

# Care and Feeding of Lead Acid Batteries

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# Usual Disclaimers

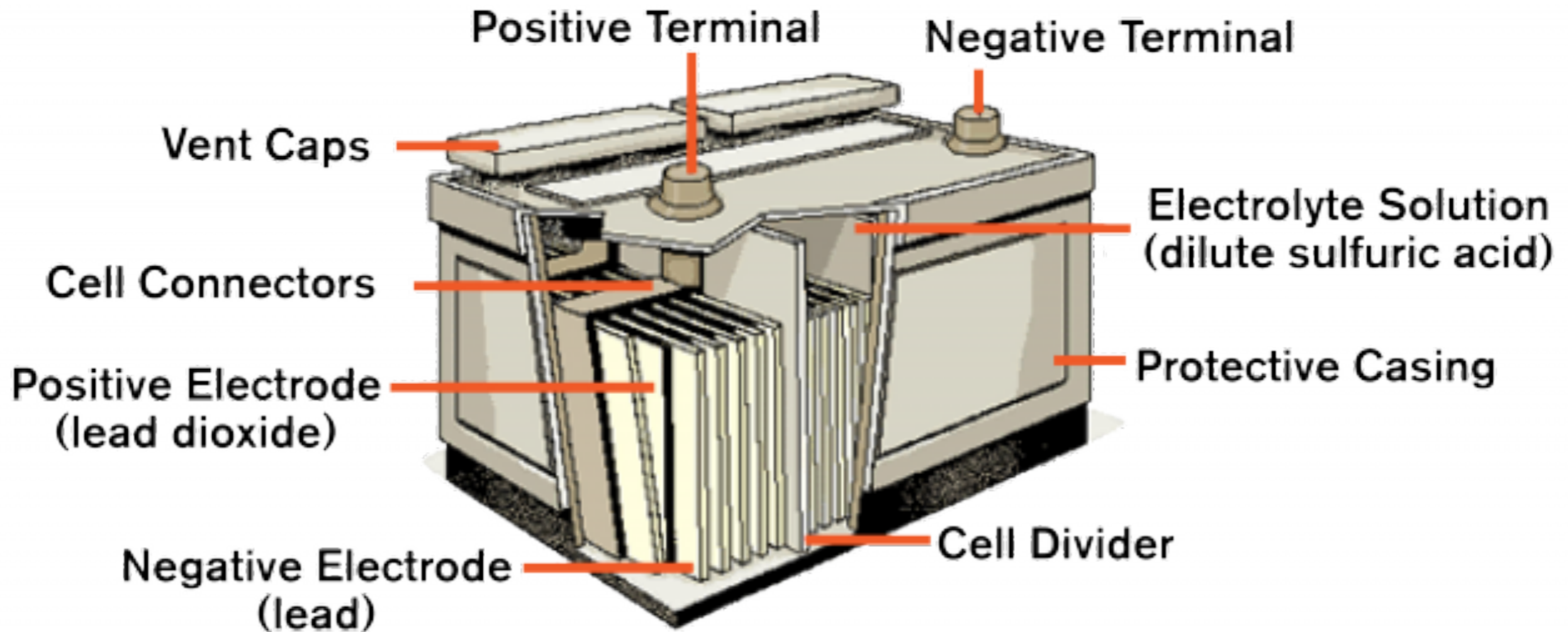
- This information is correct to the best of my knowledge and belief. The ideas in this presentation have been tested by field use on my personal 4x4 camper. They may or may not work with your vehicle or any other vehicle. ***Specifically, this information may NOT be correct for Lithium batteries.***
- Products and specifications may change, specific products mentioned are only some of many which may perform the required purpose and may not be the ones actually used on my vehicle.
- Get professional assistance if you are not comfortable working with high amperage circuits.
- When in doubt, follow the instructions of your battery manufacturer over the instructions of your charger manufacturer, this paper, or any other source. Do not undertake any modifications which may void your vehicle's warranty.
- Pay careful attention to fusing - at both ends - and protection of wiring from physical damage.
- YMMV, etc.
- Remember: FUSE IT!

# Points to Cover

(What you will know at the end of this presentation.)

- How lead acid batteries work.
- How to properly charge batteries.
- How to wire batteries correctly.
- How to monitor the health of your batteries.

# Our Friend, the Lead Acid Battery



# Battery Types:

## The really basic, basics.

- **Open Lead Acid Batteries** - Open vents to let gas escape. Venting can lead to corrosion of terminals and require topping up with water. Less expensive, need the highest charging voltages. (Flooded Lead Acid - FLA)
- **Absorbed Glass Mat** - Sealed, does not need topping up. (Indeed, cannot be topped up in the event of overcharge.) “Maintenance Free” in that, as there is no venting of fumes, terminals are less subject to corrosion. More resistant to vibration, can be mounted on side. Slightly lower charge voltage, may take higher amperage charge. (AGM) (Valve Regulated Lead Acid - VRLA)
- **Gel** - Older form of sealed battery. Lowest charge voltage. (VRLA)
- **Lithium Iron** - Newest, very, very expensive. Great potential for lower weight and higher performance - deeper discharge. Faster and easier to charge, but some challenges in matching to high voltage vehicle alternators. Rumors of temperature sensitivity, i.e. cannot be charged below freezing.

For most, the easiest options are FLA and AGM. Lithium has tremendous potential, but there is not much proven data in the field yet.

# Battery Charging:

The really basic, basics.

*There are four stages to lead acid battery charging:*

- **Boost/Bulk Charge** - High voltage, high amperage, until the battery reaches 80-90% charge.
- **Acceptance/Absorb Charge** - Highest voltage, lower amperage for several hours to complete the charge.
- **Float** - Lower voltage and lower amperage to keep the battery from either discharging or overcharging.
- **Equalization/Desulfation** - Very high voltage, short time charge to bring each cell to the same voltage and to break up any lead sulfate deposits. Not usually required or even safe with AGM batteries.

