Circuit Breakers

- Fuses and Circuit breakers help prevent fire!
- Wires can only support a limited amount of current without melting.
- Each branch circuit is protected so that the wires won't reach a temperature where they can make things around them catch fire.
- Adding equipment without proper fusing is a recipe for trouble.
- The current possible from a battery which is not limited is enormous. Don't underestimate the energy available.

Ask yourself, what will happen if I short out this wire? You don't want uncontrolled energy consumption. Many vehicle fires can be traced to improper protection of circuits. Remember you have lots of vibration and sharp edges which can easily damage insulation. Properly fuse, secure and protect wring from abrasion. Overloading a circuit might seem to work fine, but can lead to fires and damage even a shock hazard.

Park Power

We plug in our rigs all the time. Sometimes we worry and sometimes not. I've had generally very good experiences with few problems. There have been exceptions! Don't be paranoid, enjoy your trek!

Park Power

- If the park is neat and well kept, it's a good sign!
- Look for poor workmanship, shoddy construction and exposed wires. It won't have passed inspection if it looks shoddy.
- Loose fitting receptacles. These can get hot and create voltage drops under load. Feel the case of the plug when under load, it can be a little warm, but if it's hot, you have a problem.

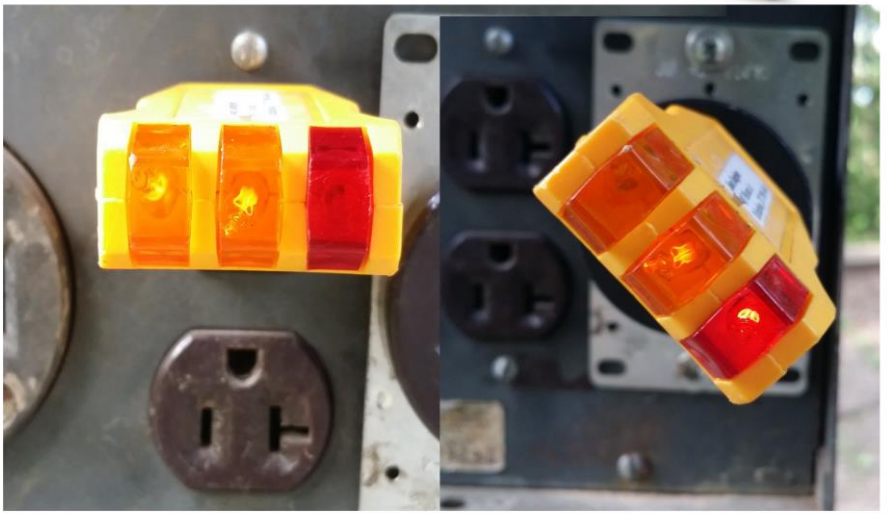
Use your eyes first!

Three Light Tester

Use with 15 to 30 amp Adapter!

Test the circuit you are going to use!

Example 15 Amp Correct
30Amp Wrong



I found this recently. Same pedestal. The 30 Amp circuit had hot neutral, but the 15 amp was fine. Any red light is bad and if all three are on you are probably plugged into 240 volts!

A missing ground is also very dangerous. Both of the yellow lights should be on. If you have power and one of the lights is not on, you have a missing safety ground.

If you sometimes pop a circuit breaker when you plug in, you have a short between your neutral and your safety ground. The breaker pops because you have plugged into a circuit with a hot neutral creating a short circuit. Get it repaired!

The safety ground is like a seat belt. It does nothing unless something goes wrong. When it does it will protect you.

Are You the First???

- If you are the first to use a connection look out!
- Wiring errors are common and many electricians are not familiar with the 30 Amp RV receptacle. More than one has been connected to 240Volts with terrible consequences.

Be careful, this is by far the greatest risk!

What to Worry About

- The Air Conditioner is the most at risk appliance due to low voltage. If the voltage is low, below 110 volts with the AC running, don't use the AC. It's much harder to start and the motor will run hotter. Normal voltage should be between 114 to 126 volts.

- Measure the voltage under load inside the rig, not at the pedestal. You want to include the voltage drop in the cable and connection.

If you are plugged into a 15 or 20 amp circuit, you are going to be limited to 1 high power device like the AC or microwave. Don't cheat, it might work, but it's hard on equipment an you risk damaged equipment or even a fire.

Most things will work on low voltage and few things will be damaged, but most just won't work very well. The A/C is a notable exception!

Test Equipment

Voltmeters

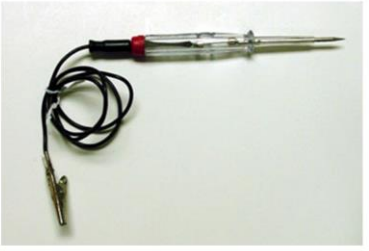
Note Expanded Scale
About $15
Very Easy to Use

Kill A Watt Measures Voltage, Current, Wattage, KWH and more.
About $20. Get at Home Depot or Lowes.

