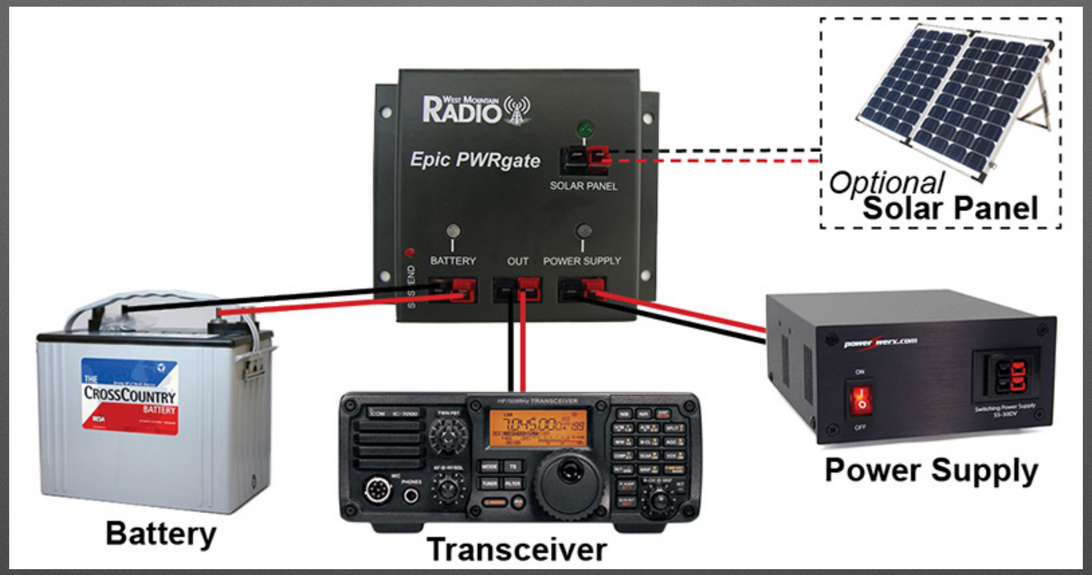



# Solar Primer for Ham Radio

ABØL - April 11, 2023

# Take your shack off grid - or portable!

- Ohm’s Law review
- Calculating your power budget
- Solar panels
- Batteries
- Charge controllers
- Accessories

# Wait, there’s gonna be MATH?

- P = V x I
  Compare power, not amps…
  100W panel is indeed about 20V x 5A in full sun!
  100Ah lead acid battery yields about 630Wh (12.6V x 100A x 50%)
  100Ah LiFePO4 battery yields about 1,320Wh (13.2V x 100A x 100%)

- V = I x R
  Watch those voltage drops!
  50’ of 18 AWG wire = 3.2V drop (5A x 50’ x 2 x 0.006385Ω) or 16% loss
  50’ of 10 AWG wire = 0.5V drop (5A x 50’ x 2 x 0.000999Ω) or 2% loss

# I’m givin’ her all she’s got, captain!

What’s your power budget?

- Tally up your daily watt-hour needs.
- Determine your solar wattage required. Assume 5 hours of sun per day, so a 100 watt panel under ideal conditions can generate 500 watt-hours.
- How much bad weather can you stand? That determines your battery size. (Total watt-hours times number of days suffering.)

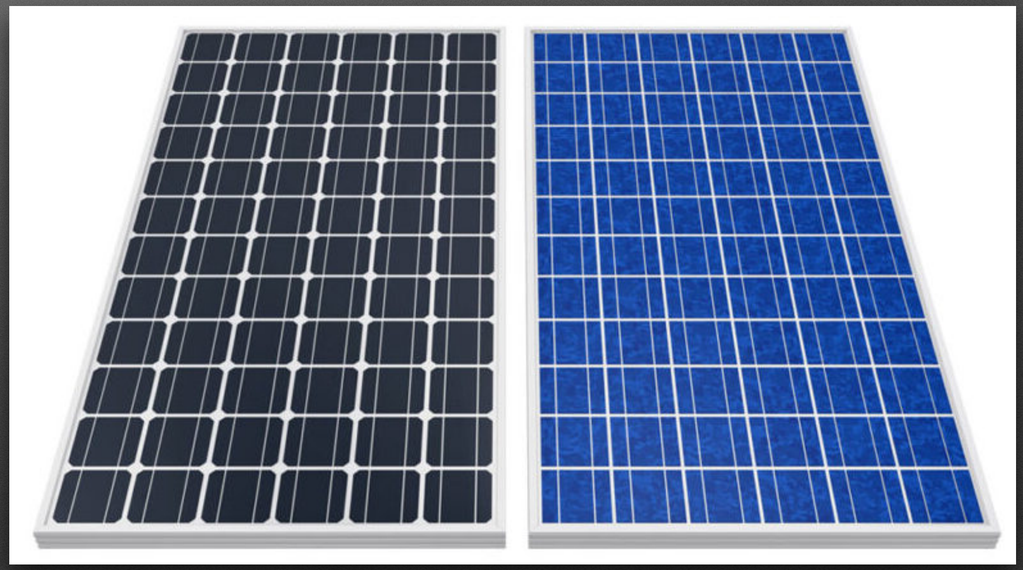
# Photon harvesting devices

## Mono-crystalline

- Cells made from single silicon crystals
- More efficient
- Typically black in color

