SEAPAC CHARGE CONTROLLERS

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Basic Function Of A Solar Charge Controller

- Charge controllers regulate **how high** the voltage gets in the battery during charging, otherwise the battery can be damaged or destroyed if directly connected to a solar panel
- Charge controllers have at least **two sets** of connection **terminals**, one for **solar power input** and one for **power output** to the **battery**
- Some charge controllers have an **additional set** of **terminals** for a **load** to be connected, the load connection terminals may provide **LVD** (Low Voltage Disconnect) which protects the battery from being discharged too low

Simple Solar Charge Controller With Battery And Solar Connections

More Advanced Solar Charge Controller With PV(Solar), Bat(Battery) And Load Connections

Sizing Your Battery, Charge Controller, And Solar Panel, Basic Example

- **First** step is what charging current will you need for your **battery**?
- AGM **lead-acid** battery **ideal charging current** is C/10 or 0.1C, so 55Ah/10 = 5.5 amps of charge current
- **Second** step is what **size solar panel** will supply the needed charge current, 100 watt solar panel provides ~ 5.5 amps in full sun

Selecting A Charge Controller

- **Third** step is selecting a **charge controller**
- Need to know the **maximum solar input voltage** the charge controller will accept? Which is the Voc (**O**pen **C**ircuit **V**oltage) of the solar panel
- Need to know the **max solar amperage** the charge controller is rated for?
- Will the charge controller operate at the **battery voltage** you are using? Your **system voltage**?
- Could be 12v, 24v, 36v, or 48v

Selecting A Charge Controller

- Need to know what **battery chemistry** you are using, FLD, SLA, GEL, LITH, USER
- FLD = flooded lead-acid
- SLA = Sealed lead-acid, AGM, (might include GEL)
- GEL = gel cell
- LITH = Lithium Iron Phosphate, LFP
- USER = user defined charge parameters

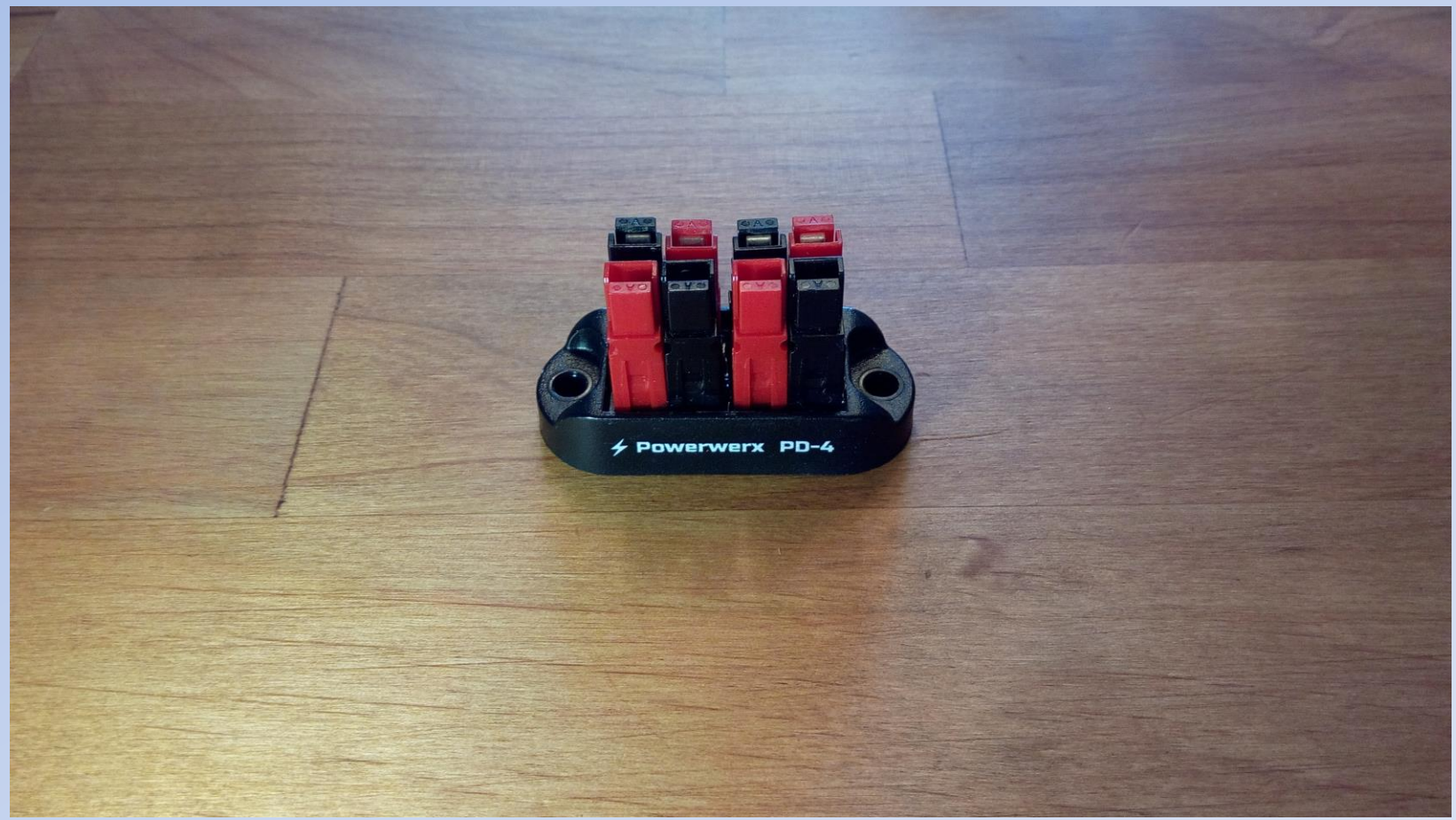
System Sizing Example

- 55Ah AGM battery…ideal charge current is 5.5 amps
- 100 watt Renogy monocrystalline solar panel…output is ~ 5.5 amps in full sun
- **Morningstar SunSaver-6 charge controller**
- SS-6 system voltage is 12 volts, can do FLD and SLA
- Max solar voltage = 30v, 36 cell PV
- Rated PV input = 6 amps, max short circuit amps = 8.1

How Do I Hook Up My Solar Panel To A Charge Controller And My Battery?

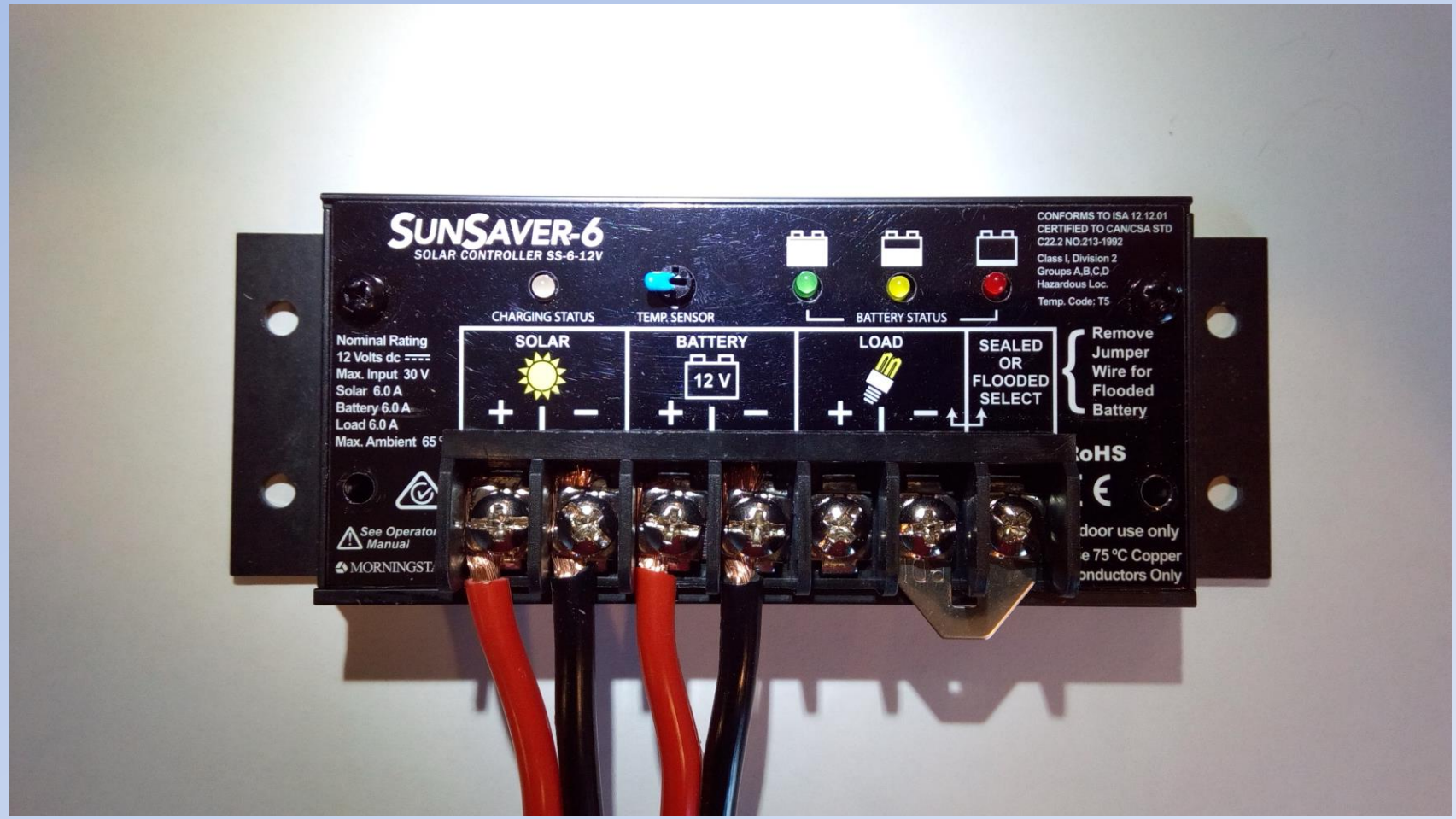
- Step by step process
- Connect the **battery** to the **distribution block**
- Connect the charge controller "**battery terminal**" output to the **distribution block**
- Connect the charge controller "**solar input**" terminal to the **solar panel**
- Now connect any additional **load** to the **distribution block**
- **Battery, charge controller battery, charge controller solar, and load in that order connected to the distribution block**

Solar Power To Your Station…Start With Your Distribution Block

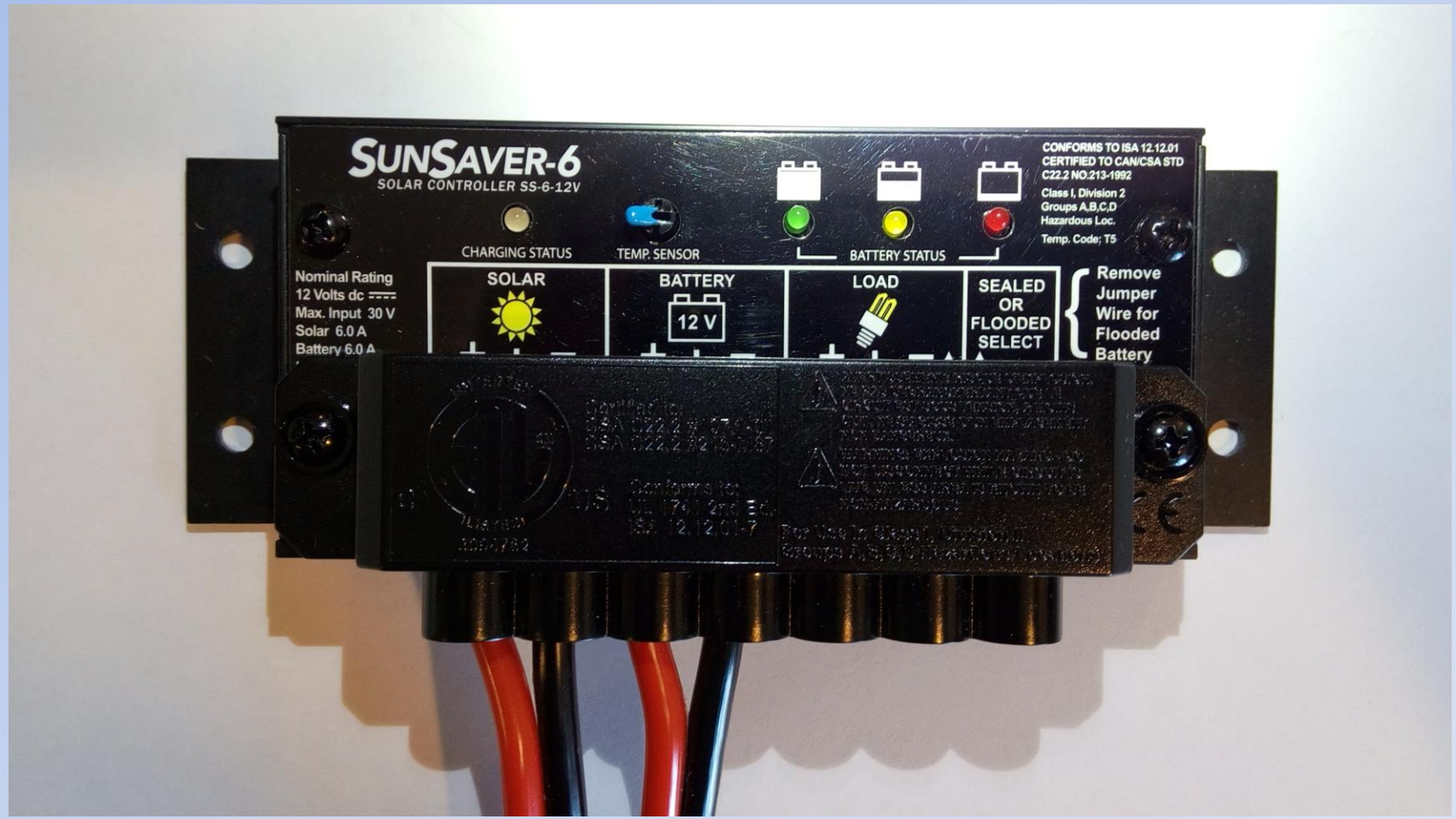


Then Hook Up Your Battery…Note Inline Fuse For The Circuit

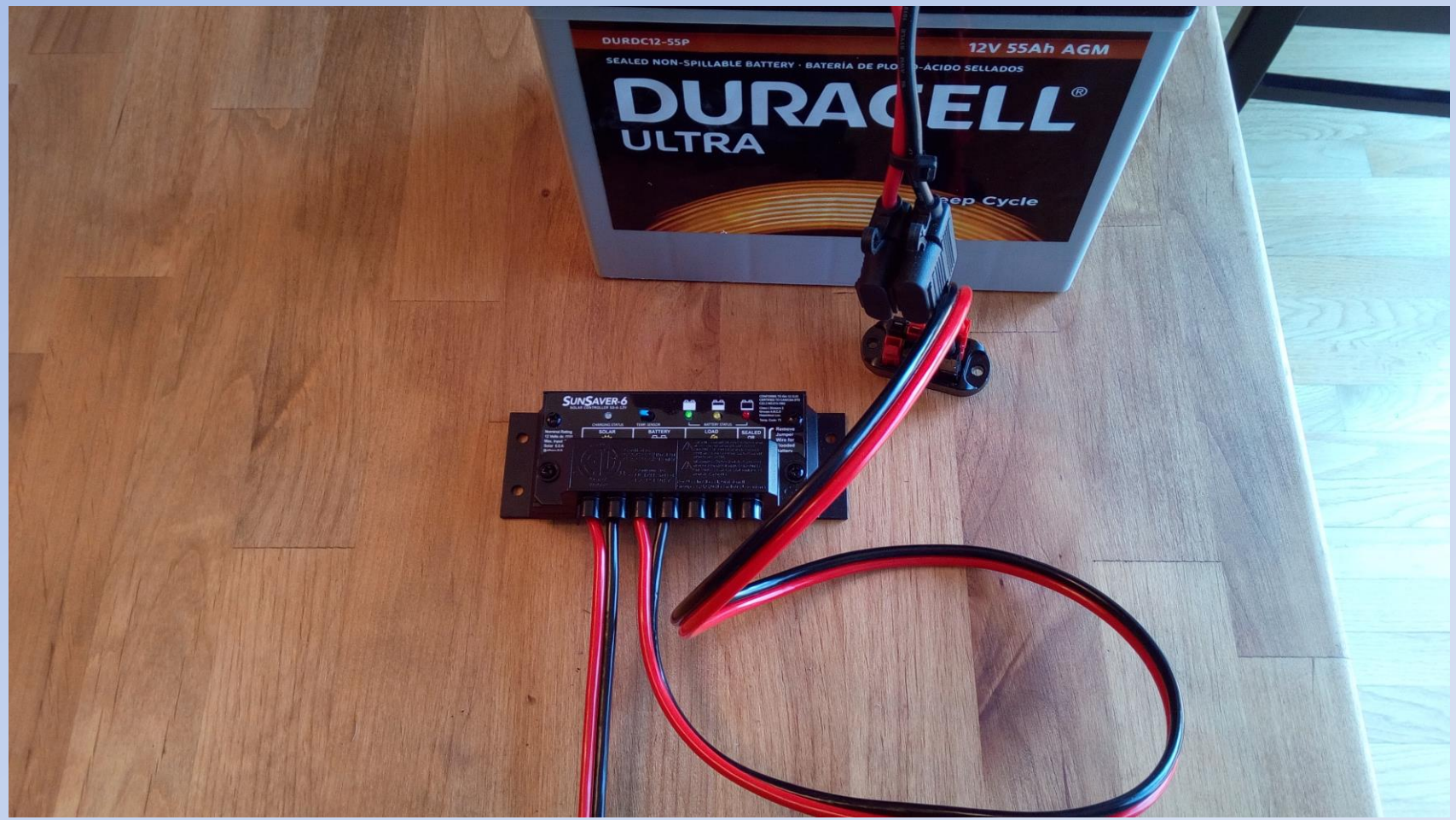
SunSaver-6 Charge Controller With “Solar”, “Battery”, And “Load” Connection Terminals