*Final Notes:*

**Voltage Matters** - As battery charge rate depends on the voltage difference between the charge source and the battery; you want to charge at the highest possible voltage that does not cause the battery to overheat and lose moisture. (This is especially true of AGM and Gel batteries as you cannot replace any water lost.)

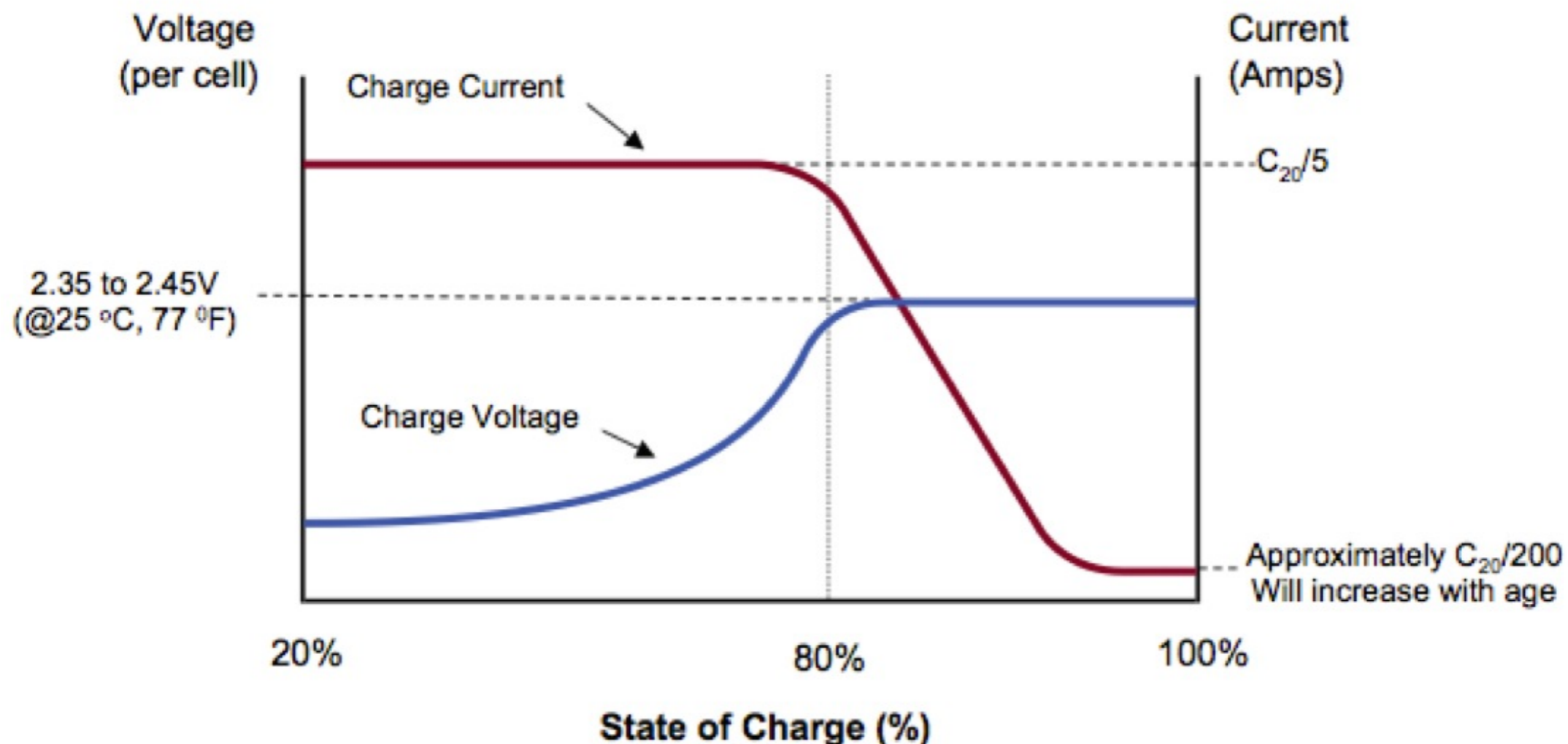
**Time Matters** - Lead acid batteries do not have a memory, like NiCads, but if they are not fully recharged, they will sulfate and lose the ability to accept a full charge over time. Also, it takes time for the bulk charge to fully distribute into the battery

**None of this applies to Lithium batteries.**

## Why is this taking so L O N G ?

**Dirty Secret:** Even with a high current charge source, the rate at which the battery will charge drops off (rapidly) as it reaches full charge. This means that the long, last stage - acceptance/absorb, is the most important.