## Polycrystalline

- Cells made from silicon fragments melted together (more eco friendly)
- Cheaper
- Handle shadows & clouds better
- Typically blue



# Feelin’ flexible?

## Flexible panels

- Lightweight
- Easy to store
- Can be fragile
- aerodynamic mounting
- 2-4 year life span (heat is a real killer)
- $$

## Rigid panels

- Easy to orient for maximum sun exposure
- Heavy (100 watt panel is about 15-16 lbs)
- Very long life

## Foldable portable panels

- Best of both worlds?
- $$$$

# Need even more powah?

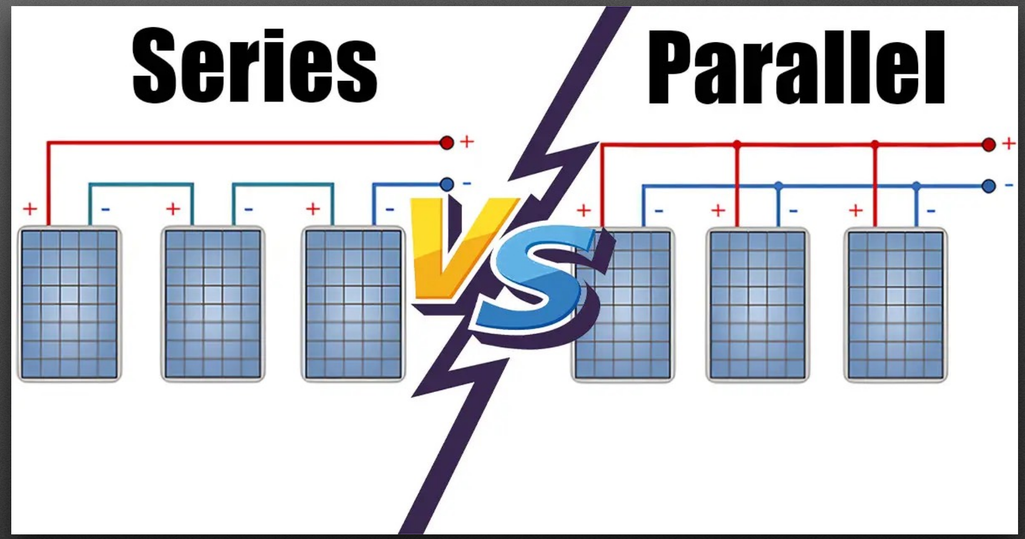
## Parallel

- Doubles current, voltage unchanged (2 panels)
- Watch that wire gauge / voltage drop!
- Pre-made Y cables make for easy wiring
- Relatively shade resistant

## Series

- Doubles voltage, current unchanged (2 panels)
- Wiring more complex but cheaper
- Shade brings the whole party down
- Typically MPPT controllers only!
- Beyond two panels gets into “Ow that hurts!” voltages

Panels have built-in blocking diodes supporting chaining
Mismatched panels can be chained but there will be efficiency hits



# Panel recommendations

- Rich Solar 100 watt poly $100
- HQST 100 watt mono (same panel as Renogy but cheaper) $80
- Flex panel (any) AVOID
  Larger panels are just too fragile and only last a couple years.
  Ultra portable low wattage mil spec ones are OK but very spendy.
- Foldable (any) MAYBE
  Rigid foldable / portable panels can be a good solution for space constrained.
  Expect to pay a premium and watch out for integrated charge controllers.
  Power stations often sell their own foldable panel for plug-and-play solutions.

# It’s all lithium these days… …except for lead acid?

- 2.1V per cell, 6 cells in series = 12.6V nominal voltage
- Great temperature tolerance
- Inexpensive, but HEAVY
- Only 50% usable capacity
  Exceeding ~50% discharge results in grid corrosion and sulfating, which increases internal resistance and eventually prevents the battery from accepting a charge.