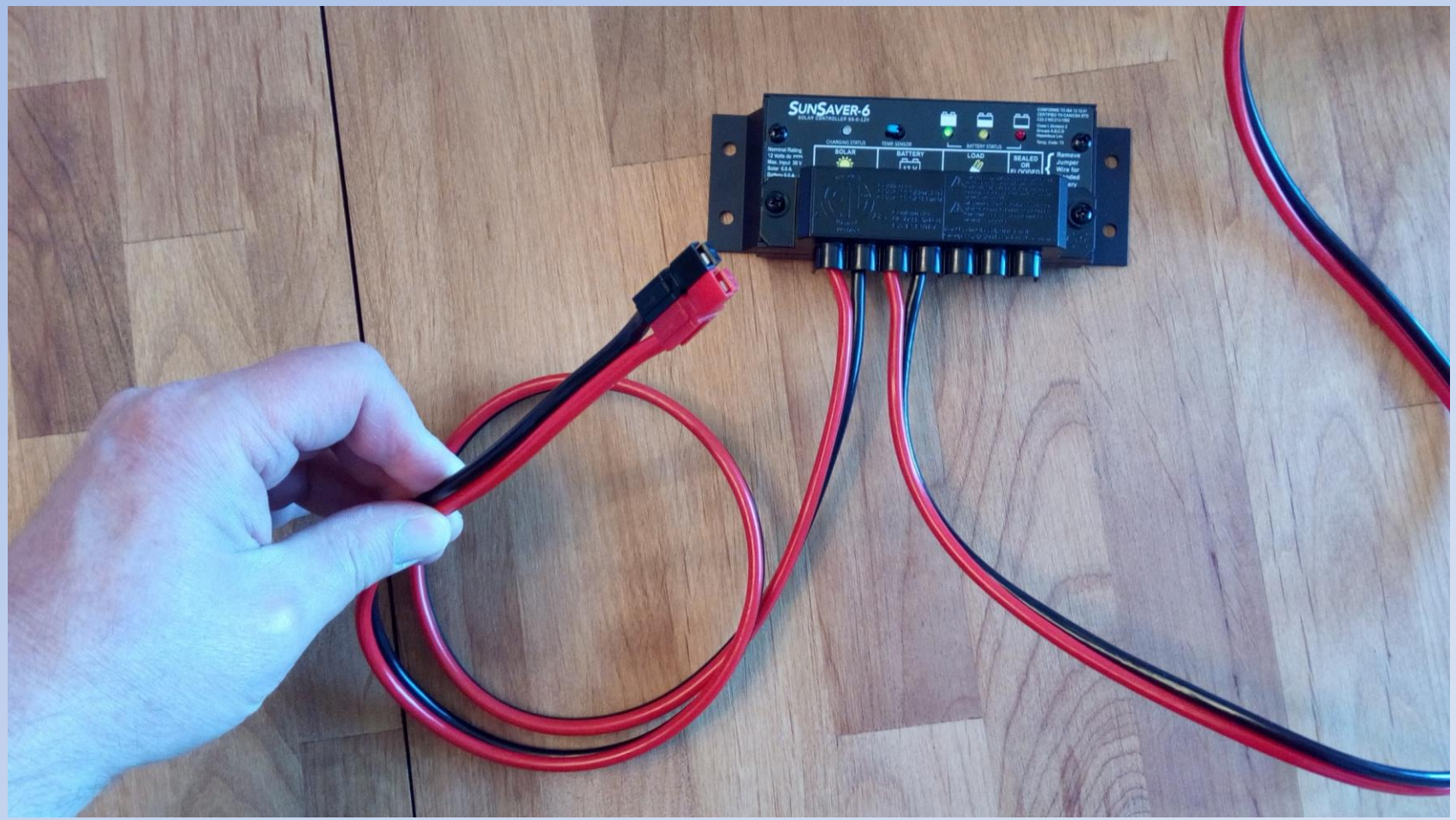
SunSaver-6 Charge Controller With “Solar”, “Battery”, And “Load” Connection Terminals



Hook Up The Charge Controller “Battery” Terminals To The Distribution Block



Hook Up The Charge Controller “Solar” Terminals To Your Solar Panel



“Solar” Terminals Go To A Power Cable(30’) Running Outside To Your Solar Panel

MC4 Connections Versus Anderson Power Poles Under Load

- MC 4 connectors are rated for **20 amps** and **600VDC** and it is **not recommended** to connect or disconnect an MC4 connection under load
- Anderson Power Pole(PP) connectors are rated for 100,000 no-load connections and 250 hot-plug connections at full load
- Connecting an MC4 to PP first, then PP to the circuit would avoid an MC4 connection under load

Now Connect Your Additional Load (Radio) To The Distribution Block

Basic Solar Power Connection Info

- Connecting the charge controller first to the battery before connecting the charge controller to the solar panel allows the battery to clamp down voltage in the charge controller internal circuit and helps prevents a sudden inrush voltage spike from the solar panel

Solar Charge Controller

- The solar charge controller is the **brain** of your power system, **many** can even do temperature compensated charging
- **Temperature compensation** means the controller can intelligently adjust the output voltage to your battery based on how hot or cold the temperature is
- As the temperature drops, the controller can provide a higher constant voltage set point during the absorption phase of charging with lead-acid batteries

Three Types of Lead-Acid Charge Controllers

- **Simple On/Off**…cut in and cut out type
- **P**ulse **W**idth **M**odulation…**PWM**, uses short pauses in charge current to top off the battery
- **M**aximum **P**ower **P**oint **T**racking…**MPPT**… converts higher solar panel voltage down to the lower battery voltage and increases the amps during bulk charging, **can cause RF interference** if not designed to be more RF quiet

Simple **On-Off** Charge Controllers

- Earliest models would have a high voltage set point and a low voltage set point and **short circuit** the solar panel during the charge cycle
- The controller **passes** solar panel **current** to the battery when **charging starts**
- As the battery charges, the battery voltage will rise
- Once the battery voltage reaches the **high voltage set point**, the controller would then **short circuit** the solar panel

Simple On-Off Charge Controllers

- Short circuiting the solar panel was not a problem for the solar panel
- The battery then **receives no current**, and the battery **voltage drops down over time** until the low voltage set point is reached, at which time the controller **reconnects the battery** to the solar panel and process repeats going to high voltage, charging stops, going to low voltage and charging starts again

Simple On-Off Charge Controllers

- Later charge controllers would go from **short circuiting** the solar panel to just going to **open circuit**
- The effect was the same on the battery side whether the solar panel went to short circuit or open circuit
- Periods of **time with no charge** until the battery voltage dropped down to the low voltage set point
- These are the **least efficient** charge controllers, and not recommended

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Shortcut That Could Crowbar Your Power Supply

- Ham radio operators are very creative people
- One idea that may come to mind, is why not use a solar charge controller connected to my power supply with the voltage cranked up to 14.2-14.5 volts? Peak charging voltage for AGM battery
- **Solar charge controllers** can easily **"short" the panel** briefly while in operation, shorting a solar panel does no harm…**short your power supply and you will Crowbar it**

Nature Power 8 Amp **Cut-In/Cut-out** Solar Charge Controller For Lead-Acid Batteries

Nature Power 8 Amp Cut-in/Cut-out

- Simple charge controller designed for charging 12 volt lead-acid batteries
- Designed for up to a **130W solar panel** or **8 amps solar** output
- When you start charging your battery, the battery voltage will rise up to 14.2 volts, then disconnect the battery
- When the battery voltage reaches 13.0 volts, the charge controller reconnects the solar input to the battery

Typical Set Up For An 8 Amp Cut-In, Cut-Out Charge Controller

- Solar input must not exceed 8 amps with this charge controller
- 100 Watt solar panel in full sun provides ~ 5.5 amps
- The 100 watt solar panel is a good choice for this charge controller

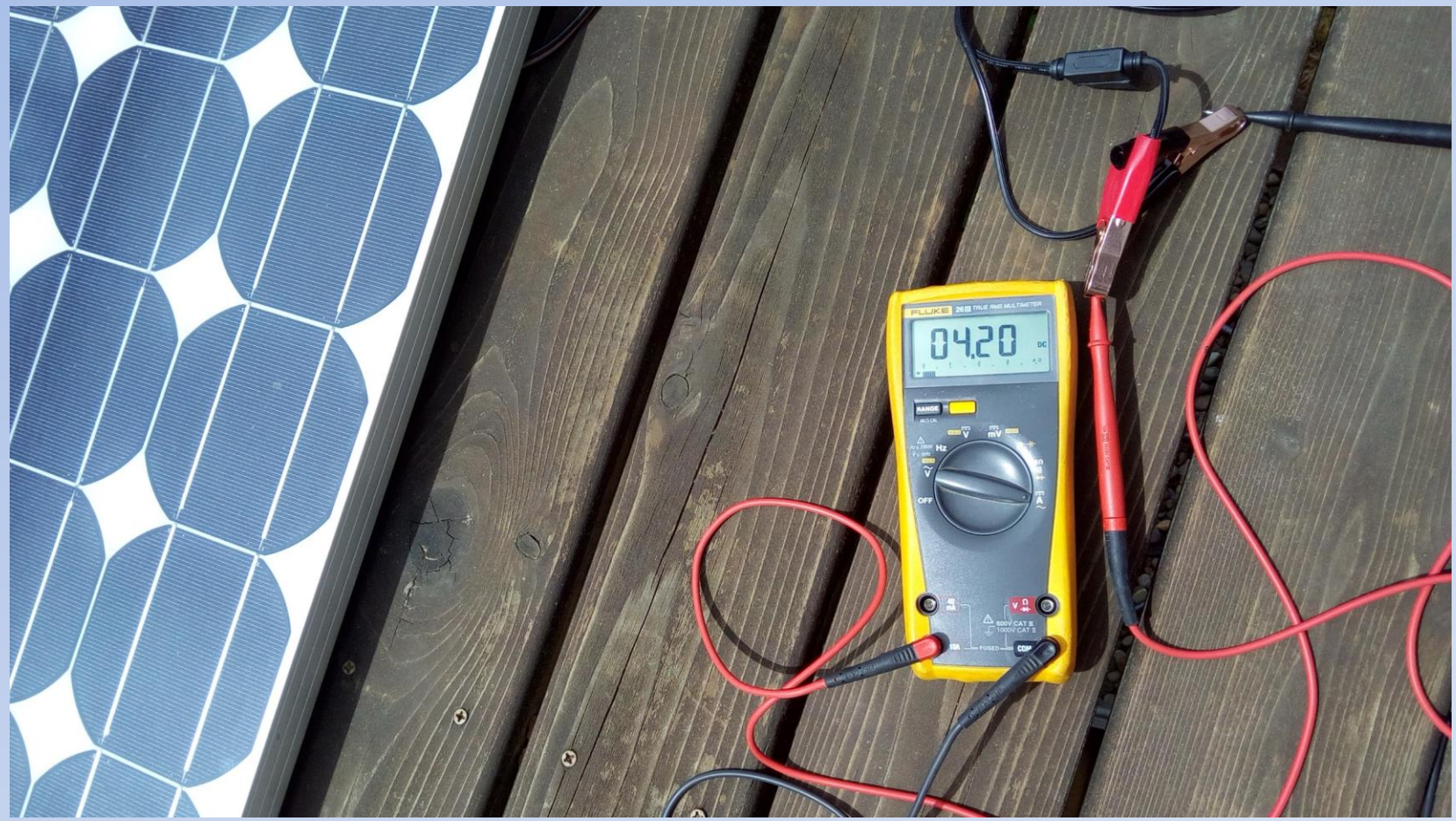
Typical Set Up For An 8 Amp Cut-In, Cut-Out Charge Controller

- Charge controller has headroom of 2.5 amps
- It is a good idea to **use less than the total rated amps** of your charge controller due to **Edge Of Cloud Effect** amperage spikes that can happen while charging a battery when there is clouds in the sky

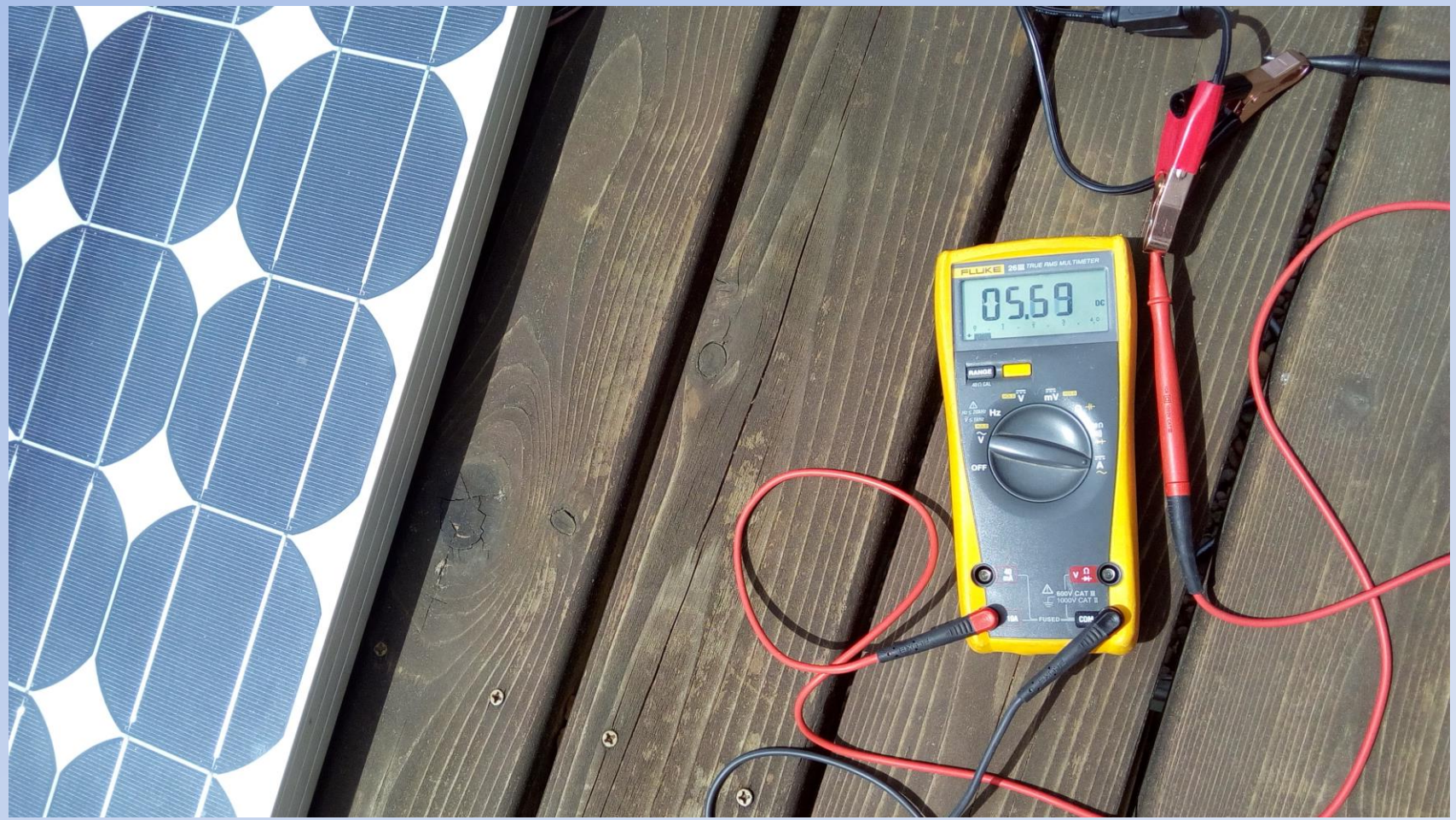
Edge-Of-Cloud Effect And Solar Charge Controllers

- **Edge of cloud effect** can happen when the sun just goes behind a cloud in the sky or when it begins to reappear from behind some clouds
- When the sun strikes the **edge of the cloud**, there can be a sudden concentration of sunlight causing an increase in solar intensity
- Generally lasts about ~10-15 seconds while the sun passes the edge of the cloud

75 Watt Solar Panel Putting Out 4.2 Short Circuit Amps In Full Sun



75 Watt Solar Panel Now Showing 5.69 Short Circuit Amps During The Edge-Of-Cloud Effect



75 Watt Solar Panel Edge-Of-Cloud Effect Info

- 75 Watt solar panel shows **short circuit amps = 4.2**
- Same solar panel just **minutes later** when the sun was at the **edge of a fluffy cloud, amps = 5.69**
- 5.7 – 4.2 = 1.5 amp increase during a short duration
- Represents about a 35% temporary increase in power
- Most solar charge controllers should be able to withstand some amount of temporary spike in input

PWM Charge Controllers Do 3 Stage Charging…More In Depth Charge Info

- **Stage 1** is **Bulk Charging**…power produced from your solar panel flows into the battery…this stage will charge your battery up to about 80-85% of full
- Battery voltage will slowly rise and then reach an upper limit **set point**…at this point, the next charging stage begins

PWM Lead-Acid Charging Stage 2

- **Stage 2** is the **Absorption** phase
- Battery voltage has reached a **set point** and the charge controller will **hold the battery voltage** at this set point while **amperage** flowing into the battery **tapers down** over time

PWM Lead-Acid Charging Stage 2

- The battery determines **naturally** how much current flows
- The charge controller does not determine the amount current flowing to the battery in this stage, it just holds the voltage

PWM Absorption Set Point Too High?

- If the **battery voltage rises too high**, **electrolysis** will happen and **water molecules** will start being split into **oxygen and hydrogen** and **gassing** will occur
- The lead-acid battery **gassing voltage** changes with battery **temperature**
- The use of short pauses with PWM controllers helps interrupts gas bubble formation in the battery

PWM Absorption Set Point Too High?

- Increasing grid corrosion can occur if the battery voltage is too high
- **Corrosion** happens on the **spines(grids) of the positive plates**, some corrosion is a normal process
- No grid corrosion happens at 12.9 volts
- Extremely slow grid corrosion happens at 13.5 volts which is a **float voltage**
- Some noticeable grid corrosion happens at 14.1 volts

PWM Absorption Set Point Too High?