### Recommended Trojan AGM Charging Profile

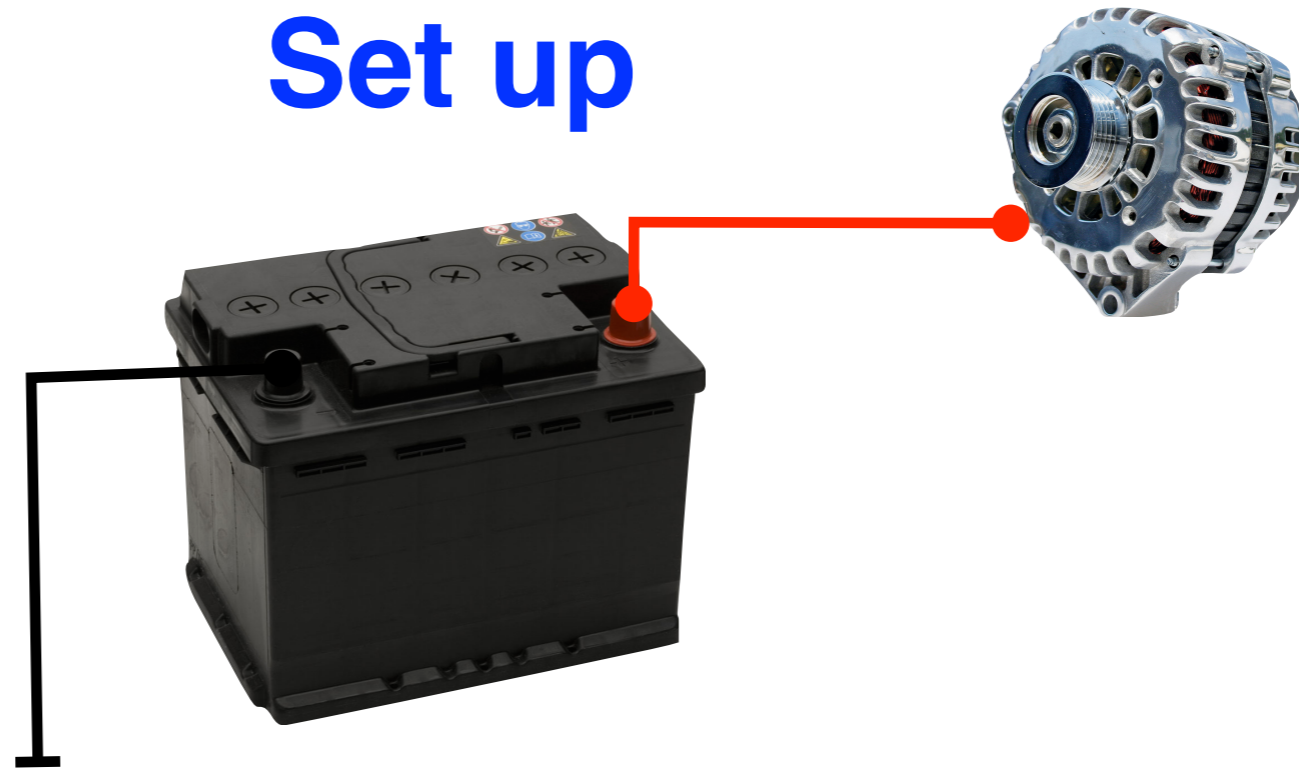


# The “Magic” Number: 14.4v

- Most Lead Acid batteries call for a charging voltage of around 14.4v **at 70F/20C**. (Actual charging voltages increase as temperature drops and decrease as temperature rises.)
- Most modern vehicles easily meet this voltage, but some, most notably some Toyotas and Mercedes Benz, do not.
- Your charging voltage **MUST** meet the requirements of your battery(s). Get, read, and understand the technical manual for **your** batteries.



# Basic Alternator/Battery Set up



- Alternator charges battery when engine is running.
- Regulation provided by the vehicle's charging system.
- Modern charging systems are increasingly sophisticated, allowing them to respond to additional factors like headlights, temperature, equalization.

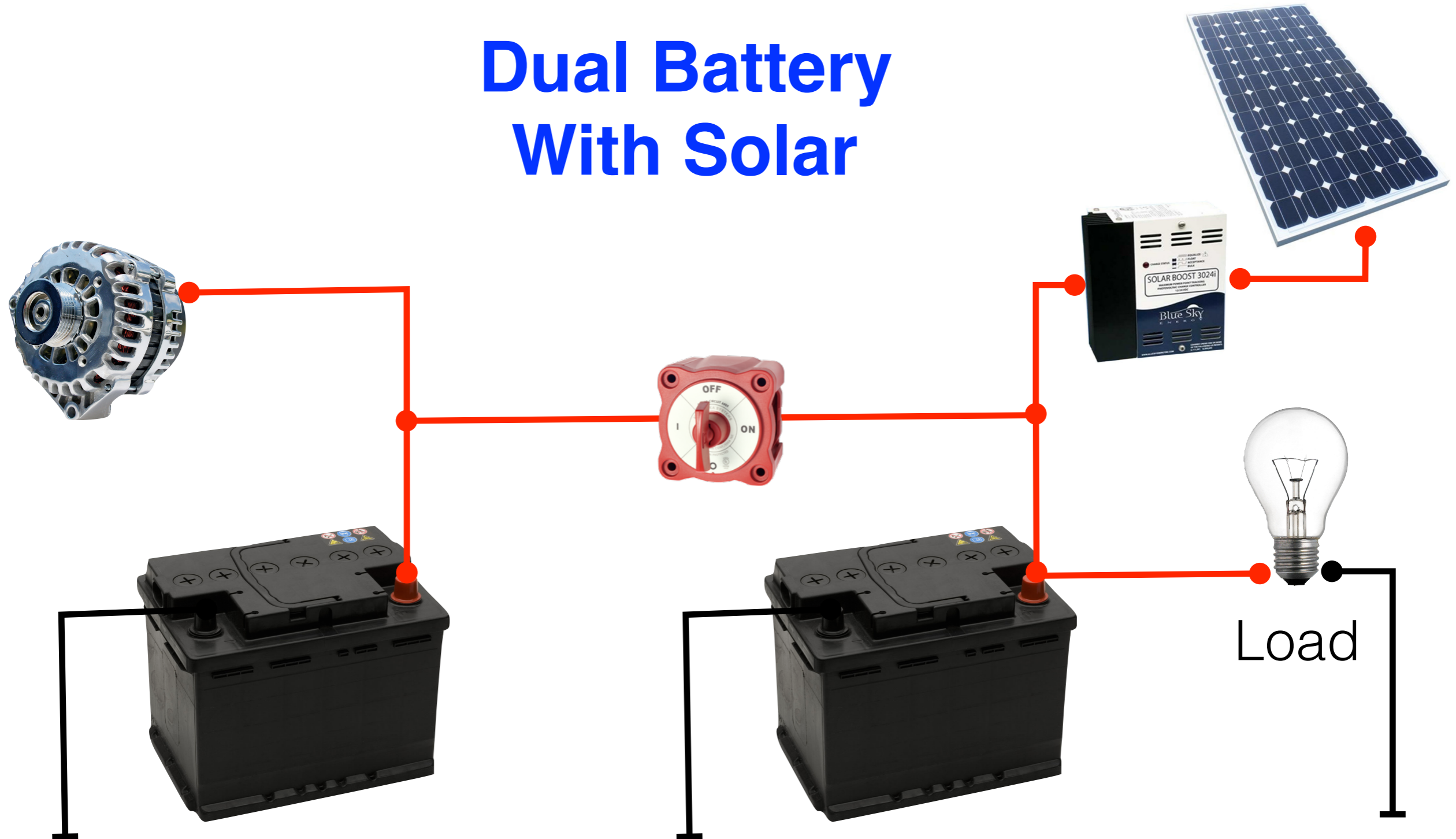
***Problem is that most of us don't drive long enough to fully recharge our camper batteries.***