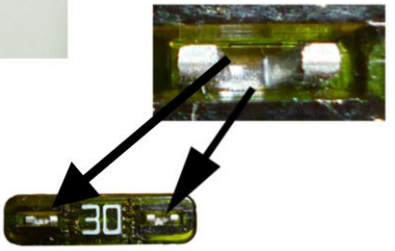
You need to measure the AC voltage inside your rig. The Kill-a-watt device is inexpensive and will let you check the power of any device you might use. Note that both of these devices will fail to properly measure the output of most inverters.

Test Equipment

12 volt test light



- About $5
- Very versatile
- Easy to use.
- Check fuses easily in place.
- Only use on 12 volt circuits.
- Loads the circuit. (good!)



You can use a DVM to make this kind of measurement, but the test light is a quicker and easier way to identify a bad fuse. Not having to pull the fuse out is worth the price! This type of fuse has a little metal nub on each side, so you can make connection easily. Connect the clip lead to a grounded metal part and touch the probe to the nubs on the fuse. It should light on both sides. If it does not, the fuse is open. Try this sometime when things are working properly.

Test Equipment

Advanced users only!
Digital Volt Ohm Meter DVM

- **$20 and up.**
- **Very versatile**
- **Difficult to use.**
- **Can be damaged easily.**
- **Readings can mislead!**
- **Does not "load" circuit**

The DVM is a great tool and you can use it in many situations. However unless you have a good understanding of it's limitations you can easily misinterpret readings. Really a tool for an advanced amateur or professional. There is risk of personal injury if you come into contact with a live circuit.

Test Equipment

Advanced users only!
Combination Clamp Ammeter / DVM

- $45 and up.
- Measures both DC and AC current.
- DVM functions
- Clamp current accuracy not great, but useful.
- Make sure you buy a AC/DC version.

Unlike the DVM, you can measure high current. You do have to access an individual wire to make a current measurement. Not all clamp meters can measure DC current.

An individual wire must pass though the jaws to measure current. For example if you clamp around both the wire connecting to a load and the associated return wire the currents will “cancel” and you won’t get a reading. You can “multiply” the sensitivity by passing the current carrying wire through the jaws more than once. Twice, doubles the reading and three times triples the reading.

This tool is for an advanced amateur or professional. Like the DVM there is risk of personal injury.

How To TEST

- Do a visual inspection.
- Plug in the 3 light circuit tester using a 15 to 30 amp adapter to check the 30 amp receptacle.
- Turn on 30 amp breaker.
- Proper lights on circuit tester?
- Turn off Breaker.
- All large 120 volt loads off in rig, AC in particular.
- Plug in power cord, nice tight fit?
- Turn on Breaker.
- Check voltage in rig.
- Turn on a load, electric heater, hair dryer
- Check voltage again in rig. (Still okay?)
- If you add more big loads, check voltage again.

Check with tester first.

Big loads off in the rig.

Then connect!

The plug should be “retained” if you have to hold it in place, it’s too loose.

Check voltage, first without a load and then with a big load.

Adapters are safe to use

For the most part TRUE with some caveats.

- The most common adapter is a 30 to 15/20 Amp
- Use at home or when 30 amp receptacle not available.
- You are limited to 1 high current appliance.
- Overload and you might damage the adapter or receptacle. Don't depend on the breaker!
- Connections should fit tightly.
- Watch for too hot to touch plugs!
- Get one of good quality.

Some of these are really cheaply made and get hot even with moderate loading. Get a good quality adapter.

Adapters are safe to use

- The 15 Amp to 30 Amp adapter is commonly used in conjunction with the little 3 light circuit tester.
- Used to connect to a 30 amp receptacle using a ordinary 15 to 20 amp plug.
- This might seem like a good way to use a light weight extension cord with a 30 amp receptacle. Not a good idea!

- An extension cord rated for 30 amps with the 30 Amp plug and receptacle is the correct choice.

There is almost never a reason to use this except with the tester.

Adapters are safe to use

- Some of us have a 30 amp to 50 amp adapter. Now you are using a circuit with 50 Amp circuit protection with external wiring designed for 30 amp.
- Avoid this unless you have no choice. The load is limited only by your RV circuit breakers.
- Rarely it is necessary to use this adapter unless you are “doubling up.”

Don’t use this unless you have no choice.

Adapters are safe to use

- Never use a 2 to 3 wire adapter to connect your RV for any reason. That two wire extension cord you have lying around is not worth the risk.

This is really a bad idea. Admit it, have you ever hooked up the little lead?