- **Significant** grid corrosion happens at 15.3 volts
- **Very significant** grid corrosion happens at 15.9 volts
- The goal in charging a lead-acid battery is to keep the voltage just **under the gassing voltage** and limit normal grid corrosion, yet high enough to **prevent sulfation** from happening

Leave No Sulfation Behind After Charging Your Lead-Acid Battery

- In order to **remove all the sulfation** on the positive and negative battery plates, plan to bring the battery voltage **right up to the edge of gassing**
- If the stage 2 set point, is too low, you will leave behind some sulfation on your battery plates, the soft sulfation can then turn into hard crystals and shorten the life of your lead-acid battery
- Remember to **charge your lead-acid battery soon after each use, if you forget, over time** sulfation can go on to crystallize

Special Type Of Stage 2 Charging For **Flooded Lead-Acid Batteries**

- **Flooded lead-acid batteries** can also have a special controlled period of higher voltage called **equalization** which balances out the active materials of the battery and **some gassing does happen**, and water is replaced
- Equalization is done **about once per month**
- Sulfuric acid is heavier than water, the top part of the plates could have less of the active material over time, the bottom part of plates could have more sulfation
- Stirring up the active material with equalization helps

PWM **Lead-Acid Battery** Stage 3 Charging

- Stage 3…after the current tapers down slowly and the battery is topped off…the battery voltage is then **dropped down** to a **second set point** where the charge controller will allow a “trickle of charge” to go into the battery to keep it topped off
- Battery voltage will then drop down more once the sun goes down

PWM Solar & Battery Voltage Transition

- While charging in the **bulk phase**, the **solar panel voltage** is slightly higher than the **battery voltage**
- Once the absorption battery voltage set point is reached, **circuit amperage** starts to **taper down** and **solar voltage** begins to **rise** higher and higher as the circuit amperage continues to fall
- **Battery voltage** is held at the temperature compensated set point, while **solar voltage rises**

Transition From Bulk Phase To Absorption Phase Example…What Happens

- SunSaver-6 charge controller…6 amp controller
- 100 Watt solar panel…5.5 amps in full sun
- 55Ah lead-acid AGM battery that was **nearly full**
- **Solar meter** = inline meter between the solar panel and the charge controller
- **Battery meter** = inline meter between the charge controller and the battery
- Readings were taken over about 15-20 minutes

SunSaver-6 PWM, 55Ah AGM, 100 Watt PV, Transition From Bulk To Absorption Phase

Solar Current In Amps	Solar Voltage	Battery Current In Amps	Battery Voltage
5.53 Just started the test	13.75	5.52	13.42…just hooked up
5.73…little edge of cloud	14.07	5.7	13.7…starting to rise
5.46	14.12	5.43	13.76
5.03	14.22	5.02	13.89
5.47	14.38	5.46	14.03
4.94	**14.93**…starts to rise more	**4.96** starting to taper	**14.23**…hits the set point
3.87	14.77	3.85…tapering more	14.23…steady voltage
3.67	15.29…> 1.0 volt higher	3.63	14.24…steady voltage
3.25	15.8…>1.5 volts higher	3.23	14.25…steady voltage
2.68	16.26… 2.0 volts higher	2.35	14.26…steady voltage
2.54	18.08	2.51	14.28…holding steady
1.78 Just ended the test	**20.00**…>5.5 volts higher	**1.76**…still tapering	**14.24**…still holding

Solar Reading On The Right, Battery On The Left…Absorption Phase Current Tapering

PWM Charge Controllers

- Battery current tapers down to a point where the controller then goes into the **float phase, stage 3**
- The battery is considered basically full
- In the **float phase**, battery voltage is then throttled back down to a **lower float voltage** and the battery inline meter will show short periods of **no current**, followed short periods of **some current** flowing

PWM Charge Controllers

- While in the **float phase** you will see the solar voltage go to the Voc of the panel due to **no current flowing briefly** from time to time
- This is why your **charge controller must be able to accept the maximum voltage from your solar panel which is the open circuit voltage (Voc)**
- While the battery is being topped off during the absorption phase, **excess current can be used** to charge other batteries or devices

Solar Amps = Load Amps, No Where Else For The Electrons To Go

- When a solar panel is providing power to a load (Battery + Radio + USB power bank, etc.), **if the battery is full**, then the only load for the solar panel is the radio and USB power bank
- Your solar panel will throttle back the power to meet the **total load**
- 100 watt solar panel is “capable” of providing ~ 5.5 amps in full sun
- Lets say loads other than my main battery are 1.3 amps

Solar Amps = Load Amps

- The inline **meter on the solar side** of the charge controller **will display about 1.3 amps plus any battery trickle charge**
- The solar panel can not supply more amps right now, because there is nowhere for the electrons to go

Morningstar **SunGuard** 4.5 Amp PWM Charge Controller For Lead-Acid Batteries

Morningstar SunGuard 4.5 Amp PWM Charge Controller For Lead-Acid Batteries

- Designed to work with up to a 75 watt solar panel with maximum solar input of 30 volts…which is an off grid type solar panel…36 cell solar panel
- Rated to 4.5 amps input with a max short circuit rating of 5.5 amps (5 minutes)
- Does temperature compensation of -28mV/C
- Relative humidity …100%

Morningstar SunGuard 4.5 Amp PWM Charge Controller For Lead-Acid Batteries

- Self-consumption is 6mA
- Minimum operating battery voltage is 6 volts
- Designed for the 12 volt lead-acid battery
- PWM set point is 14.1 volts, will change as the temperature changes

SunGuard 4.5 Amp Solar Charge Controller

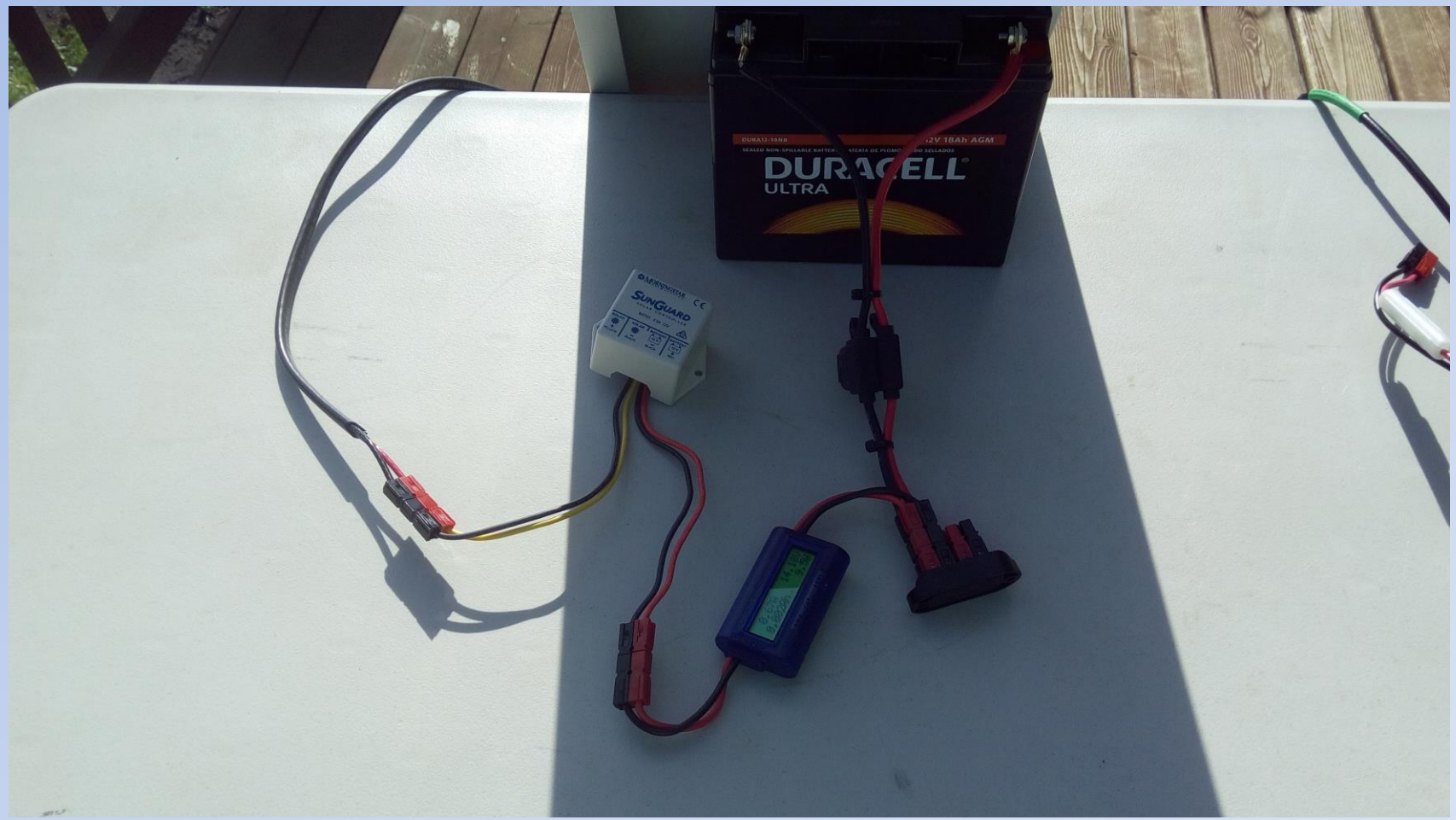
- Two sets of connection points
- No indicator lights
- No display
- Inexpensive and it works

40 Watt PV, 18Ah AGM, SunGuard Charge Controller, Distribution Block, Meters, & Radio

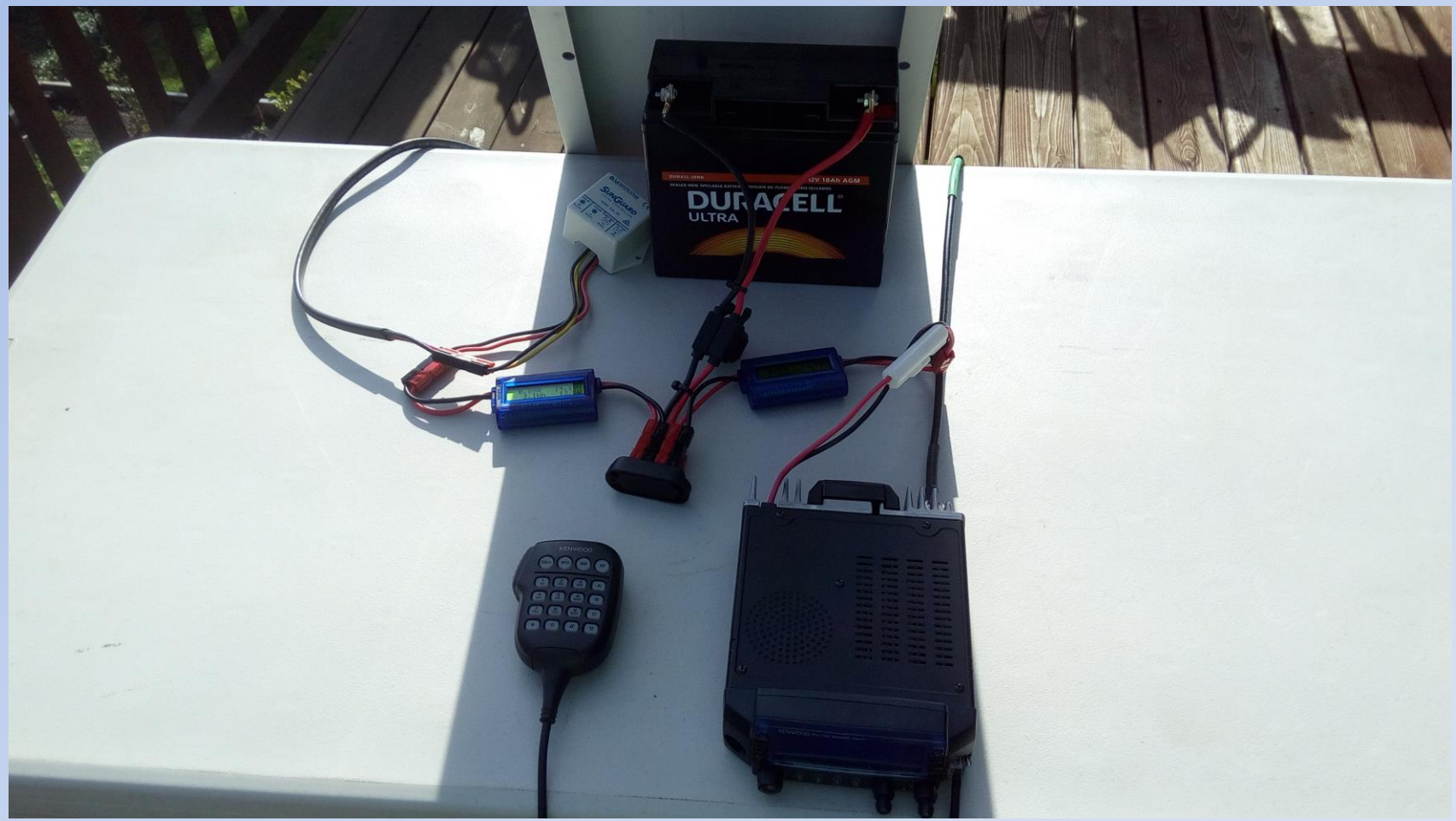
Set Up Start…Hook Up The Battery To The Distribution Block

Next Connect The Charge Controller Battery Side To The Distribution Block…Meter Added

Now Hook Up The Charge Controller Solar To The PV

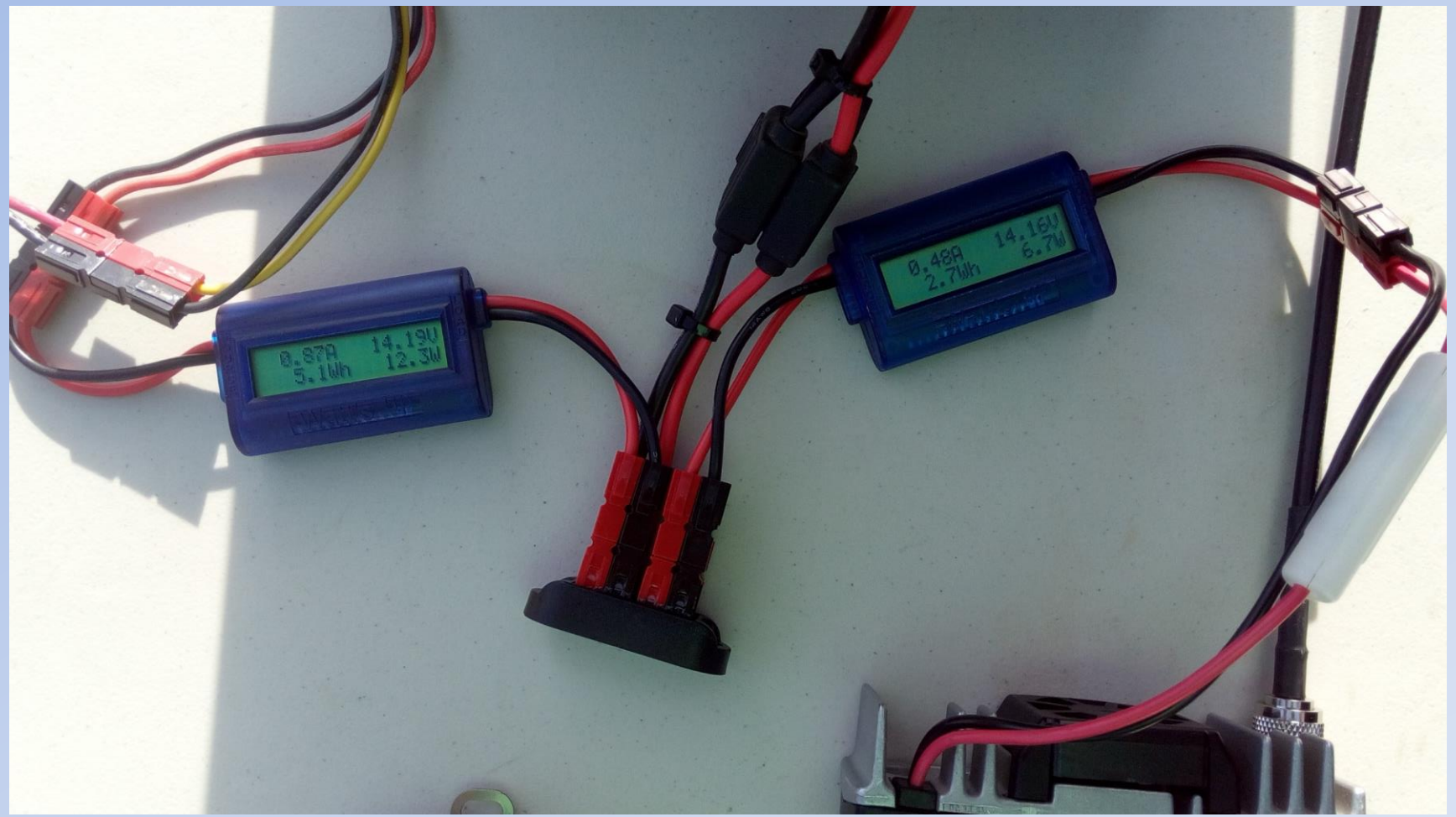


Now Connect Your Radio To The Distribution Block…Meter Was Also Added



Side View Of Everything Connected With The Older 40 Watt Solar Panel Which Works Great

Solar On The Left, Radio Receive On The Right



Radio Transmitting On Medium Power, Solar Is 1.76 Amps At 1740 On 05/09/2019

18Ah AGM Battery, 40 Watt PV, Sunguard Charge Controller And Your Radio

- Solar input was just 0.87 amps while topping up the 18Ah AGM battery and powering the radio…no where else for amps to go
- When you key up the radio, you then saw the total amount of amps the solar panel could provide to the circuit, the rest was provided by the 18Ah AGM battery
- On transmit solar provided 1.76 amps and the battery provided 2.53 amps for a total of 4.29 amps

Off Brand 5 Amp PWM Charge Controller That Comes With The Acopower 50W Foldable Solar Panel

LandStar EU (Off Brand) Solar Charge Controller

- Comes with the Acopower 50 W foldable solar panel
- PWM solar charge controller for lead-acid batteries
- Working environment temp is -35C to 55C
- Relative humidity is <=95% non condensing
- Max solar input voltage is 30 volts…36 cell PV
- Battery voltage 8v to 16v

Morningstar Sunsaver PWM Charge Controllers

- Model numbers
- SS-6-12v…rated for 6.5 amps, with no LVD
- SS-6**L**-12v…rated for 6.5 amps with LVD, the “L” stands for LVD
- SS-10-12v…rated for 10 amps
- SS-10**L**-12v…rated for 10 amps with LVD
- SS-10**L**-24v…rated for 10 amps in a 24 volt system
- SS-20**L**-12v…rated for 20 amps with LVD
- SS-20L-24v…rated for 20 amps in a 24 volt system