# Basic Rule:

- Different types and ages of batteries may be combined when ***charging*** but must be separated when ***discharging***.
- Batteries within the same bank, that is, batteries that are ***always connected*** to each other, should be as close to identical as possible - size, type, date of manufacture, etc.
- You want a system that combines your batteries when a charge is present and separates them when they are discharging.

**This allows you to match the best type of battery (starter/deep cycle) to each of your loads (vehicle/camper).**

# Dual Battery With Solar



*This is the basic setup for most overland campers.*

# Additional Charge Sources

*You need one, preferably both, of these:*

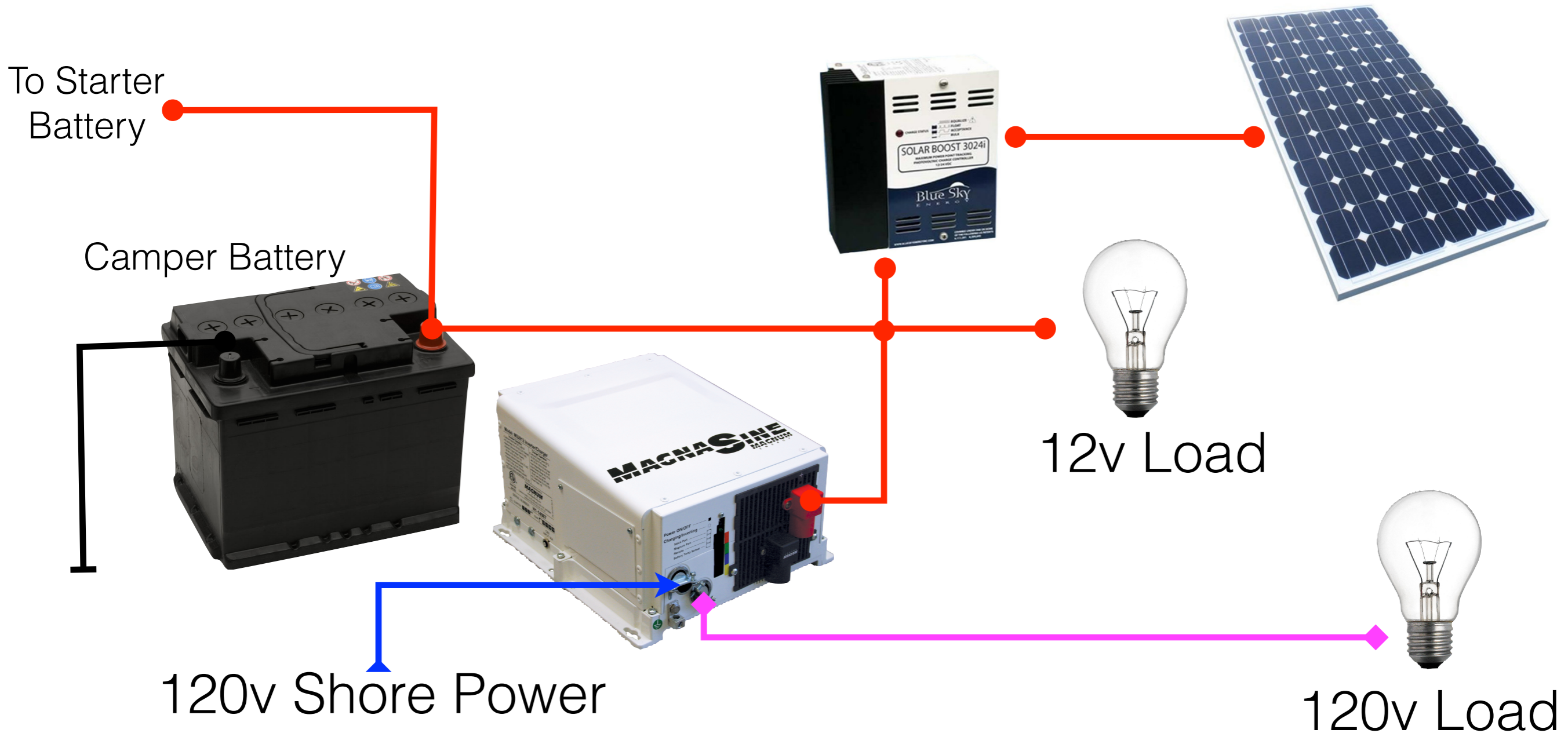
## **Shore Power**

- Could be a generator.
- Higher output - faster charge.
- Sophisticated, multistage charger - better charge without overcharging.
- Long connection time, e.g. overnight, assures complete charge.
- An inverter/charger allows one piece of equipment to perform the functions of both a converter/inverter and a battery charger.