A Power Monitor is the Solution

- Automatically detects low / high voltage and most wiring errors.
- Be sure what you are buying is of high quality.
- They are usually quite expensive.
- The surge suppression feature is often a bit oversold.

These are nice, but not required. They are not a substitute for common sense. Pay attention!

Inconvenient Facts

- Circuit breakers are not very precise. So a 30 amp circuit breaker operating at a current of 40 amps might not trip for hours, if at all.
- Circuit breakers trip faster at high currents, so a short circuit will trip much more quickly than an overload.
- It's important not to "overload" a circuit because the circuit breaker might not trip before you have a fire or damage.

Never "depend" on circuit breaker to "protect" you from an overloading a circuit. They will trip quickly on a high current fault due to a failure, but may not trip on an overload.

I've seen folks always use the 15 amp plug because it works and "I never have a problem."

Common Problems

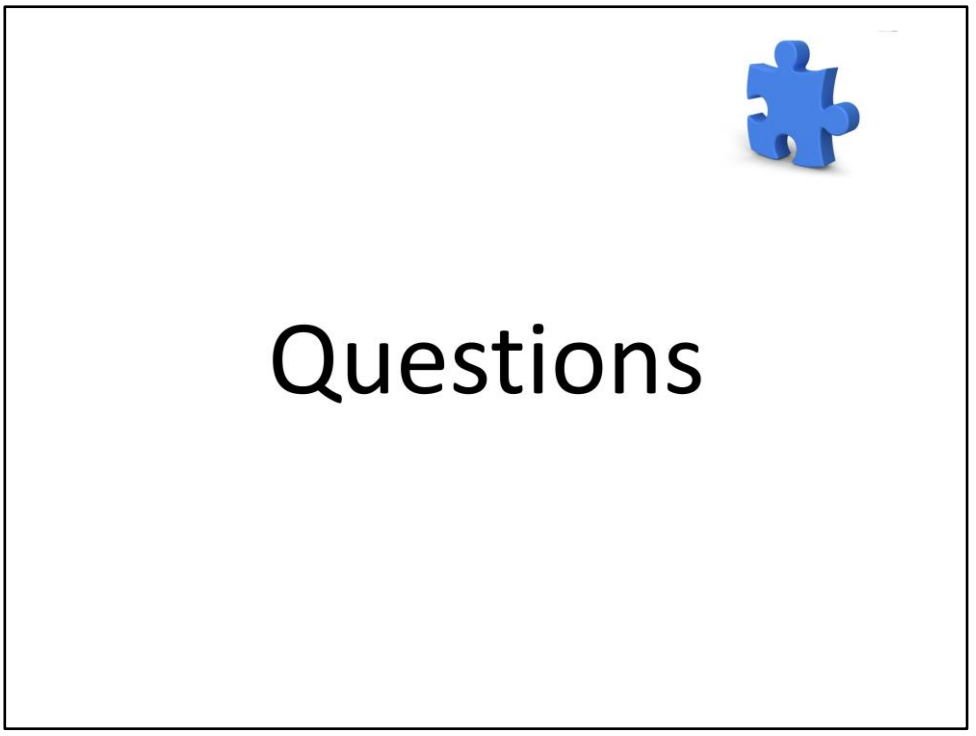
- The receptacle above the sink is a GFCI it can trip.
- The inverter if left on, will drain your battery even if the switch is off.
- Flickering lights are usually caused by a “no battery” connection condition.
- Loose connections in 120 volt panel
- A failed Isolator can appear to be a bad alternator.
- Separators draw power (1amp) when active.
- Unrealistic expectations for solar panels.
- Phantom loads drain battery.
- Most batteries die of neglect or misuse, not age.
- A bad battery might make the charger look bad!

The flickering light problem is often caused by intermittent 12 volt circuit breakers. When they open, the Trip-Lite will not operate properly. Poor connections at the battery can create the same symptom. Older, before about 2006 or so have the Trip-Lite connected such that when the battery switch is off, the lights will flicker. Always turn on your battery switch before plugging in. Most of us turn on the switch at the beginning of a trip and leave it on until we get home.

A failed isolator may cause the alternator light to illuminate. If this happens you will quickly damage the RV batteries because of overcharging. Don’t operate the vehicle under this condition. Many perfectly good alternators have been replaced due to bad isolators. Make sure any mechanic who works on your vehicle is aware of how the isolator works. Most do not!

Things to do

- Get a circuit tester and plug in voltmeter
  - Use the tester and be careful when you plug in.
- Don't overload your wiring!
- Pay attention to your batteries
  - Keep them charged
  - Have a strategy for storage
  - Don't discharge needlessly!
- Get LED lights!
  - Get ones of high quality with a regulator



If you have any questions or comments, please let me know. I want to correct any errors you may find. john@pochiro.com