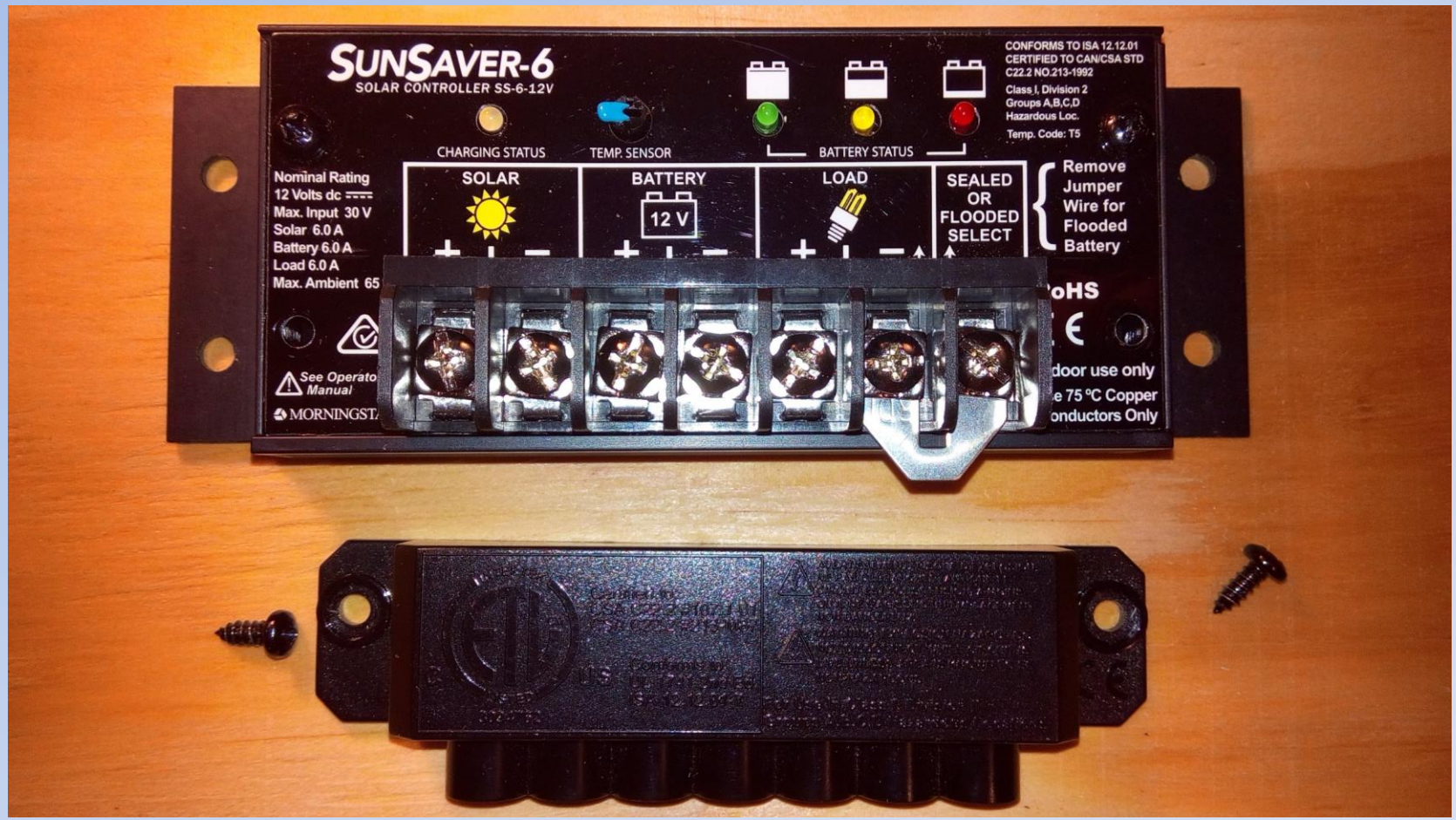
PWM Charge Controllers

- Morningstar 12v SunGuard 4.5 amp, works for up to 75 watts $33…altE Store
- Morningstar 12v SunSaver 6, great for up to 100 watts $47…altE Store
- Morningstar 12v SunSaver 20L, is great for up to 350 watts of solar $96 (LVD is 11.5 volts)…Northern Arizona Wind & Solar
- Morningstar 12v ProStar PS-30M is great for up to almost 500 watts, ProStar line used at repeater sites a lot $152…altE Store

Morningstar SunSaver Noise Comment

- The SunSaver circuit minimizes switching noise and filters all noise output to extremely low levels when the system is properly grounded. If noise is present in a telecom load, it is most likely a grounding problem in the system

Morningstar SunSaver-6 PWM Charge Controller For Lead-Acid Batteries



Morningstar SunSaver-6 PWM Solar Charge Controller…Perfect Choice For Your 100W PV

- System voltage is 12v
- PWM charge controller for FLD or SLA
- Max solar input voltage is 30 volts…36 cell PV
- Rated solar input current is 6.5 amps
- Has terminals to hook up a load, but will not turn off the load if battery voltage goes real low, no LVD

Morningstar SunSaver-6 PWM Solar Charge

- **Safety Message**…Must be located at least 3 feet from **vented batteries** or separated by a barrier to prevent contact with **explosive gases**…more of a concern with FLD
- Battery type selected by a jumper

SunSaver-6

- Jumper in place is for SLA batteries with absorption at 14.1v and float at 13.7v
- Jumper removed is for FLD batteries with absorption at 14.4v and float at 13.7v, plus equalize at 14.9v
- SLA = **S**ealed **L**ead-**A**cid
- FLD = **Fl**oo**d**ed Lead-Acid

Using The Morningstar Battery Status Indicator During Solar Charging

- How to use the **battery status indicators** during solar charging
- While charging, if battery status indicator is **solid green**, you are collecting all the current coming from your solar panel, **bulk phase**
- Once the battery status indicator starts to **flash at 1 flash/second**, you are not capturing all the power available from your solar panel, **absorption phase**

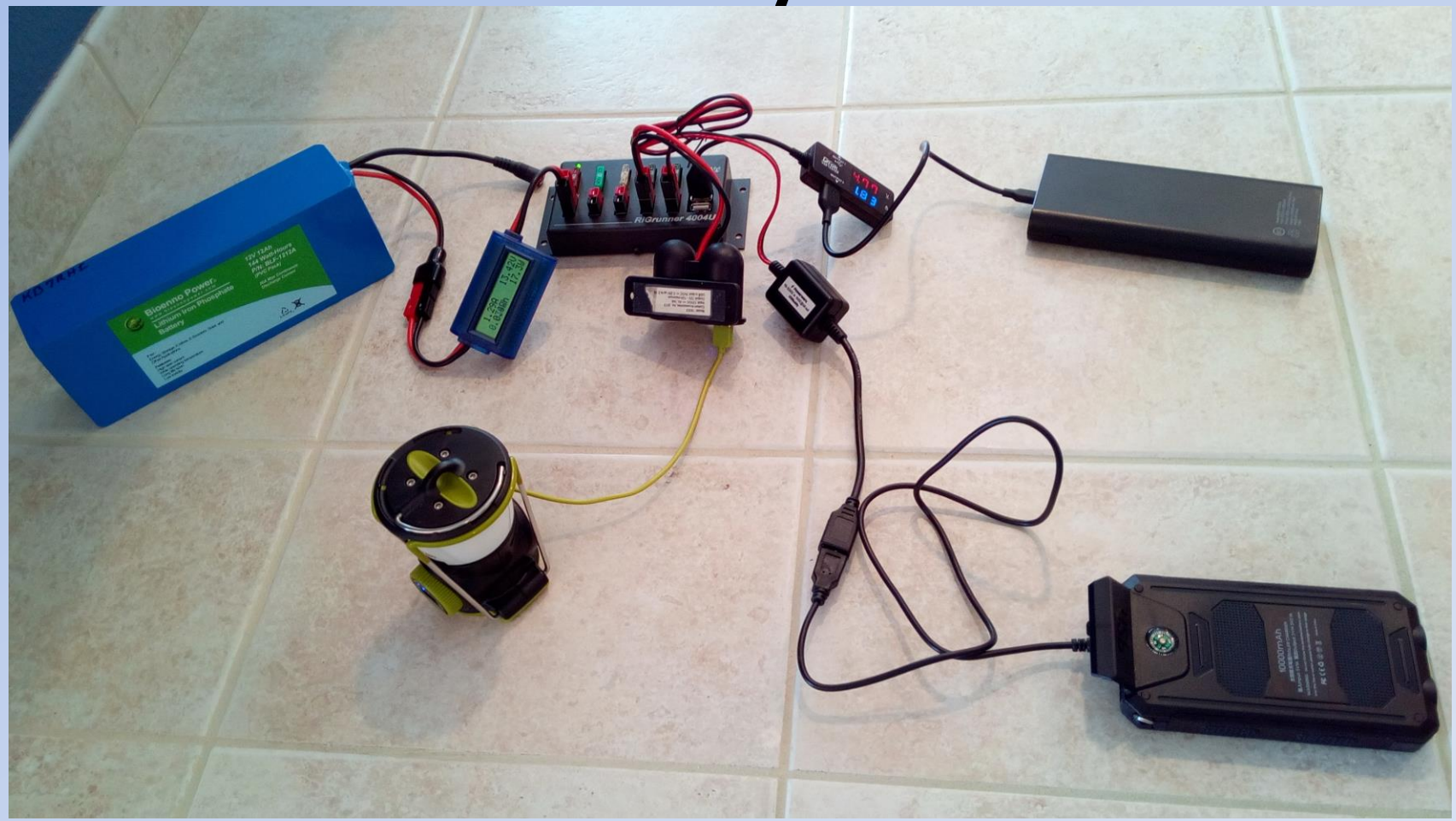
SunSaver 6 Battery Status Indicator…Note Time To Add More Load…1 Flash/Second

SOC LED	Indication	Battery Status
RED	On solid	Battery empty
RED	Flashing, 1 flash/second	Battery low
Yellow	On solid	Battery half full
Green	On solid	Battery nearly full, bulk phase
Green	**Flashing, 1 flash/second**	**Battery in absorption phase**
Green	Slow flashing, 1 flash/ 2 seconds	Battery is full, float phase
Green (Wet cells only)	Fast flashing, 2 flashes/seconds	Battery Equalization phase
None	No LEDs on	Battery missing

Charge Controller Is Going Into The Absorption Phase In The Middle Of The Day

- You are charging your AGM battery and the PWM charge controller shows it is now starting the absorption phase
- You **do not want** your **charge controller** to stay in absorption phase in the middle of the day, **unless you have nothing else to for your solar panel to charge up**
- **Time to add more load for your solar panel to charge**
- Just add USB power banks, the **battery current will taper down on its own**

WMR 4004U Charging USB Batteries 3 Ways



Absorption Phase

- It is ok for your **battery** to go into the **absorption phase**, holding the charge voltage allows that to happen naturally
- You **do not** want your **charge controller** to stay in absorption phase **during an emergency in the middle of the day**, unless there is nothing else to charge up
- While the battery is slowly accepting less amperage, that is **more amperage available** to charge USB power banks or other devices

Operating In An Emergency

- You have an AGM 12 volt battery for radio comms and USB power banks to charge
- Start by **bulk charging your AGM battery first** thing in the morning
- When the charge controller reaches the absorption phase, **note the absorption voltage**(varies according to temperature) and then add USB power banks to charge

Operating In An Emergency

- As you add USB batteries, watch to keep your charge controller battery voltage just below the absorption voltage you noted earlier
- Your “total load” will **only accept so many amps** when held at a constant voltage

Operating In An Emergency

- **If the "total load" current acceptance drops below the amperage available from the solar panel**
- Then solar panel voltage will rise and solar amps will fall
- It will **appear** that the charge controller is throttling back the power from your solar panel, but in actuality, there is no where for the solar amps to go
- Add more USB batteries, give the electrons somewhere to go

Disaster Situation Example

- You have stood up an Ad Hoc field station and are keeping the 12v battery charged with solar power
- You have **excess power** that you want to store
- People around you are helping all day in the field, then need their phone charged at the end of the day
- Their phone is a camera, GPS, calculator, address book, etc
- If you **charge some USB power banks during the day**, then people can charge their phones overnight

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Disaster Situation Example

- USB Power Bank loads
- 20Ah 5v USB power bank = 0.8 amps at 12v
- X-Dragon 5v 10Ah power bank = 0.53 amps at 12v
- Android phone = 0.74 amps at 12v
- Above readings taken with 12v inline meter
- How to charge the USB devices

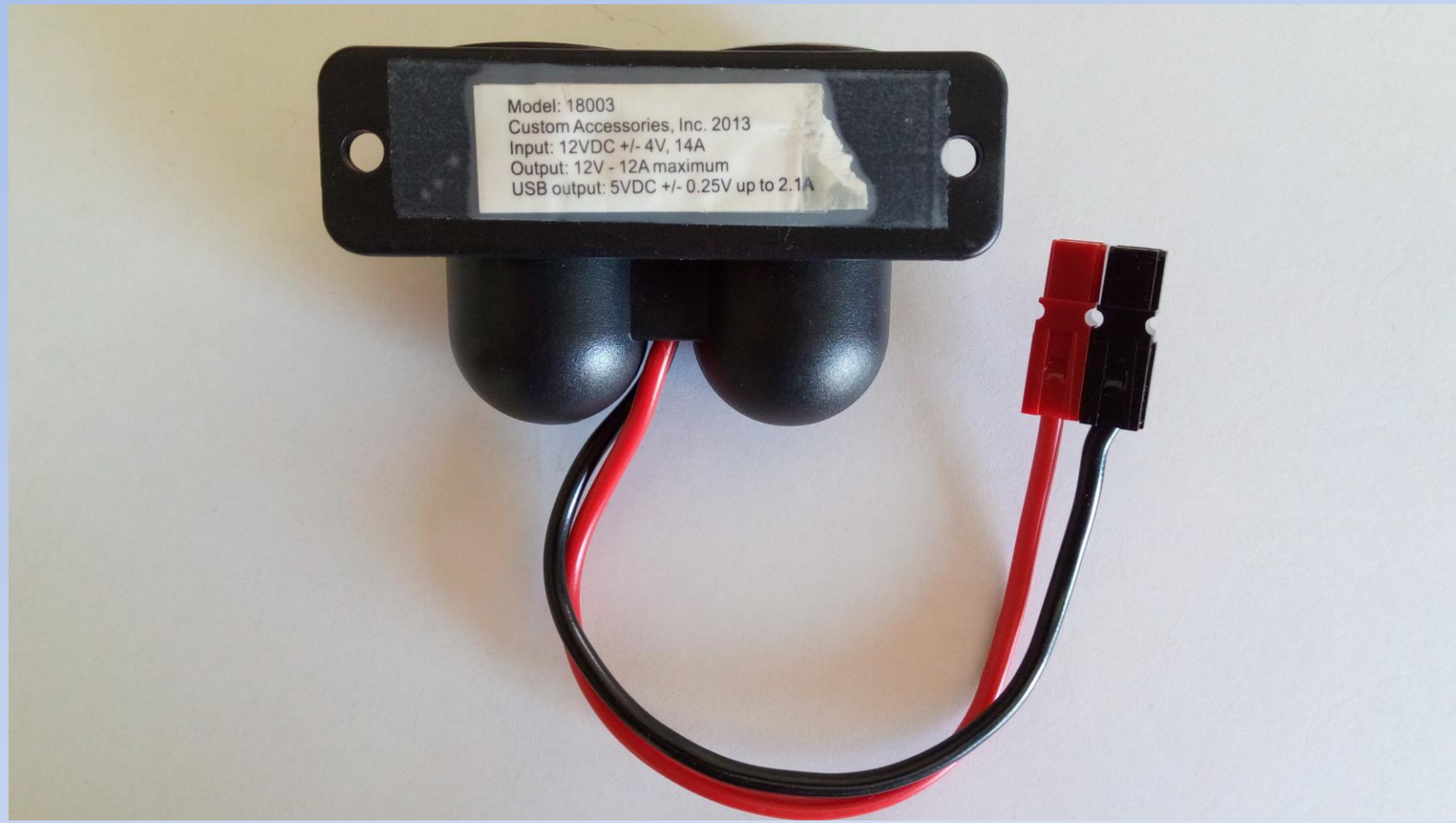
Charge Your 12v Battery, Plus Charge 5v USB Devices/Power Banks

- Charging 5 volt power banks or 5 volt USB devices requires using a **power converter** to go from 12v to 5v USB
- Some power converter choices are…
- You have the **PWRbox**
- You have **automotive 12 volt to 5 volt power converters**
- You have the **West Mountain Radio RIGrunner 4004U**

PWRbox With An LFP Battery, Has Two USB Ports Built Into The Lid

12 Volt Automotive Power Port And Two 5 Volt USB Charging Ports

Automotive Power Port And USB Ports Specs



West Mountain Radio RIGrunner 4004U Distribution Block With USB Charging Ports

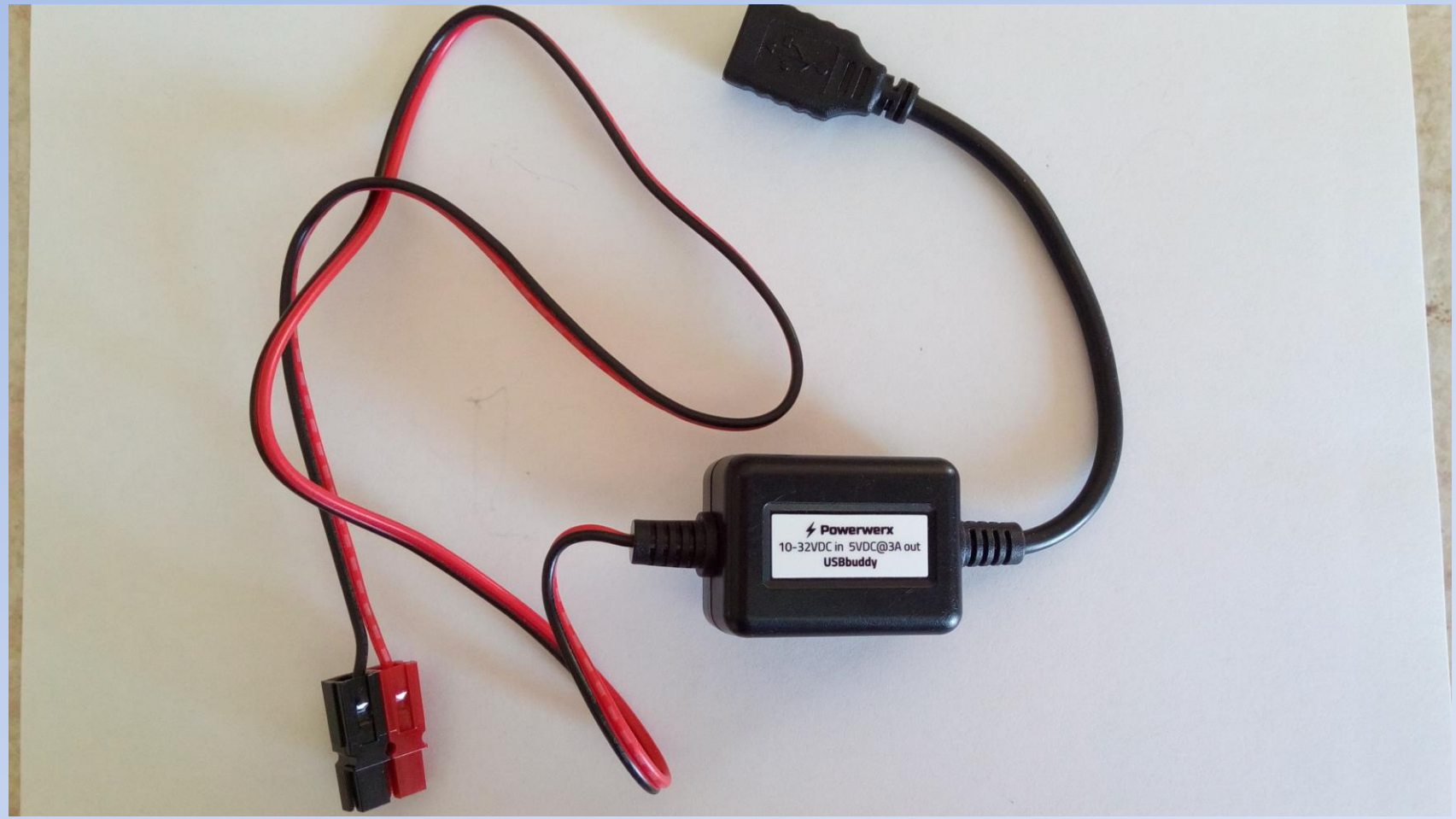
12 Volt To 5 Volt Voltage Converter Note