## **Solar Power**

- Lower output - slower charge.
- Sophisticated, multistage charger - better charge without overcharging.
- Longer duration may assure more complete charge.

# Adding Solar and Shore Power



- Solar panels/controller charge batteries when there is light.
- The Inverter/Charger takes in 120V, when available, and uses it to charge the battery.
- When 120v is not available, the Inverter/Charger converts 12v to 120v to provide for 120v loads.

# How BIG is Big Enough?

Most relay based, dual battery systems perform poorly because the wiring is, by an order of magnitude, too small. If your camper batteries are not under the hood, you probably need 0 AWG or larger. This is large, heavy, and expensive.

Wire size is critical for Battery-to-Battery Charger systems as well.

The links below are useful for calculating wire sizes. Size matters, when in doubt, go larger or double up the runs.

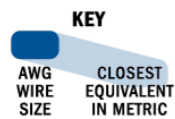
<http://circuitwizard.blueseas.com>

<http://www.calculator.net/voltage-drop-calculator.html>

# Size Matters

Standard and Metric Wire Comparison Table

Available Wire Size AWG	Available Wire Size Metric
16	1.5
14	2.5
12	4
10	6
8	10
6	16
4	25
2	35
1	50
0	
2 0	70
3 0	95
4 0	120

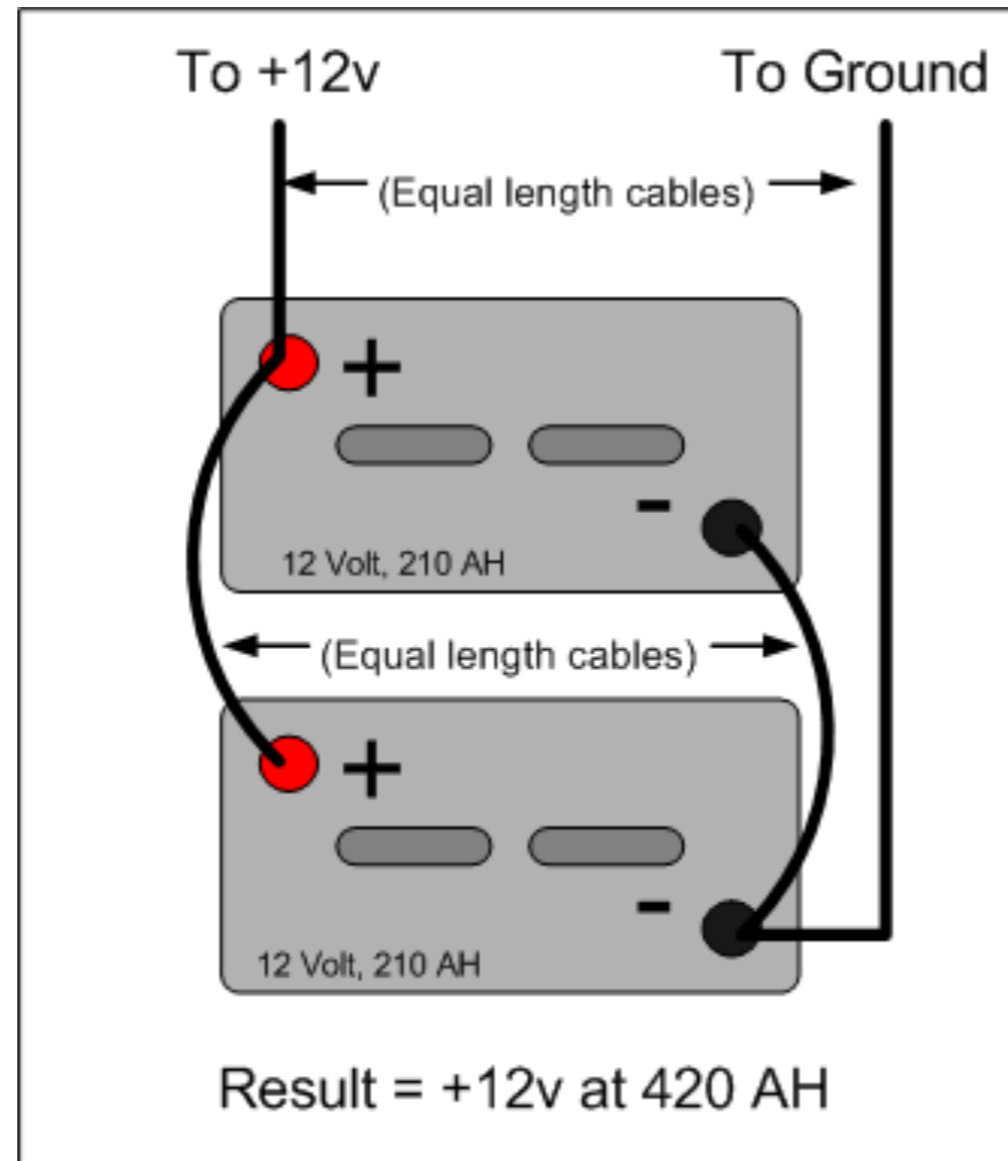


CIRCUIT TYPE		CURRENT FLOW IN AMPS															
Non-Critical 10% VOLTAGE DROP	Critical 3% VOLTAGE DROP	5A	10A	15A	20A	25A	30A	40A	50A	60A	70A	80A	90A	100A	120A	150A	200A
0 to 20 ft	0 to 6 ft	16 AWG	16 AWG	14 AWG	14 AWG	12 AWG	10 AWG	8 AWG	6 AWG	6 AWG	6 AWG	4 AWG	4 AWG	4 AWG	2 AWG	1 AWG	2 0 AWG
30 ft	10 ft	16 AWG	14 AWG	12 AWG	12 AWG	10 AWG	10 AWG	8 AWG	6 AWG	6 AWG	4 AWG	4 AWG	4 AWG	2 AWG	2 AWG	1 AWG	2 0 AWG