- Both the automotive converter and the West Mountain Radio 4004U **cannot be directly connected alone to a solar panel** and provide 5 volts USB power
- The **solar input voltage** exceeds the input voltage for both of these devices
- **Connect your battery first to the distribution block**
- Then connect the voltage converter to the distribution block

Voltage Converter That Can Be Directly Connected To A Solar Panel (36 Cell)

- **USB Power Buddy** by Powerwerx can be directly connected to a 36 cell solar panel, off grid type
- **USB Power Buddy** input voltage is 10-32 volts
- **USB Power Buddy** output voltage is 5 Volts at 3 amps
- A single solar panel can be used to charge a USB power bank or USB device

12 Volt To 5 Volts USB Power Converter That Can Be Directly Connected To A 36 Cell PV



Morningstar SunSaver-20L PWM Charge Controller For Lead-Acid Batteries

SunSaver 20L

- System voltage is 12 volts
- Rated for solar input of 20 amps or about 350 watts of solar
- Does have a third set of terminals that will monitor voltage on a load and disconnect that load at 11.5 volts and will reconnect the load at 12.6 volts
- Solar charge controller load terminals are **not designed for inverters** or any load that has lots of amperage swings

55Ah AGM Lead-Acid Battery Charging With Solar Power

Ideal charge current is C/10 = 5.5 amps or one 100 watt solar panel

Fast charge current is C/5 = 11 amps or two 100 watt solar panels…this charging level may decrease the life of your battery some

0.25C is the **max emergency charge** current for the 55Ah AGM battery or 13.75 amps which is about 250 watts of solar power

Parallel Two 55Ah AGM Batteries With Two 100 Watt Solar Panels

- Batteries that are used in **parallel need to be the same size and SOC**(State Of Charge) when put into service in parallel
- Each 55Ah battery can be connected with the inline fuse to a distribution block, start with both fully charged
- Two 100 watt solar panels in parallel
- Using the **SunSaver-20L** solar charge controller you now have **110Ah of battery capacity and 200 watts of solar**

Bioenno Power SC-4830JUD 30 Amp **PWM** Charge Controller For FLD, SLA, GEL, And **LFP** Batteries

Bioenno Power SC-4830JUD 30 Amp PWM Charge Controller For FLD, SLA, GEL, And Li Batteries

- No experience with RF noise being heard
- Max solar input voltage = <50v
- Max solar current = 30 amps
- Chemistry is LFP, SLA(AGM), GEL, and FLD
- Operating temp is -31F to 131F (-30C to 50C)
- SLA(Sealed Lead Acid) = AGM and GEL, but GEL chemistry needed separate charge parameters

MPPT Charge Controllers

- MPPT charge controllers are the **most efficient** charge controllers, and use a built in transformer
- MPPT charge controllers due to their basic design **can introduce some RF noise** to your radio
- Adjusting solar panel voltage **down** to battery voltage is a **buck converter**
- Adjusting solar panel voltage **up** to battery voltage is a **boost converter**

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MPPT Charge Controllers

- Most MPPT charge controllers transform the **higher solar panel voltage down** to the **battery voltage**, at the same time **increasing the solar current** to provide **more charge to your battery**, the buck converter
- DC power is changed to AC power
- The AC power is then run through a transformer to adjust the voltage to the battery voltage
- The AC power is then rectified back into DC power

MPPT Charge Controllers

- With transformers, **power in = power out**
- Transformers are very efficient and with MPPT charge controllers you will get **more power** from a solar panel during **bulk phase charging**
- With MPPT charge controllers, colder weather is best, because the colder a solar panel, the greater the power output
- Not as much benefit when in hot conditions, the difference from the solar panel voltage to the battery voltage is not as great

MPPT 100 Watt Solar Panel Power Transformation In Full Sun

- **High battery voltage**
- By the **ratio** that you reduce the solar panel voltage, you will increase your solar panel amperage when passing **power through a transformer**…power in = power out
- Solar panel voltage is 17.8 v/ battery voltage is 14v = 1.27:1 ratio that you will drop the voltage
- You will increase the amps by the same ratio
- 100 watt solar panel **amps of 5.5** x 1.27 ratio = **7 amps after going through the MPPT charge controller**

MPPT 100 Watt Solar Panel Power Transformation In Full Sun

- **Low battery voltage**
- **Solar panel** voltage of 17.8v /**battery voltage** of 11.7v = 1.5:1 ratio, (1.5 to 1)
- 1.5 ratio x 5.5 amps = **8.25 amps after going through the MPPT charge controller**
- 11.7 volts x 8.25 amps = 96.5 watts (Low voltage)
- 14 volts x 7 amps = 98 watts (High voltage)

Compare To PWM With 100 Watt Panel

- 100 watt solar panel full sun output of 5.5 amps
- Volts x Amps = Watts
- During the bulk charging phase with PWM
- The solar panel is capable of providing 17.8 volts, but solar panel voltage **is pulled down** to the battery voltage
- **Low battery voltage** 11.7v x 5.5 amps = 64 watts
- **High battery voltage** 14v x 5.5 amps = 77 watts
- Versus 96.5 watts to 98 watts with MPPT

MPPT Charge Controllers For Lead-Acid Batteries

- **MPPT** charge controllers have an **advantage** during **the bulk charging stage only**
- **There is no MPPT charging during the absorption stage**…the battery is now **slowly topping off** and the solar current being drawn by the battery is tapering down
- PWM and MPPT act **the same during the absorption stage with lead-acid batteries**, they are both holding the battery voltage at the threshold just below the gassing point

Charge Controllers For LFP Batteries

- LFP batteries need a different type of charge controller than what is used for lead-acid batteries
- There is no absorption phase, (no sulfation concern)
- The charge controller does two stages
- **CC = Constant Current** is the first stage
- **CV = Constant Voltage** is the second stage
- **Cell balancing happens at the top end of charging**

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Bioenno Power SC-1220JU 20 Amp MPPT 20 Charge Controller For **LFP Batteries**, **RF Noisy**

Bioenno Power SC-1220JU 20 Amp MPPT Charge Controller For LFP Batteries

- This is a classic MPPT charge controller designed to **charge LFP batteries**, but it produces **RF noise**
- System voltage is 12v/24v
- Max solar current is 20 amps
- Max solar input voltage is <70v, that is nice
- MPPT voltage range is 12-70v

MPPT 20

- CV is set at 14.4v
- Operating temp is -10C to 50C or 14F to 122F
- Not a good choice for radio communications
- **Good choice for attaching to a grid tie panel** and charging a larger LFP battery due to being able to handle 70v of solar input voltage

MPPT Charge Controllers That Are Designed To Be More RF Quiet

- Genasun branded models
- DIY Solar 4 U “Apollo” 16 amp and “Sol” (buck/boost) 20 amp
- These are two brands that I know of, there is probably others

Genasun GV-10 MPPT Charge Controller For Lithium Iron Phosphate (**LFP**) Batteries

Genasun GV-10 MPPT Charge Controller

- This model is for LFP batteries only, not for lead-acid batteries, other models available for lead-acid
- Is an MPPT charge controller that is designed to be **more RF quiet**, not RF silent, but still more RF quiet
- **Max solar** panel size if **140 watts**
- Solar input voltage range is 0-34 volts, recommend max **STC Voc of 27 volts** for peak voltage
- Operating temp range is -40C to 85C

Genasun GV-10 MPPT Charge Controller

- Max current is 10.5 amps
- Solar and battery terminals accept up to 12 AWG wire
- 0.125mA power consumption

GV-10 MPPT Charge Controller Sample Set Up

- **30Ah LFP battery** can accept 0.3C in charge current = 9 amps
- **120 watt foldable solar panel** can provide 9 amps with an MPPT charge controller in full sun, on a cooler day
- **Genasun MPPT** charge controller can accept up to 10.5 amps current and the 120 watts of solar has a Voc of less than 34 volts

PWRbox With 30Ah LFP Battery

The Bioenno Power BLF-1230-A Battery Is A Good Choice For The Genasun GV-10

Bioenno Power BLF 1230-A Battery With Velcro On The Bottom

PWRbox Empty With Velcro In The Bottom

PWRbox With The 30Ah LFP Battery

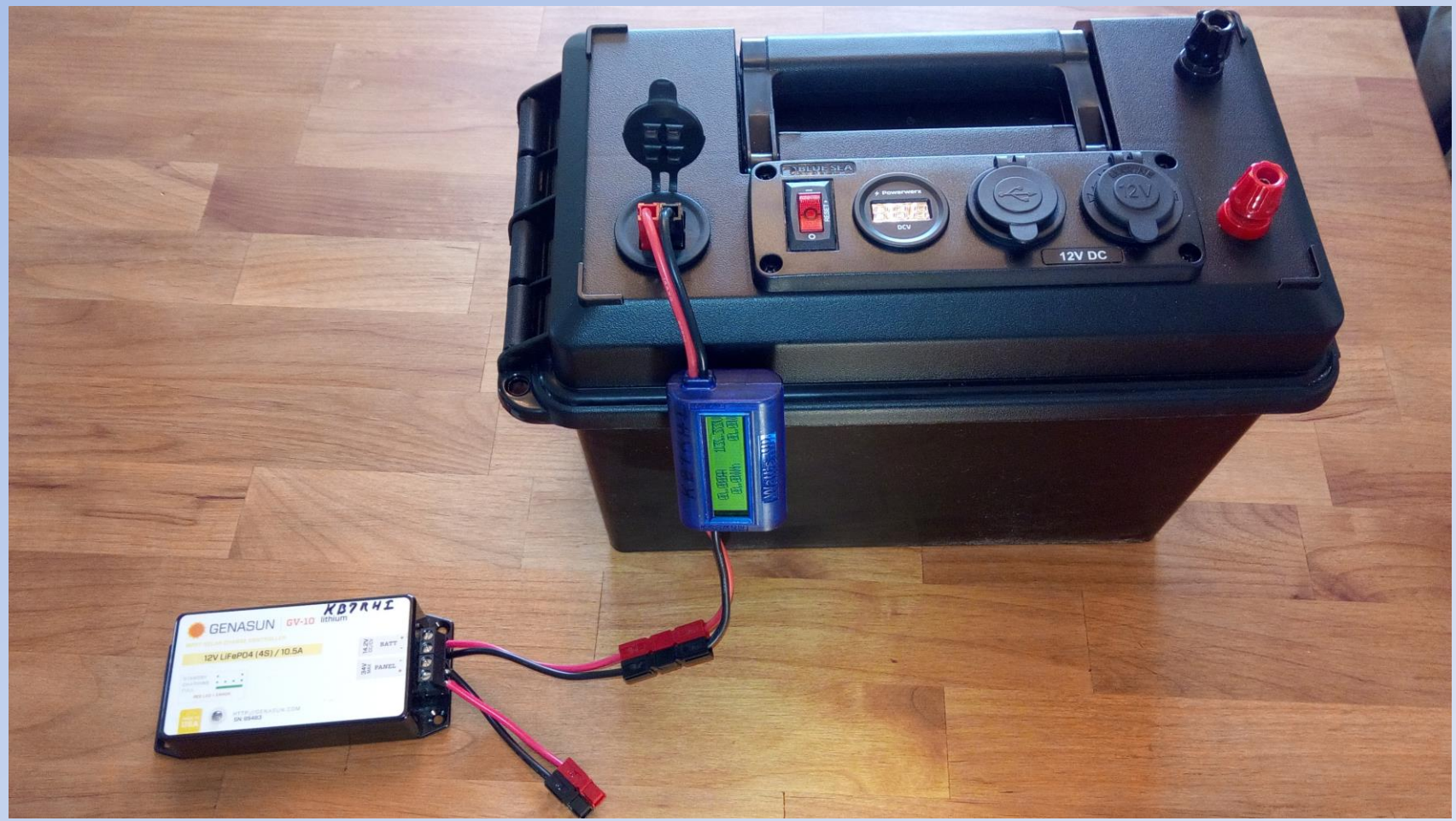
PWRbox With Solar Power Items Displayed

PWRbox Solar Power Items

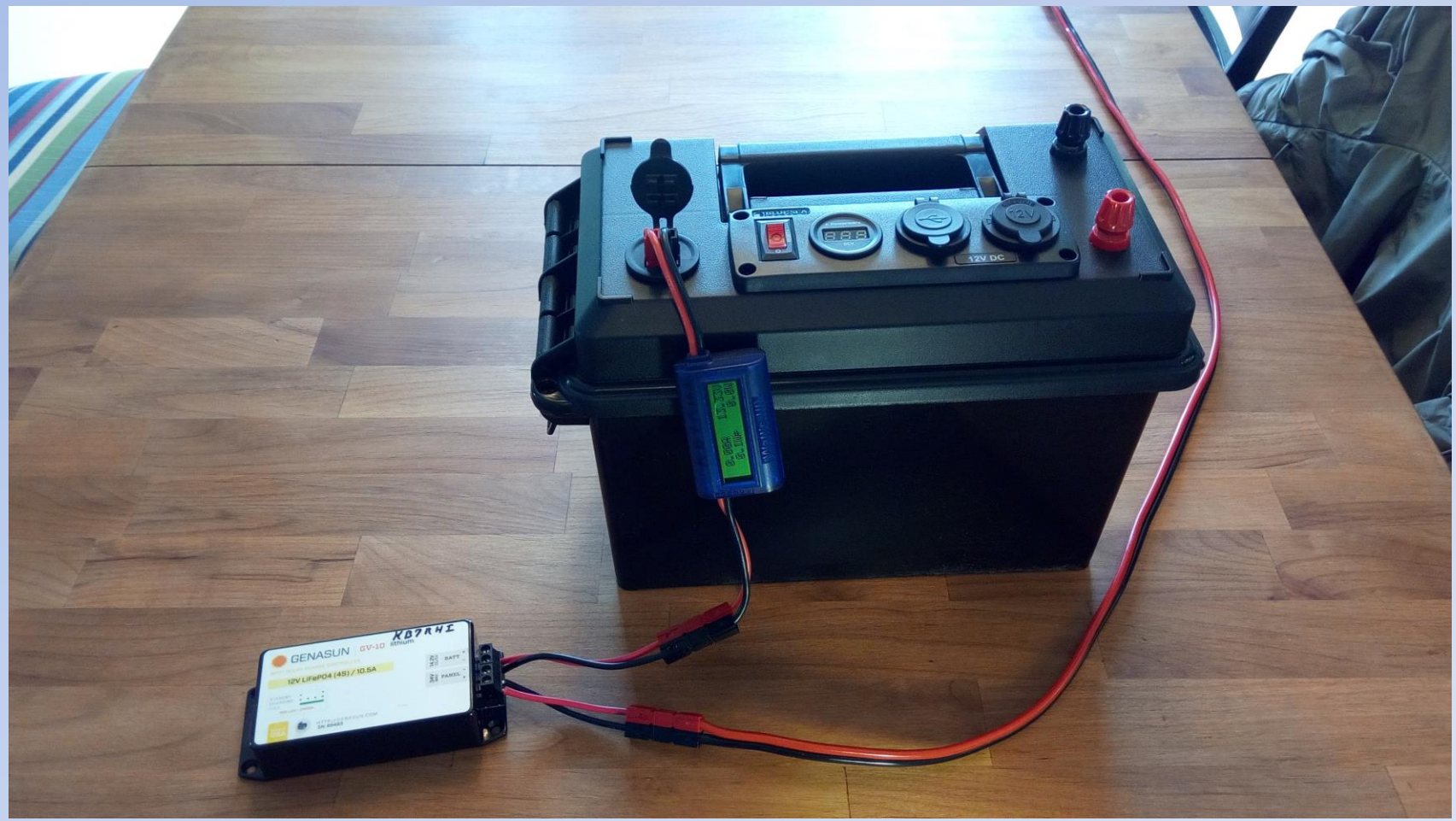
- 30 feet of 10AWG wire with PP45 connectors on each end
- Genasun GV-10 charge controller that is only for LFP batteries
- Two RC Electronics inline power meters

PWRbox With Solar Power Items Loaded

Solar Charge Controller Hooked Up With Added Inline Meter

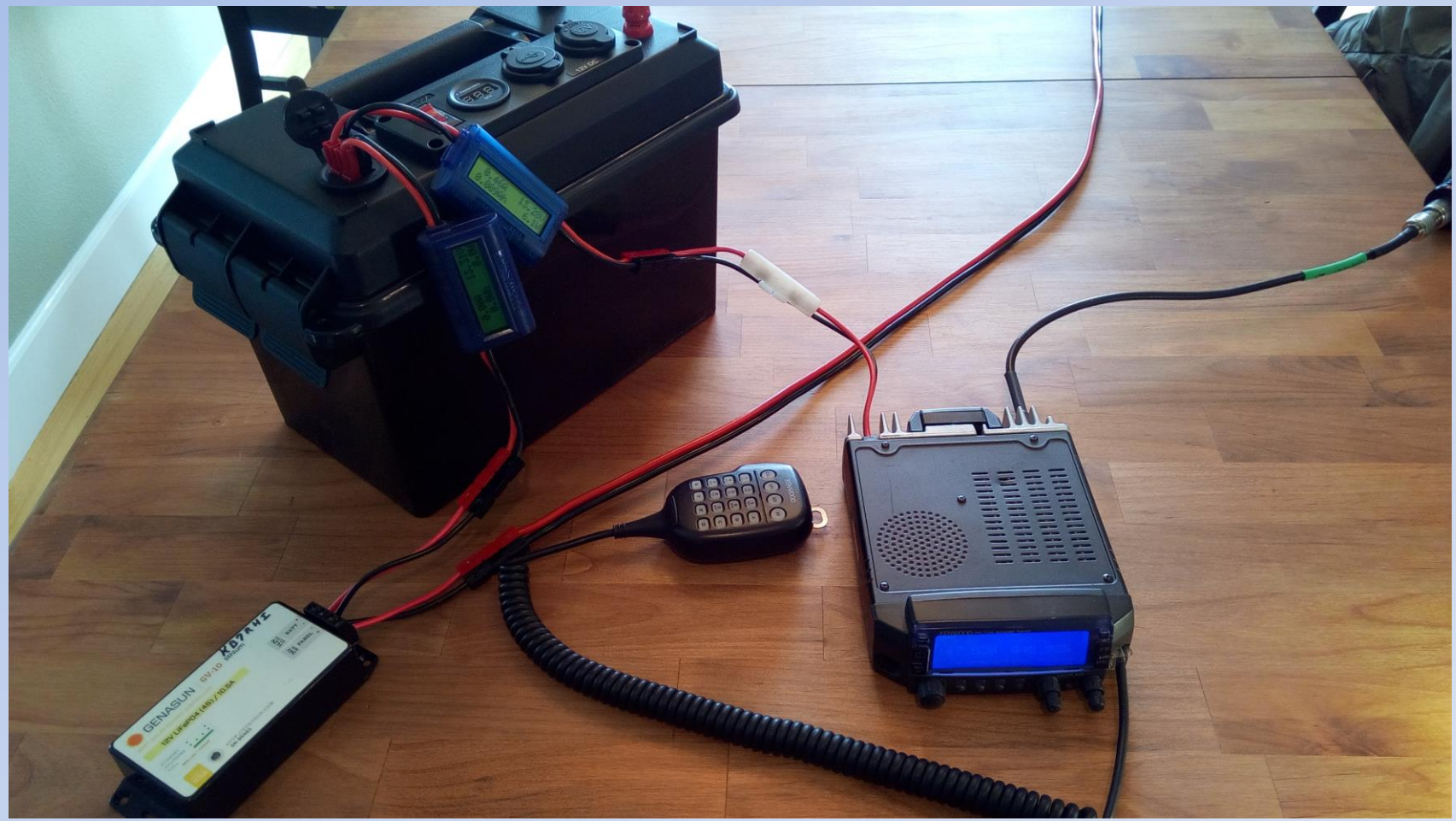


PWRbox With Solar Charge Controller Now Hooked Up To The Solar Panel Power Cable

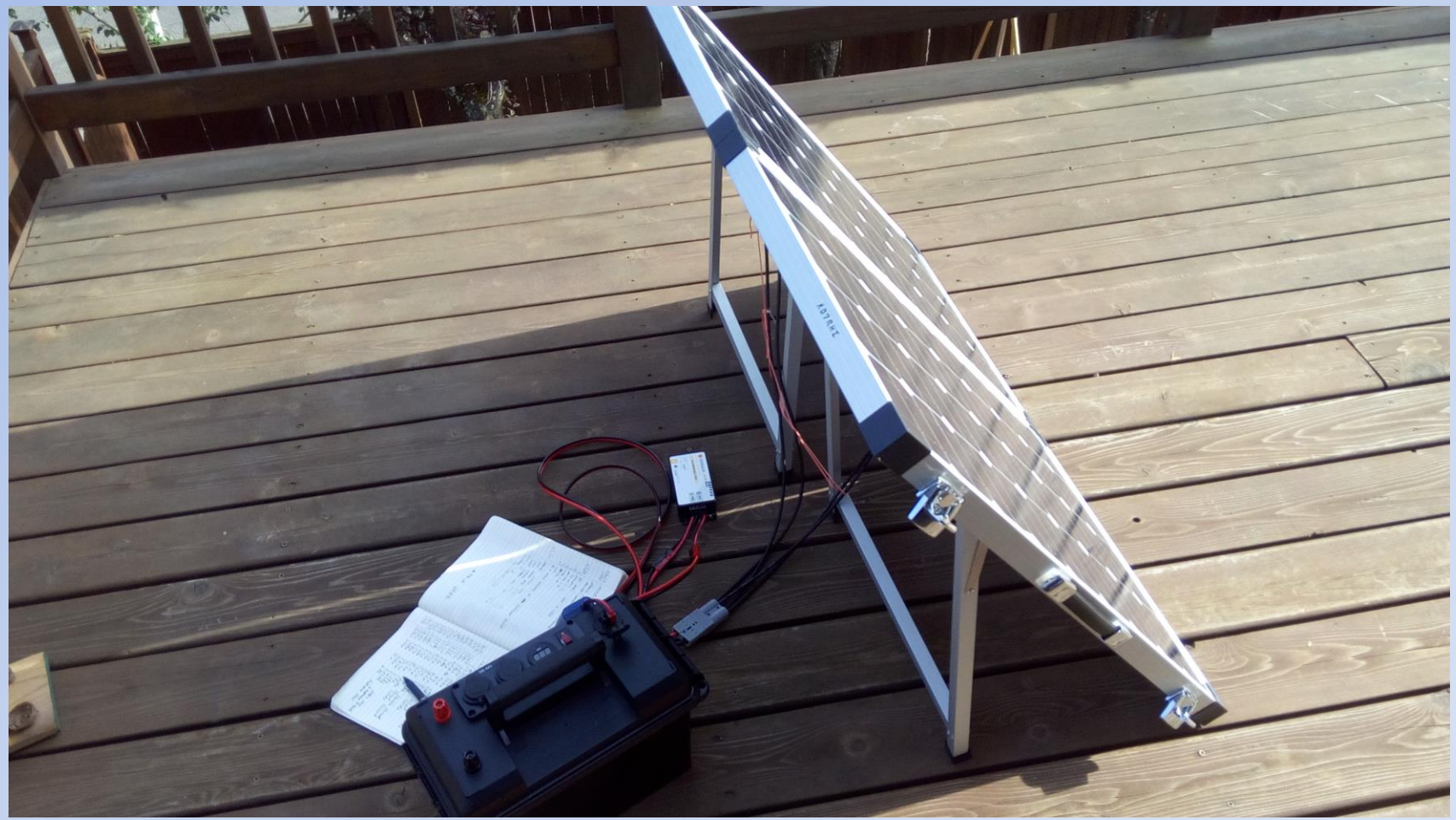


Connect The Solar Power Cable To The 120 Watt Foldable Solar Panel

PWRbox With Solar Charge Controller And Now Radio Connected



120 Watt Foldable Solar Panel, Genasun GV-10, And 30Ah LFP Battery Top Off Test



30Ah LFP Battery Top Off Test, Note The Hazy Sky Conditions

30Ah LFP Battery Top Off Test

- Nearly full 30Ah LFP battery used to power a gateway station with several modems and radios over about 3 hours…6.4Ah removed from the battery
- 120 Watt solar panel set up on the deck with some hazy sky conditions at 1630 on May 12, 2019

30Ah LFP Battery Top Off Test

- Genasun GV-10 charge controller used
- Wanted to observe voltage and current as the battery came to a full charge
- At rest battery voltage was 13.23 volts

30Ah LFP Battery Top Off Test With Sky Conditions That Became More Hazy

Time	LFP Voltage	LFP Amps	Amp-Hours	Indicator Light
1630	13.59	6.2		
1646	13.74	7.0	1.65	
1703	13.71	6.57	3.35	
1716	13.7	6.2	4.69	
1723	**13.68**	**5.57**	5.3	
1727	**13.62**	**4.38** more haze	5.67	
1731	13.57	3.58	5.94	
1736	13.62	4.25 haze up/down	6.2	
1740	13.58	3.26 more haze	6.46	
1741	13.56	2.84	6.5	
1745	13.56	2.95	6.7	
1750	**13.56**	**2.6 hazy sky**	6.95	

Sky Conditions Became Slowly More Hazy, **Then Became Brighter**

Time	LFP Voltage	LFP Amps…Sky	Amp Hours	Indicator
1755	**13.62**	**3.36** haze	7.16	**Fast Flashing**
1800	**14.04**	**6.38 brighter now**	7.75	**Solid**
1801	14.08	5.26 dropping now	7.8	Solid
1802	14.10	4.09	7.85	Solid
1803	14.16	2.25		Solid
1804	14.17	1.27	7.9	Solid
1805	14.19	0.62		Solid
1806	14.20	0.35		Solid
1807	14.20	0 then 0.23		Solid
1808	14.21	0 then 0.2		Solid

DIY Solar 4 U Has Two MPPT Charge Controllers

- Company owner/engineer is an amateur radio operator who wanted to build a quieter MPPT charge controller
- "**Apollo**" MPPT charge controller is a **16 amp model**
- Limited to 280 watts STC of solar
- System voltage is 12 or 24 volts (battery bank)
- Max solar input voltage is 50 volts

DIY Solar 4 U Has Two MPPT Charge Controllers

- "**Sol**" MPPT charge controller is a **20 amp model**
- This model is a **buck boost** controller
- Max solar input voltage is 54v
- MPPT range is 10 to 50 volts
- Max solar panel rating is **350 watts STC**
- Will work with SLA, AGM, and LFP batteries

Light Weight Charge Controllers For Backpack Use…Genasun

Backpack With High Power

- Acopower 50 watt foldable solar panel
- Genasun GV-5 MPPT solar charge controller
- RC Electronics inline 12 volt meter
- Your radio and portable antenna
- Distribution block and power cables
- Bioenno Power 12Ah LFP Battery
- Add a second 50 watt foldable solar panel as needed

Acopower 50 Watt Foldable Solar Panel In The Sun


ACOPOWER

Bioenno Power ML2430 30 Amp MPPT Charge Controller For FLD, SLA, Gel, And Li Batteries

ML2430 Charge Controller

- System voltage is 12v, 24v
- Max solar input voltage = **100v at 25C** and **90v at -25C**
- Rated charging amps = **30 amps**
- Rated load controller current = **20 amps**
- **Max PV at 12v = 400 watts**
- Operating temp **-35C to 45C**
- Does produce **some MPPT hash**

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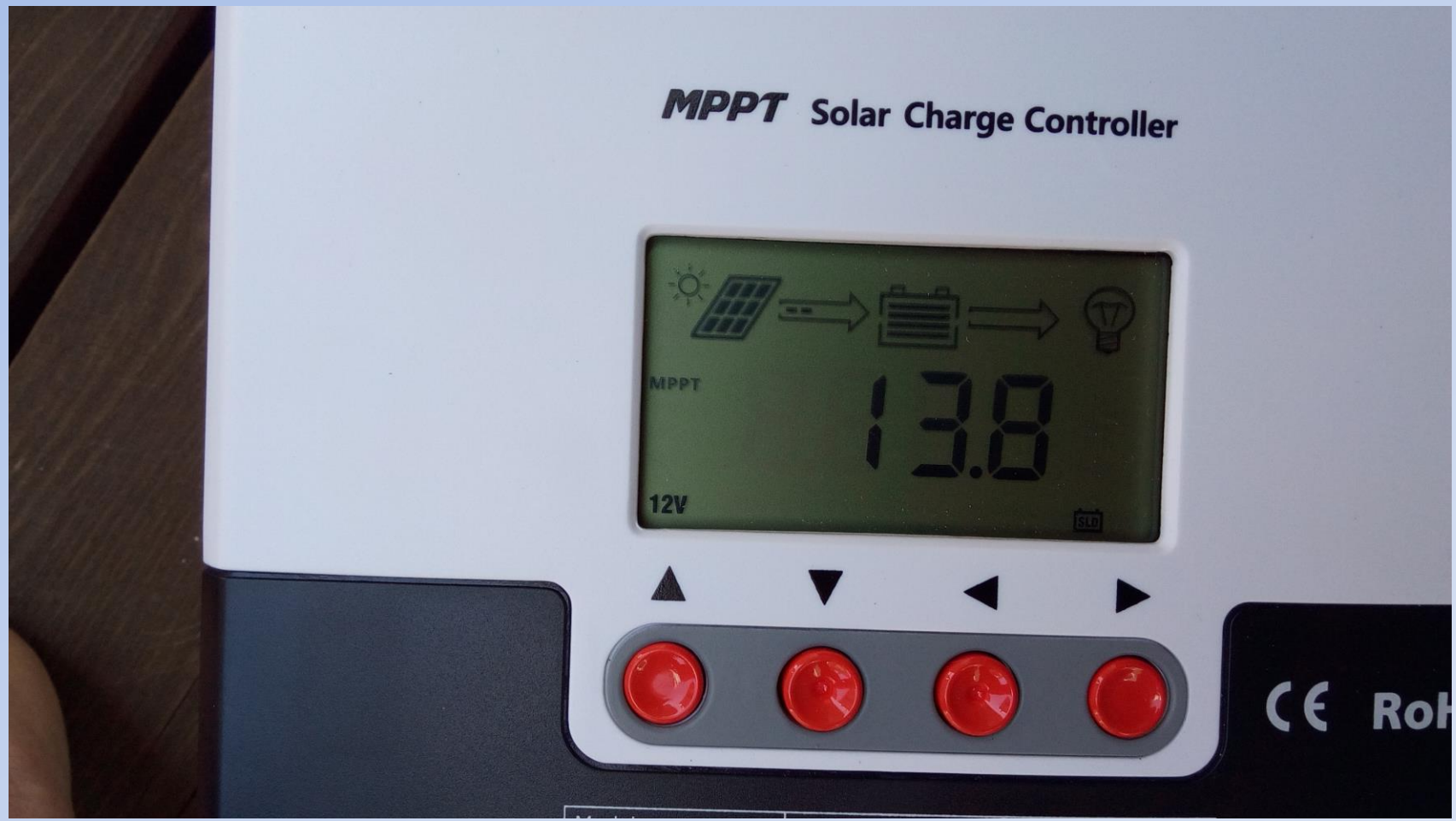
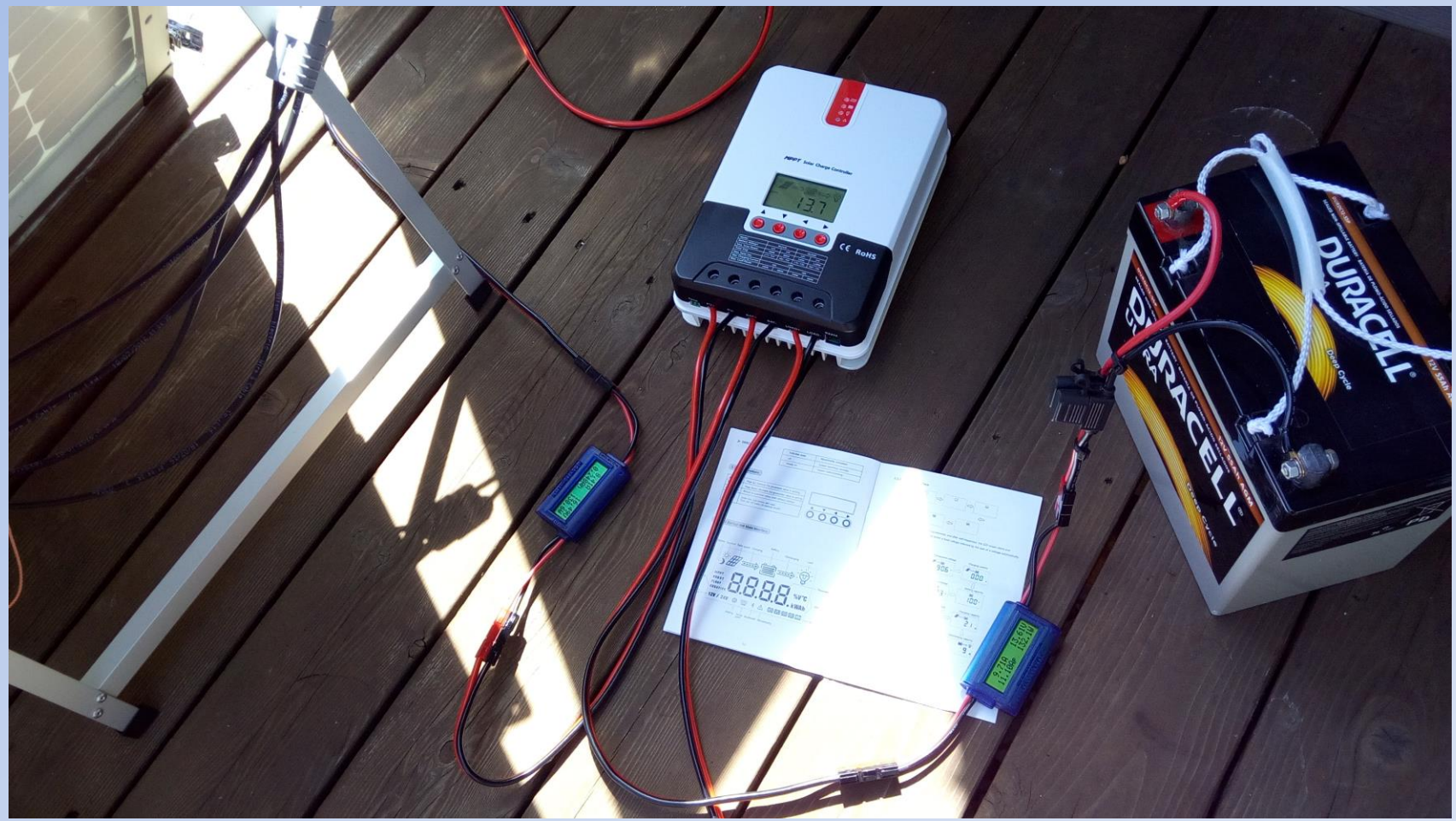
ML2430 Charging An AGM Battery In “MPPT” Mode…BULK MODE