50 ft	15 ft	16 AWG	12 AWG	10 AWG	10 AWG	8 AWG	8 AWG	6 AWG	6 AWG	4 AWG	4 AWG	4 AWG	2 AWG	2 AWG	2 AWG	1 AWG	2 0 AWG
65 ft	20 ft	14 AWG	10 AWG	10 AWG	8 AWG	6 AWG	6 AWG	6 AWG	4 AWG	4 AWG	2 AWG	2 AWG	2 AWG	2 AWG	1 AWG	0 AWG	2 0 AWG
80 ft	25 ft	12 AWG	10 AWG	8 AWG	6 AWG	6 AWG	6 AWG	4 AWG	4 AWG	2 AWG	2 AWG	2 AWG	1 AWG	1 AWG	0 AWG	2 0 AWG	3 0 AWG
100 ft	30 ft	12 AWG	8 AWG	6 AWG	6 AWG	6 AWG	4 AWG	4 AWG	2 AWG	2 AWG	1 AWG	1 AWG	0 AWG	0 AWG	2 0 AWG	3 0 AWG	4 0 AWG
130 ft	40 ft	10 AWG	8 AWG	6 AWG	4 AWG	4 AWG	4 AWG	2 AWG	2 AWG	1 AWG	0 AWG	0 AWG	2 0 AWG	2 0 AWG	3 0 AWG	4 0 AWG	4 0 AWG
165 ft	50 ft	10 AWG	6 AWG	6 AWG	4 AWG	2 AWG	2 AWG	2 AWG	1 AWG	0 AWG	2 0 AWG	2 0 AWG	3 0 AWG	3 0 AWG	4 0 AWG	4 0 AWG	4 0 AWG
200 ft	60 ft	8 AWG	6 AWG	4 AWG	4 AWG	2 AWG	2 AWG	1 AWG	0 AWG	2 0 AWG	2 0 AWG	3 0 AWG	3 0 AWG	4 0 AWG	4 0 AWG	4 0 AWG	4 0 AWG
	70 ft	8 AWG	4 AWG	4 AWG	2 AWG	2 AWG	1 AWG	0 AWG	2 0 AWG	3 0 AWG	3 0 AWG	4 0 AWG	4 0 AWG	4 0 AWG	4 0 AWG	4 0 AWG	4 0 AWG
	80 ft	8 AWG	4 AWG	2 AWG	2 AWG	1 AWG	0 AWG	2 0 AWG	3 0 AWG	3 0 AWG	4 0 AWG	4 0 AWG	4 0 AWG	4 0 AWG	4 0 AWG	4 0 AWG	4 0 AWG
	90 ft	6 AWG	4 AWG	2 AWG	1 AWG	0 AWG	2 0 AWG	3 0 AWG	3 0 AWG	4 0 AWG	4 0 AWG	4 0 AWG	4 0 AWG	4 0 AWG	4 0 AWG	4 0 AWG	4 0 AWG
	100 ft	6 AWG	4 AWG	2 AWG	1 AWG	0 AWG	2 0 AWG	3 0 AWG	3 0 AWG	4 0 AWG	4 0 AWG	4 0 AWG	4 0 AWG	4 0 AWG	4 0 AWG	4 0 AWG	4 0 AWG
	110 ft	6 AWG	4 AWG	2 AWG	1 AWG	0 AWG	2 0 AWG	3 0 AWG	3 0 AWG	4 0 AWG	4 0 AWG	4 0 AWG	4 0 AWG	4 0 AWG	4 0 AWG	4 0 AWG	4 0 AWG
	120 ft	6 AWG	4 AWG	2 AWG	1 AWG	0 AWG	2 0 AWG	3 0 AWG	3 0 AWG	4 0 AWG	4 0 AWG	4 0 AWG	4 0 AWG	4 0 AWG	4 0 AWG	4 0 AWG	4 0 AWG
	130 ft	6 AWG	2 AWG	2 AWG	1 AWG	0 AWG	2 0 AWG	3 0 AWG	3 0 AWG	4 0 AWG	4 0 AWG	4 0 AWG	4 0 AWG	4 0 AWG	4 0 AWG	4 0 AWG	4 0 AWG