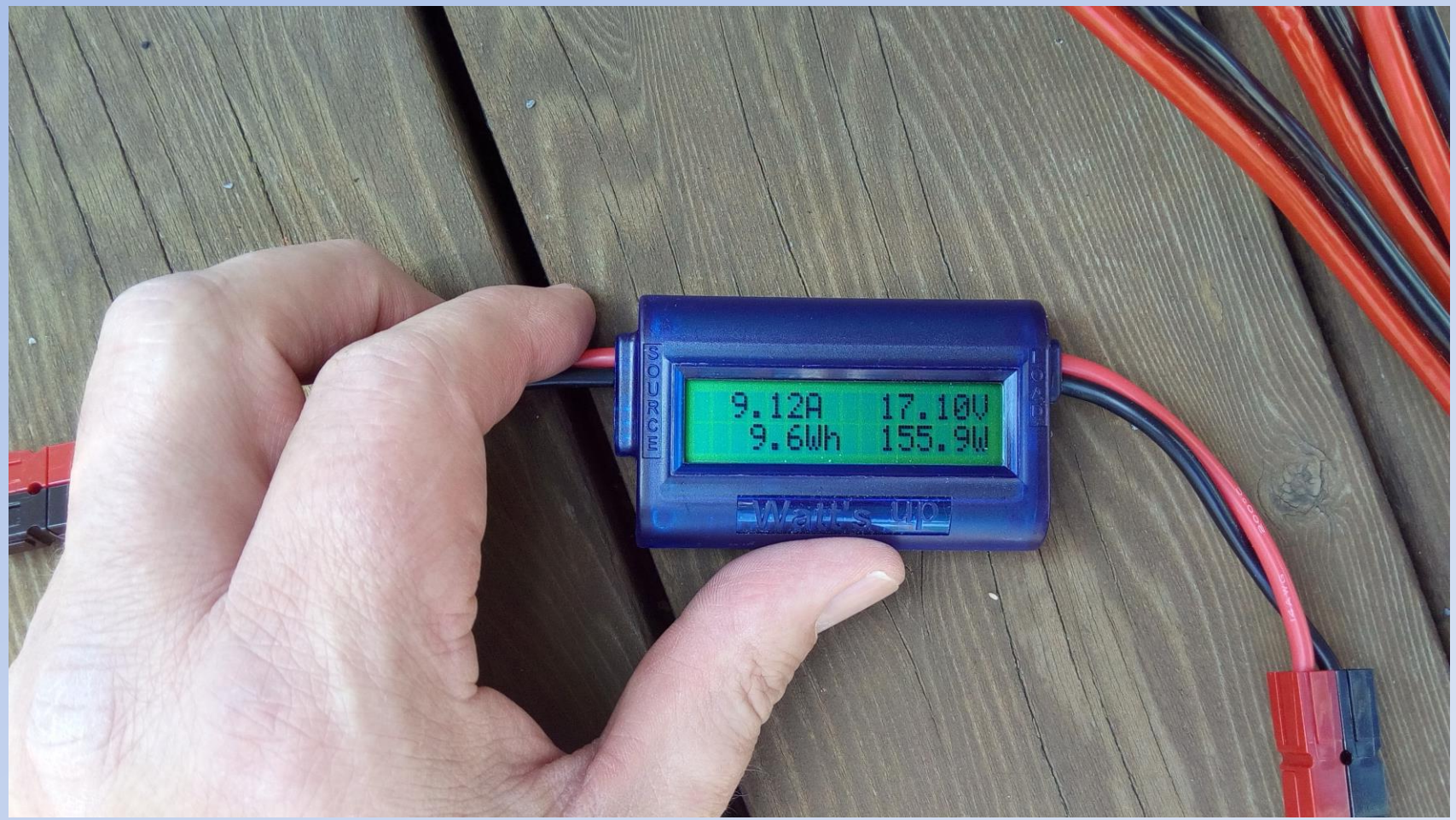


ML2430 Charging An AGM Battery In “BOOST "Mode…ABSORPTION MODE

ML2430 MPPT Charge Controller With Solar Panel Meter And Battery Meter Inline



Afternoon ML2430 Solar Panel Meter Reading, Around 74 F



Afternoon ML2430 Battery Side Meter Reading…Around 74 F

MPPT Voltage Differential Test

- **Input voltage** on the **solar panel side** of an MPPT charge controller, versus the output voltage on the battery side
- Was not ideal sun conditions during this test, but real life conditions
- The higher the solar voltage, the more power transformation that can occur, Renogy PV was not in full sun long enough to heat up all the way, so voltage was higher
- Battery voltage is well under 14 volts, so you know the MPPT charge controller is in bulk mode

Panels In Afternoon Sun(1630 On May 23) Using ML2430 MPPT Charge Controller To 55Ah AGM

Solar Panel	Solar Panel Inline Meter Amps	Solar Panel Inline Meter Voltage	Battery Inline Meter Amps/% increase	Battery Inline Meter Voltage
50W Acopower Foldable	1.77 amps	15.62v	2.13 amps 20%	12.89v
100W Renogy **Cooler panel**	4.9 amps	17.1v	6.3 amps 28%	13.25v
120W Bioenno Power Foldable	6.15 amps	16.09v	7.37 amps 20%	13.18v

ML2430 MPPT Charge Controller Noise Test

- ML2430 charge controller in MPPT and Boost mode, no noise noted on 2 meters and 440Mhz
- ML 2430 does make some noise on the HF band
- 80 Meter test result noted in the next chart

ML2430 MPPT Charge Controller Noise On 80 Meters, 4Khz Segments About Every 31Khz

Frequency	Noise Heard/Khz	Frequency	Noise Heard
3600-3609Khz	No 9Khz	3609-3612Khz	Yes 3Khz
3612-3644Khz	No 32Khz	3644-3648Khz	Yes 4Khz
3648-3678Khz	No 30Khz	3678-3682Khz	Yes 4Khz
3682-3714Khz	No 32Khz	3714-3718Khz	Yes 4Khz
3718-3749Khz	No 31Khz	3749-3753Khz	Yes 4Khz
3753-3784Khz	No 31Khz	3784-3788Khz	Yes 4Khz
3788-3819Khz	No 31Khz	3819-3823Khz	Yes 4Khz
3823-3853Khz	No 30Khz	3853-3857Khz	Yes 4Khz
3857-3889Khz	No 32Khz	3889-3893Khz	Yes 4Khz
3893-3924Khz	No 31Khz	3924-3928Khz	Yes 4Khz
3928-3959Khz	No 31Khz	3959-3963Khz	Yes 4Khz
3963-4000Khz	No 37Khz		

West Mountain Radio Epic PWRgate

West Mountain Radio Epic PWRgate

- 12 volt **backup power system** rated for up to **40 amps** from a **power supply or battery**
- Uses Anderson PP connectors
- Solar = **solar panel only**, input limited to **10 amps** and **30v solar Voc** with built in MPPT charge controller
- Would work well with a 160 watt Renogy solar panel
- Renogy 160 watt panel Imp = 7.92 amps (Max Operating Power)

West Mountain Radio Epic PWRgate

- Power supply = max is 40 amps
- Out(Load) max is 40 amps
- Battery is AGM, GEL, and **LFP**
- Supports smart charging of your battery up to 10 amps
- Solar input is designed for an off-grid 36 cell solar panel…Voc = 30 volts

Keep Your Ham Shack And Repeater Site On The Air

- The WMR Epic PWRgate can work well in the ham shack or repeater site
- Battery and power supply are isolated
- Power supply fails, power switches over to the battery
- If no power supply current, solar can charge the battery
- Solar will go to the load, and can charge the battery

Grid-Tie Panel Use During A Disaster

- Disaster happens and people are looking for DC power sources and batteries for energy storage, the grid is down for awhile…maybe weeks
- Up on roofs are grid-tie solar panels
- Around your neighborhood there is cars and trucks that still have batteries
- Could you hook up a grid-tie solar panel to a car battery and provide emergency power?

Sunbridge Solar In Washougal, Washington Grid-Tie Solar Panel Test

- **Sunbridge Solar** provided a grid-tie solar panel for testing the hook up of a grid-tie solar panel to a lead-acid battery
- 310 watt Silfab solar panel used for the test
- **Thick clouds** in the morning, amps = 1.13 amps
- AGM battery showed 12.55v
- The inline meter showed I was getting about 14 watts from a 310 watt solar panel

Sunbridge Solar In Washougal, Washington Grid-Tie Solar Panel Test

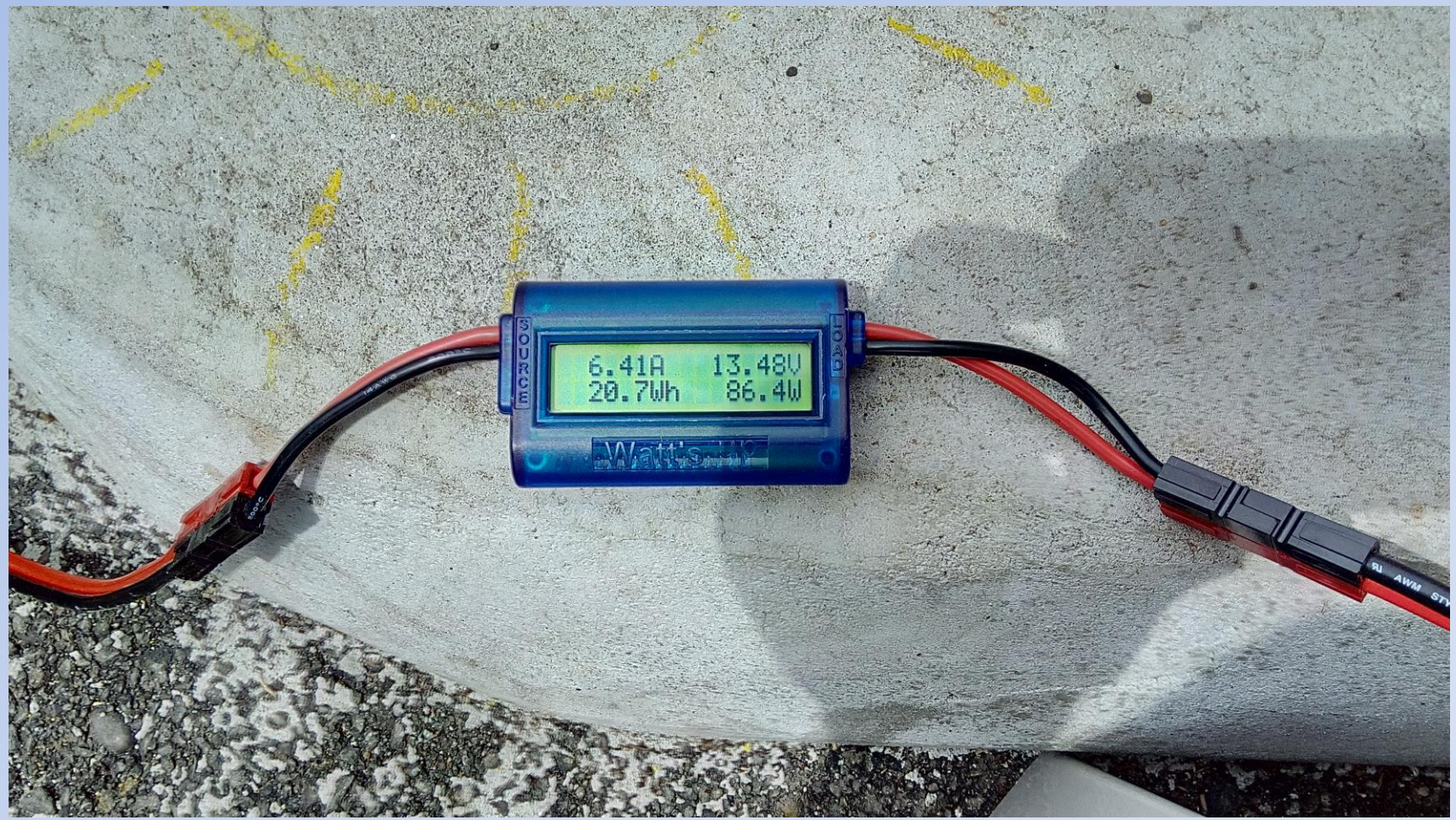
- 45 minutes later, the clouds are starting to clear some, but there is no direct sunlight
- Solar amps are about 2.3 amps, THEN
- Sun popped out from behind the clouds
- The meter readings quickly rose
- Edge of cloud effect, amps = 12.92, watts = 188.6, AGM battery voltage now 14.6v, then amps came down

Silfab 310 Watt Solar Panel Specs

- 310 watts, price = $230
- Voc = 40.25 volts
- Vmp(max operating voltage) = 33.05 volts
- Imp(max operating current) = 9.38 amps
- Isc(Short circuit current) = 9.93 amps
- Weight = 50.7 lbs
- 60 cells

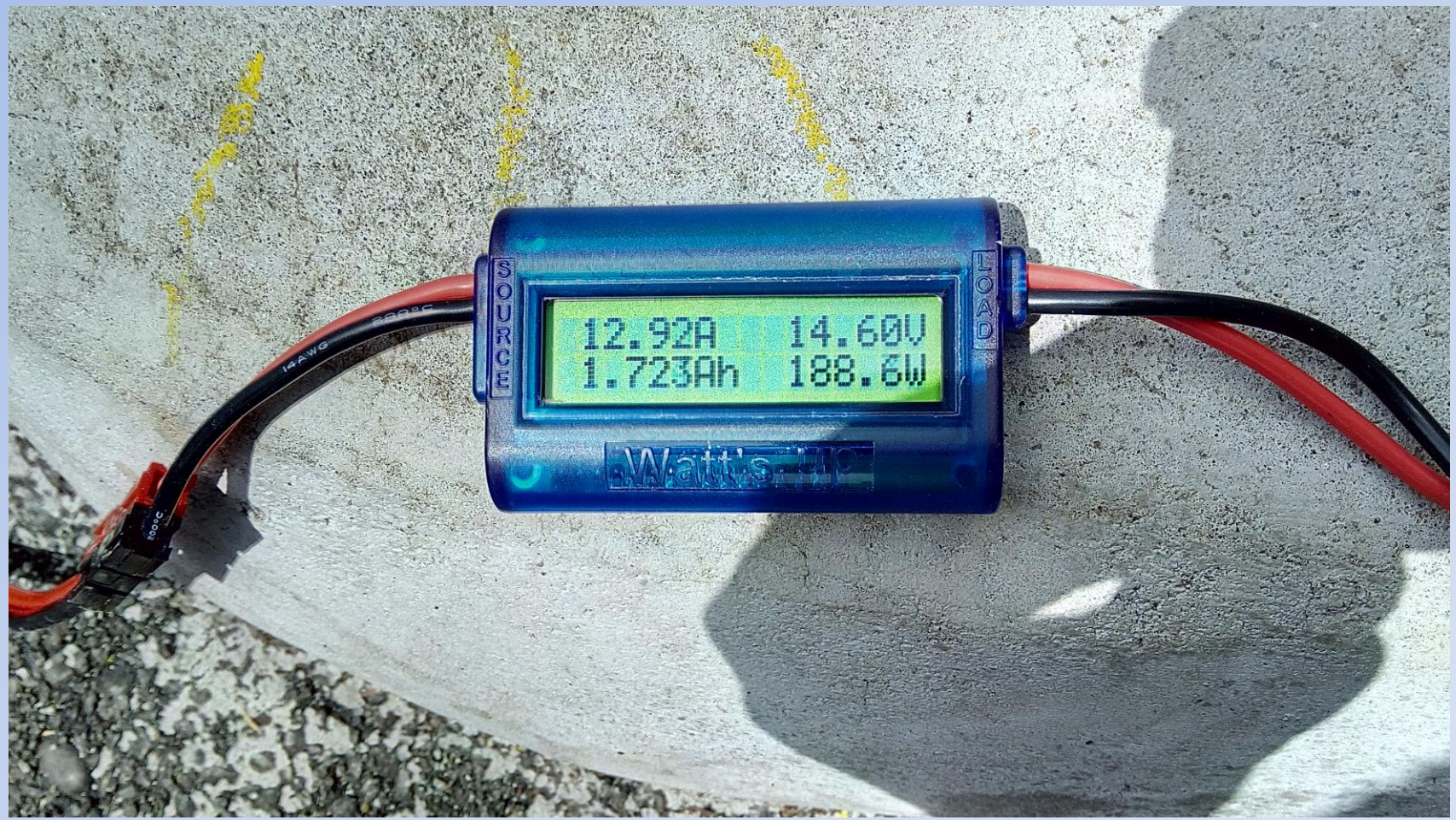
310 Watt Silfab 60 cell Grid-Tie Solar Panel Directly Connected To 55Ah AGM Battery