## AWG WIRE SIZE CHART



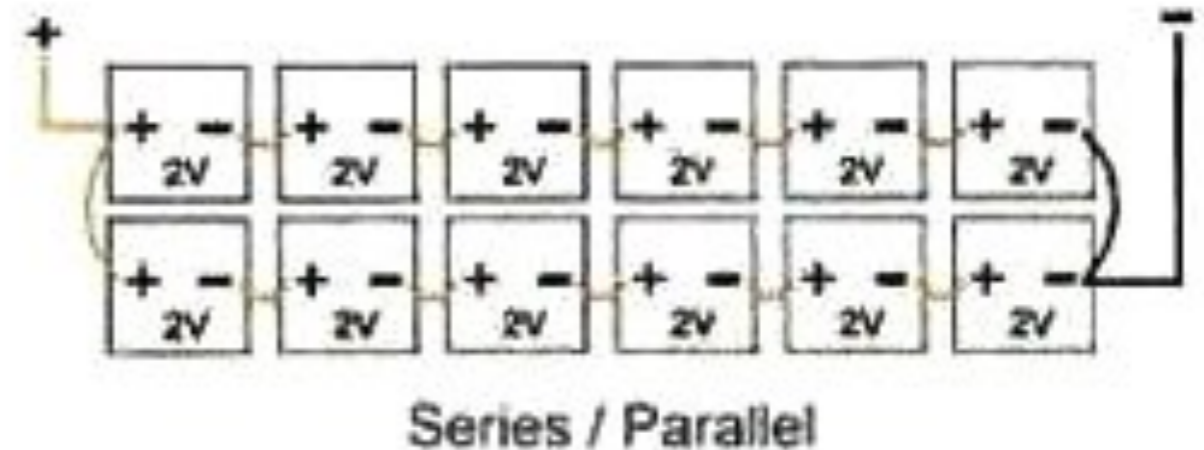
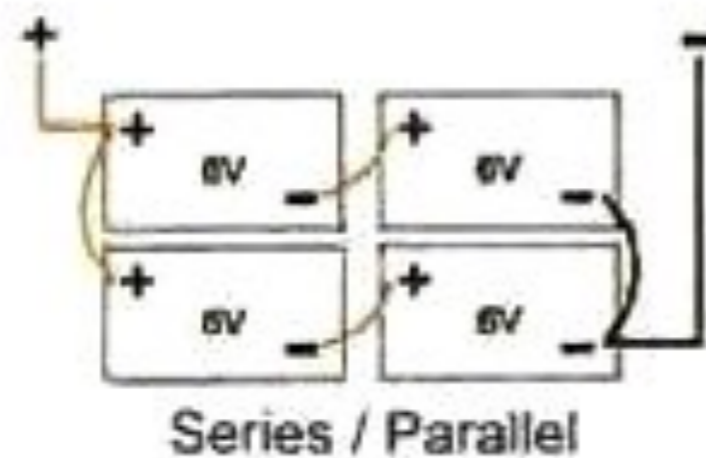
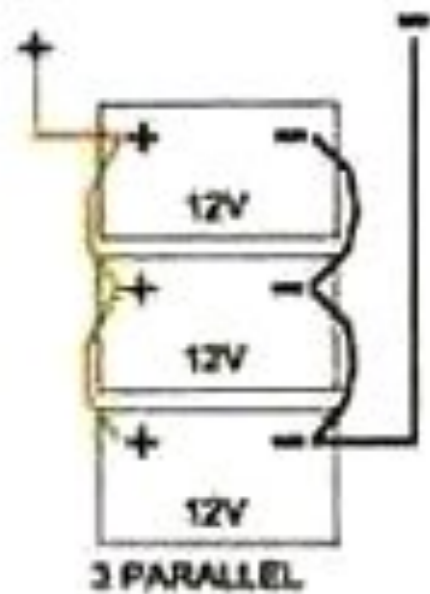
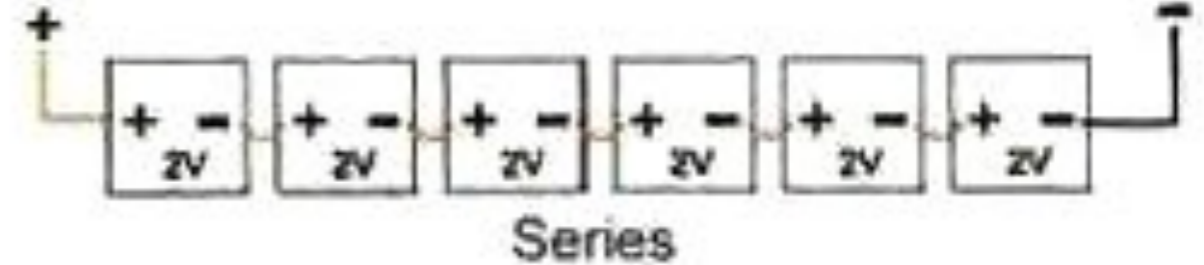
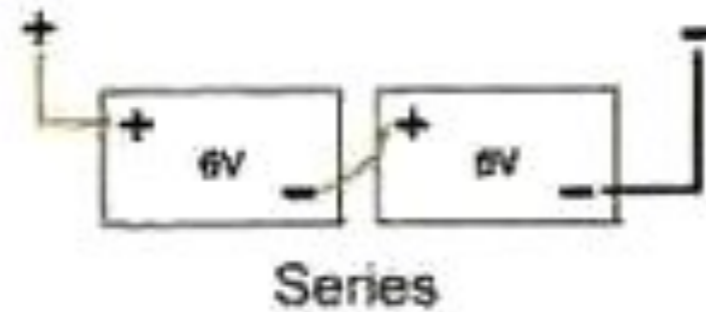
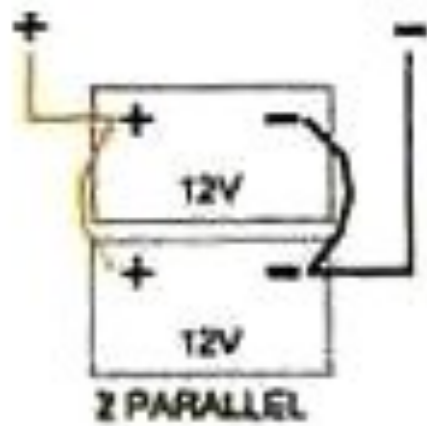
# “Diagonal” Wiring



In simplest terms, this forces the current to flow through all of the batteries equally.