Silfab Grid-Tie Solar Panel With Sun Just Coming Out From Behind The Clouds



310 Watt Silfab Solar Panel Current Rising Up To 11.02 Amps, Note PV Imp = 9.38 Amps

Edge Of Cloud Effect Caused Amps To Peak, Then The Current Went Back Down



310 Watt Silfab 60 Cell Solar Panel Designed For Grid-Tie Applications…**Sunbridge Solar**

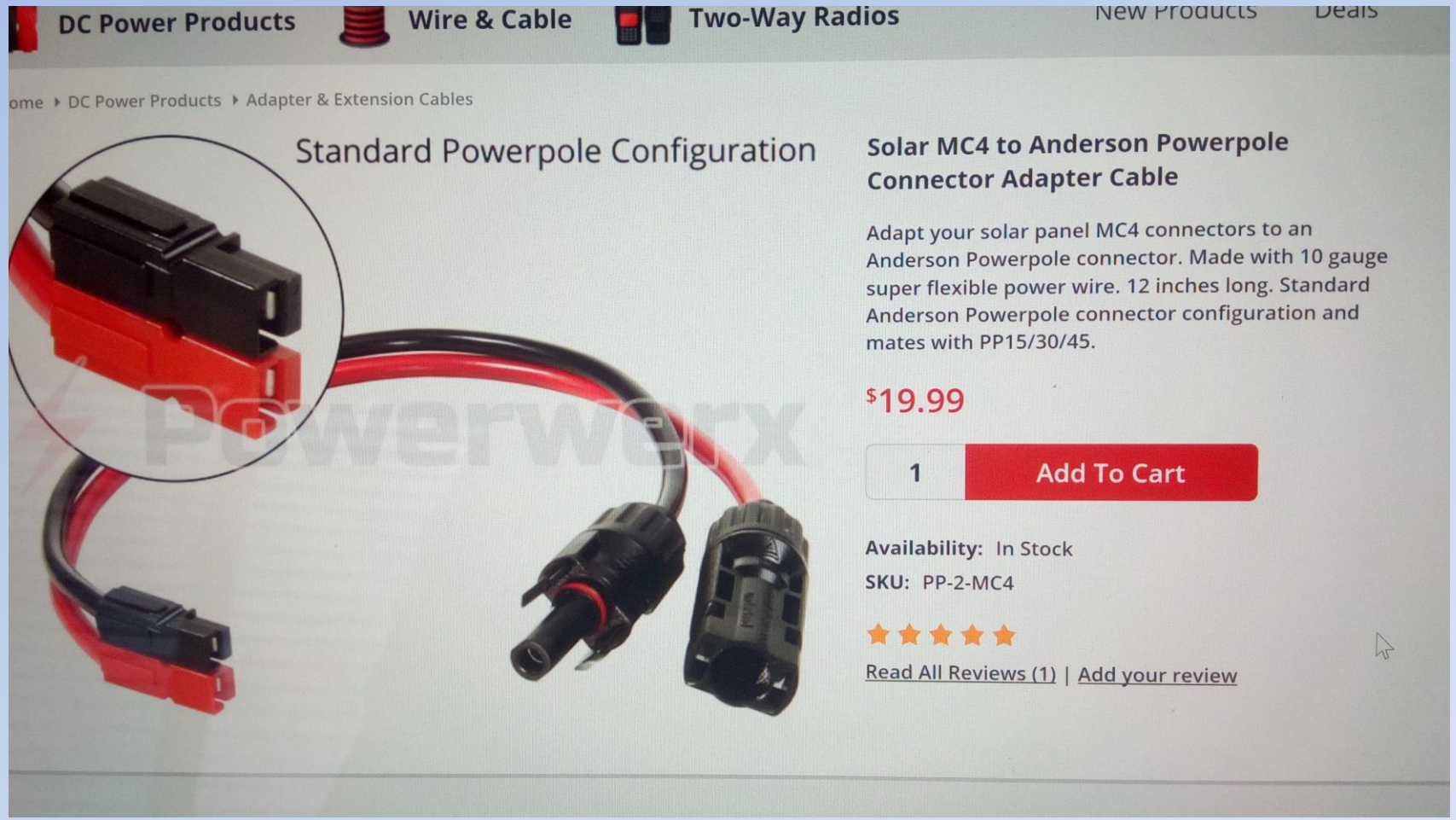
Grid Tie Panels

- Disaster happens and the grid is not expected to be brought back up for a considerable time
- If just **one** grid-tie solar panel has survived an event, it could be considered for its DC power capability
- **Safety Warning…** Grid Tie panel installations are **wired in two ways**, all wired together as a **string** in series or with each panel having an individual microinverter
- **String voltage can be up to 600VDC or 1,000VDC**

Grid Tie Panels

- **Disconnecting a cable conducting almost 600VDC during the daylight would likely be FATAL…High Voltage DC is very dangerous**
- **Plan to disconnect the solar panel cable and connect your power cable after dark, just using a tarp to de-energize the array could fail if wind removed the tarp while you were disconnecting the power cable**
- Now connect your MC4 power cable to the one panel

You Will Need This Adapter To Connect To A Solar Panel…Get The “Solar To MC4”



The Challenge With Using A Grid-Tie Solar Panel To Charge Car Batteries

- **One car battery** is ~45Ah x0.2C max charging current = **9 amps**
- One 310 watt grid-tie solar panel outputs up to about 9.4 amps
- **One 310 watt grid-tie solar panel could charge one mid sized car battery with a PWM charge controller that could handle the Voc & Imp of the solar panel**

Grid Tie Panels

- Using **one grid-tie panel**, to charge **one car battery** with a **PWM charge controller**, the panel voltage would be dropped down to the battery voltage, **not efficient**, but better than nothing
- You could use one grid-tie 310 watt solar panel and an MPPT charge controller, but you would need a **minimum of 3 car batteries wired in parallel** to accommodate that much current

Three Car Batteries Are Better

- Try to locate three batteries that are similar in size…it may be easiest to find three of the same type of car, same car = same battery?
- Three car batteries might be about 135Ah (45Ah x 3)
- 135Ah x .2C = 27 amps max charging current
- You could charge the batteries with up to ~27 amps so long as you regulate the voltage
- You would need to verify that the three batteries are fully charged first before placing them parallel

Some Vehicles Are Now Using AGM Batteries…Do Not Mix AGM & FLD

- FYI…some vehicles are starting to use AGM batteries
- Ford began offering AGM batteries in their Ford F-150 trucks starting in 2015
- Do not mix AGM and flooded lead-acid deep cycle batteries
- Nobody will be wanting to touch F-150 truck batteries, they will be a work horse vehicle during a disaster

The Challenge With Using A Grid-Tie Solar Panel To Charge Car Batteries

- **Two car batteries** is 45Ah x 2 = 90Ah, 90Ah x 0.2 = **18 amps** of max charge current, grid-tie 310W MPPT is too much here
- **Three car batteries** is 45Ah x 3 = 135Ah, 135Ah x 0.2 = **27 amps** of max charge current
- So **one 310 watt grid-tie 60 cell solar panel should be able to charge 3 mid sized car batteries using an MPPT charge controller…310W/14v battery voltage = 22 amps MPPT?**

Can You Charge A Battery Without A Charge Controller In An Emergency?

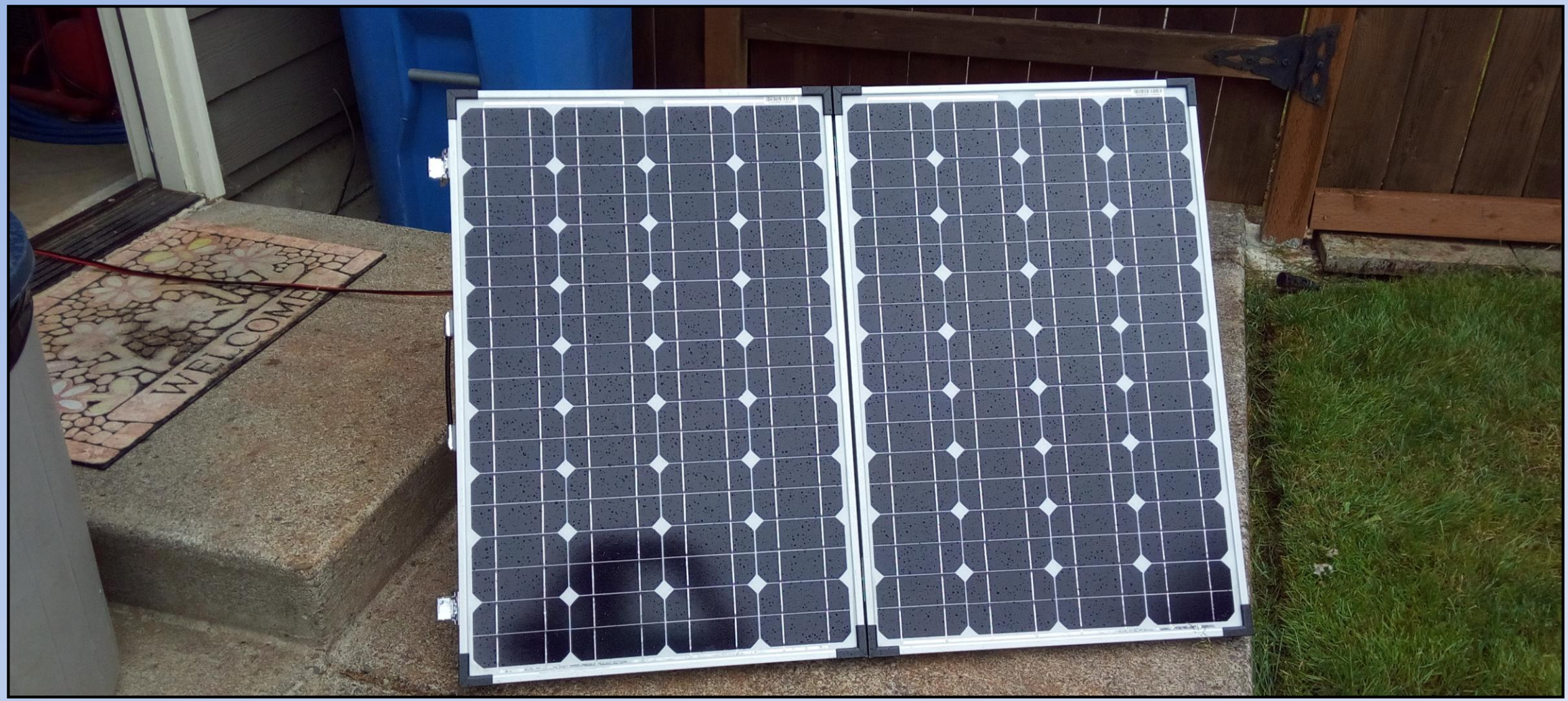
- YES…in order to do this, someone must be focused on just this task…this is a **no other choice** emergency plan
- Example…you could direct connect a 55Ah AGM battery to a 100 watt solar panel and using an inline meter, manually adjust the panel to keep the battery voltage no higher than 14.1 volts, dependent on temp
- Battery voltage will swing with clouds coming and going…must be vigilant, a task for just one person

Charging A Battery With Only An Inline 12v Meter

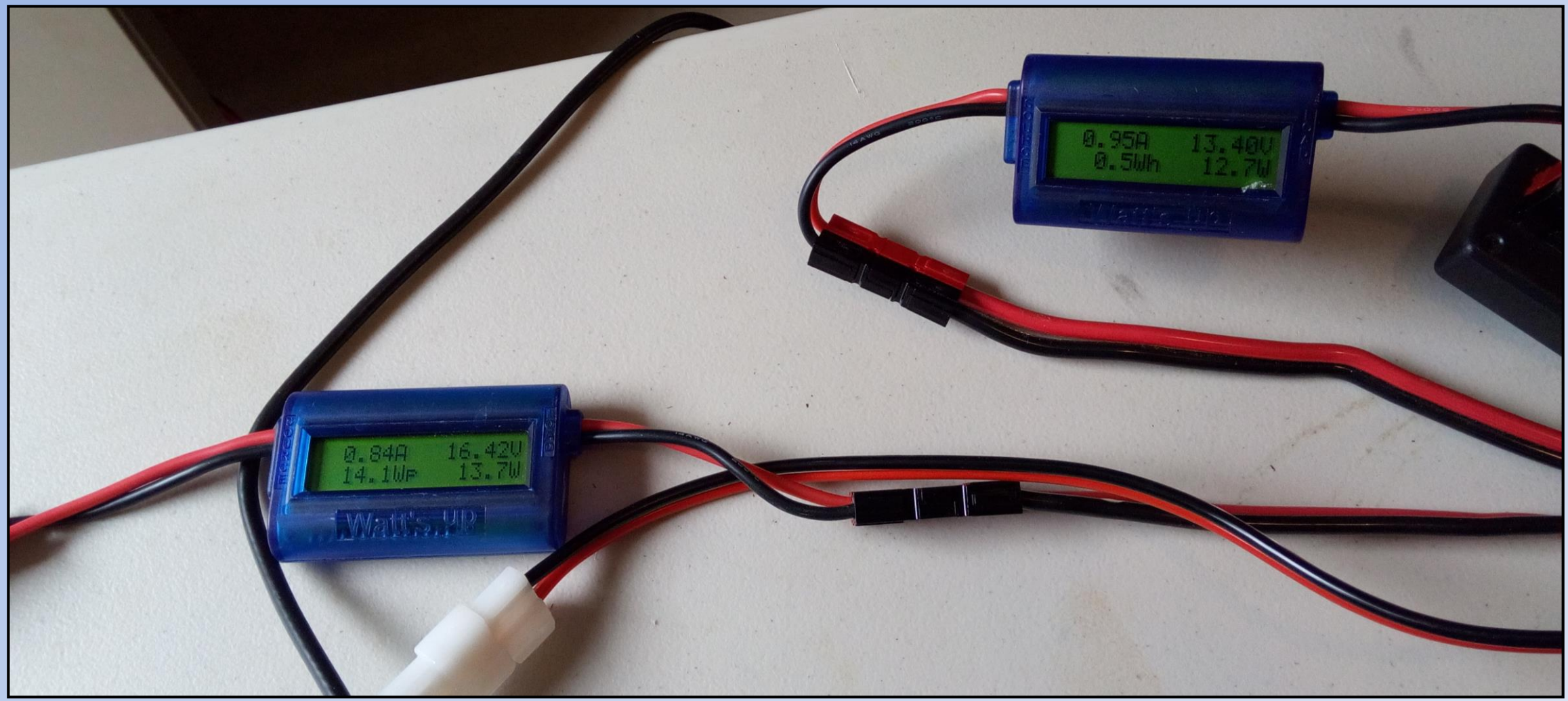
- Start out with pointing the solar panel directly at the sun and watch the voltage rise to just under 14 volts, less voltage with a hotter ambient air temp
- At that point begin turning the panel sideways some and note how much the voltage drops, the current will begin tapering down, maintain the battery voltage at about 14 volts
- You can also turn the solar panel completely away from the sun and still provide power to the battery
- As you watch the voltage, when the current has dropped down very low, say <=0.5 amps, you could decide to stop?

Emergency Grid-Tie Solar Panel Access Kit

- Need an MC4 tool…to disconnect the MC4 connector
- MC4 to PP…PP-2-MC4 from Powerwerx
- Alligator clip to PP
- A run of 10AWG wire with PP at both ends
- WattsUp inline meter of some type



BIOENNO POWER 120 WATT SOLAR PANEL WITH CLOUDY SKY, SLIGHT SPRINKLE



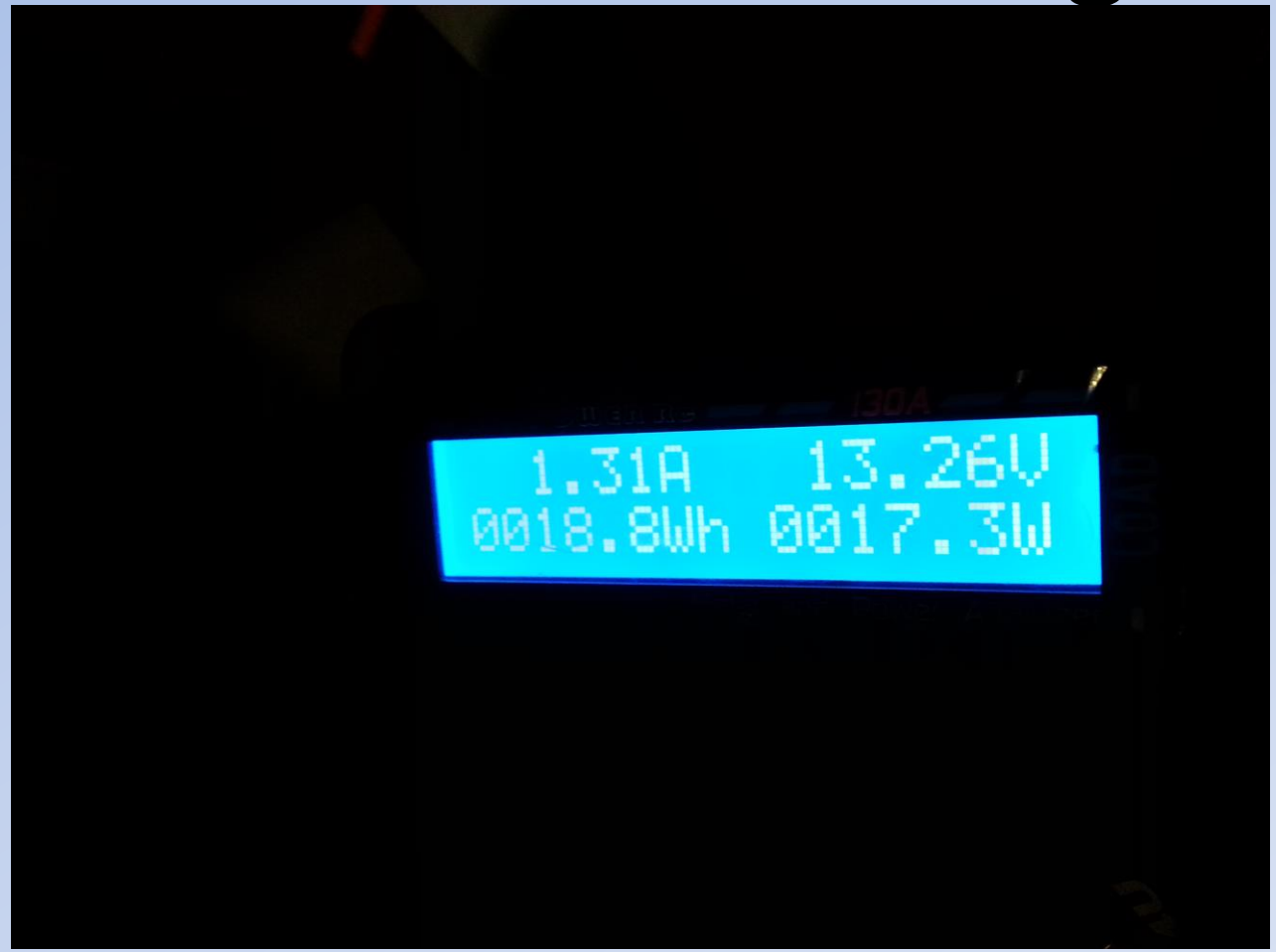
CLOUDY SKY WITH 120 WATT SOLAR AND GENASUN GV-10 MPPT CHARGE CONTROLLER, PANEL INPUT IS LEFT WATTS UP METER

Solar Power When It Is Snowing?

Solar Power When It Is Snowing Sky Conditions

Solar Panels Parallel Connected

220 Watts Of Solar Providing 1.31 Amps While It Is Snowing Outside



Solar Charge Controller “Sleep Syndrome”

- Someone new to LFP batteries leaves a load on all night and the **over discharge** protection kicks in and turns off the output, which protects the LFP battery
- That same someone says, “No problem, I will just charge up my battery when the sun comes up tomorrow morning”

Solar Charge Controller “Sleep Syndrome”

- However, a number of charge controllers will not “Wake Up” and start providing charge current to a battery **until first** there is battery voltage detected on the charge controller battery terminal
- Solution… turn back on the LFP battery, by connecting the LFP battery briefly to a 12v power source, then you are good to go
- Off grid solar panel should work or some other 12VDC power source

SEA PAC