# Wiring Variations



12 VOLT BATTERY WIRING

More variations can be found here: [http://www.smartgauge.co.uk/batt\\_con.html](http://www.smartgauge.co.uk/batt_con.html)

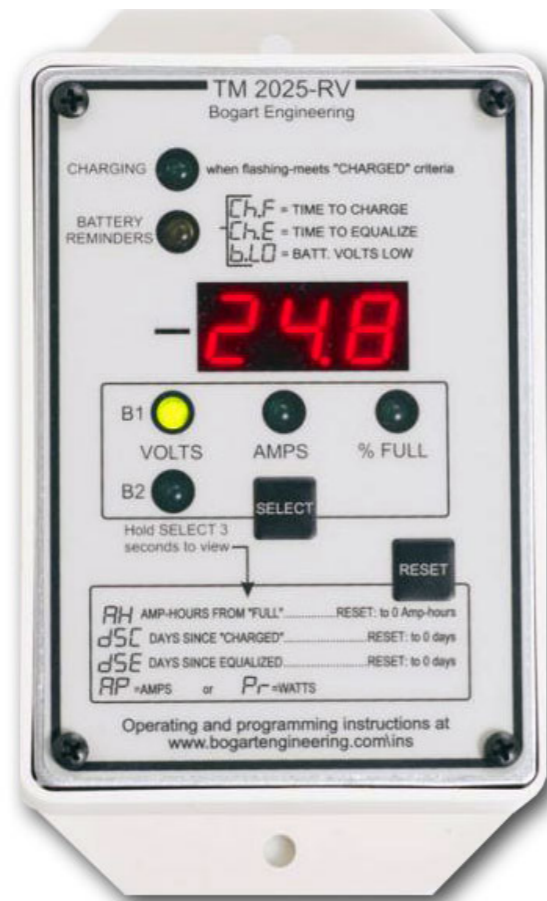
# Voltage vs. State of Charge

<b>Voltage</b>	<b>State of Charge</b>
<b>12.6+</b>	<b>100%</b>
<b>12.5</b>	<b>90%</b>
<b>12.42</b>	<b>80%</b>
<b>12.32</b>	<b>70%</b>
<b>12.20</b>	<b>60%</b>
<b>12.06</b>	<b>50%</b>
<b>11.9</b>	<b>40%</b>
<b>11.75</b>	<b>30%</b>
<b>11.58</b>	<b>20%</b>
<b>11.31</b>	<b>10%</b>
<b>10.5</b>	<b>0%</b>

This chart is for “resting” voltage and camper batteries are almost under charge or discharge and thus the reading from a voltmeter is almost always too high or too low. Thus a voltmeter can only give an estimation of the state of charge.

# Watts Goin' On

(Or how do I monitor my batteries?)



Given the limitations of a voltmeter, use a shunt based hour counter or consider the Smartgauge. Some solar or shore chargers also include integrated meters.

# Monitors and Why They Don't Work

- Voltmeters are only accurate for a “resting” battery.
- Hour counters require a shunt and the math of measuring amps in and out is too complex to be really accurate. These meters get less accurate over time.
- The Smartgauge is controversial, but gets more accurate with time. Can only measure the state of charge and is most accurate when battery is close to “rest.”

# What to Do?

There are some golden rules for long life with lead acid batteries.

Never leave a battery sitting in a discharged state. Never ask, “Is it time to recharge my batteries?” If you can, the answer is always, “**YES!**”

- Charge as soon as you can, as fast as you can, and as long as you can, every time you can.
- Try to bring the batteries to “full” charge as soon as you can and as often as you can. This may require a weekly shore power session.
- Try to make the process as automatic as possible so you never miss an opportunity. Consider automatic relays, solar, etc.

# Summary:

**Most Lead Acid camper batteries fail because they are never fully recharged.**

- Engine alternators are increasingly large, providing an good source of boost/bulk charge, but most engines will never run long enough to fully recharge after a typical overnight discharge.
- Solar kits can provide the extra charge time needed to complete the acceptance/absorb cycle.
- Shore power is the final backup. Provide for it and use it, especially if your other options are less than optimal.

# Resources:

## Warning: Extreme Geekery follows:

- **OUTBACKJOE:** Possibly the best discussion that I have found for a touring vehicle. Australian site. <http://outbackjoe.com/macho-divertissement/macho-articles/design-guide-for-12v-systems-dual-batteries-solar-panels-and-inverters/>
- **Handy Bob:** Unapologetically iconoclastic solar site. Worth reading even if you don't agree with all of his choices: <http://handybobsolar.wordpress.com>
- **Northern Arizona Wind and Sun:** Really good FAQ on deep cycle batteries: <https://www.solar-electric.com/deep-cycle-battery-faq.html#Gelled%20Electrolyte>
- **Smart Gauge:** UK company founded by Chris Gibson, a canal boat aficionado. A wealth of technical information, start reading here: <http://www.smartgauge.co.uk/technical1.html>
- **Sterling Power:** US and UK websites. Founded by Charles Sterling, Sr., another canal boat fan. Technical data is found here: <http://www.sterling-power.com/datasheets.htm> Read this on the virtues of high voltage charging: <http://www.sterling-power.com/images/downloads/advancedcharging.pdf>
- **Blue Sea Systems:** Less a technical resource and more a source for excellent, marine grade switches, fuses, etc.: <https://www.blueseas.com>
- **CTEK:** Make shore chargers and a very interesting B2B. US website: <http://smartercharger.com>
- **Warning:** None of these sites agree in all aspects, for example, Handy Bob is convinced that the Smart Gauge cannot work and Charles Sterling uses diode based systems which Chris Gibson of SmartGauge loathes. ***Only you can make the final decision on which products will best meet your needs.***

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- **Sterling Power:** US and UK websites. Founded by Charles Sterling, Sr., another canal boat fan. Technical data is found here: <http://www.sterling-power.com/datasheets.htm> Read this on the virtues of high voltage charging: <http://www.sterling-power.com/images/downloads/advancedcharging.pdf>
- **Blue Sea Systems:** Less a technical resource and more a source for excellent, marine grade switches, fuses, etc.: <https://www.blueseas.com>
- **CTEK:** Make shore chargers and a very interesting B2B. US website: <http://smartercharger.com>
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