# Lead acid flavors

## Flooded (car battery)

- Liquid electrolyte can spill
- Vents hydrogen gas while charging
- Longest life of the lead acids (if cared for)

## Absorbed Glass Mat (AGM)

- Electrolyte captured in matting; no spill or outgas risk with normal use
- Can be mounted in any orientation
- More expensive but “maintenance free”
- Great tolerance for cold

## Gel

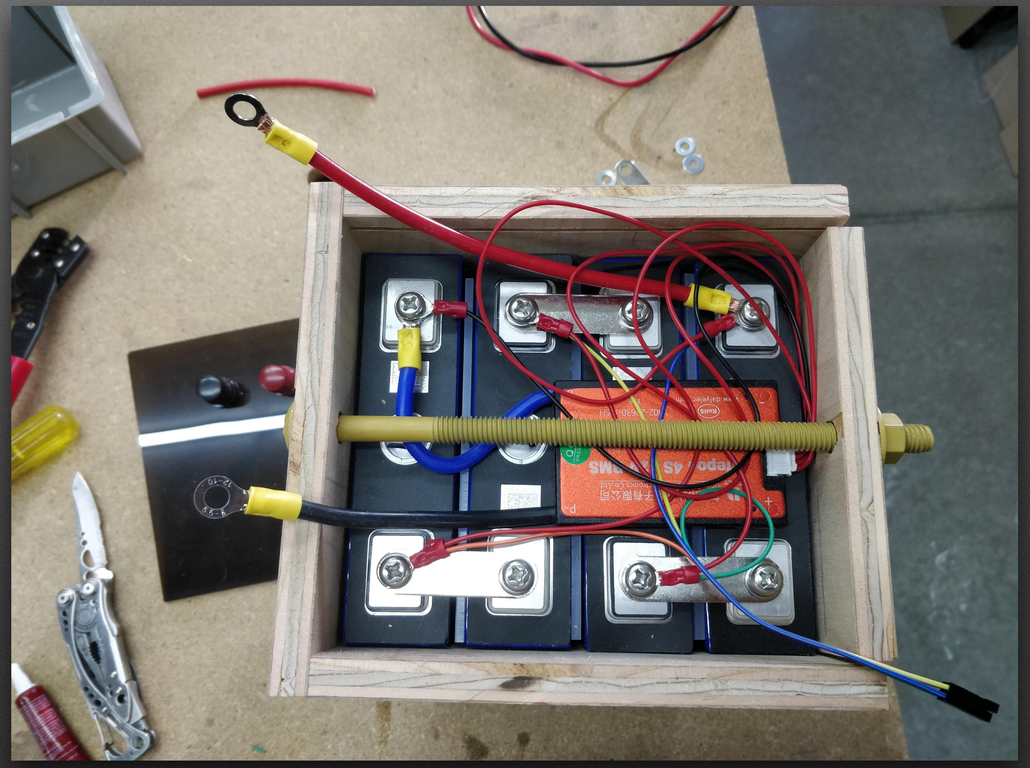
- Does not tolerate high discharge rates!
- Supports much deeper discharge before damage occurs
- Great tolerance for heat

# Lithium Polymer

- 3.7V per cell, various series and parallel geometries used along with voltage regulation.
- Highest energy density (lightweight).
- Does not suffer fools (or poor manufacturing) well; rigorous charge & discharge requirements for voltage, current, and temperature or things get explody.
- Relatively short life of 500 or so cycles.
- Highest cost per Wh but lithium polymer power stations come with added conveniences like built in AC inverter, solar charge controller, USB and a variety of 12V output options.
- 4S RC battery packs offer extraordinary discharge capacity (20C) for very low cost.
  Be aware - your equipment must tolerate 15+V!
  RC batteries rarely have much for protection circuitry- understand setup and charger requirements to avoid flaming excitement.

# Lithium Iron Phosphate (LiFePO4)

- 3.3V per cell, 4 cells in series = 13.2V nominal voltage
- Extremely safe and durable - 6,000+ cycles
- Huge discharge capacity - 40C not unusual
- Less than half the weight of lead acid
- Was expensive but prices have dropped dramatically
- Must NEVER be charged below freezing
  Normally the internal BMS manages this but not always!
- 100% usable capacity
  BMS handles specifics but if a LiFePO4 battery is rated at 100Ah, that's 100Ah or more, fully usable.
- Extraordinarily flat discharge voltage
  So flat in fact that it's impossible to gauge LiFePO4 battery capacity from voltage alone. Typically a shunt is used to monitor current out / in.



# Battery recommendations

- Roypow "Power Urus" 12V 100Ah LiFePO4 ($400)
- AmpereTime 12V 100Ah LiFePO4 ($350)
  Does NOT have low temperature protection!
- BLUETTI power stations (various models)
  BLUETTI uses LiFePO4 cells, not lithium polymer so you get a safer, longer lasting station but they’re heavier than competitors.
- Generic (off-brand) lithium polymer power stations (AVOID)
  Just too many stories of random garage fires from these things.
- Lead acid (AVOID)
  Unless you’re getting something for darn near free, save the lead acid for starting your car.

# Charge controllers

Pulse Width Modulation (PWM) vs Maximum Power Point Tracking (MPPT) controllers

## PWM

- Older tech, cheaper
- Less efficient under suboptimal sun conditions
- Steps panel voltage down to battery charging voltage
- Typically cannot regulate current - panel current in = current out to battery
- PWM switching is RF noisy

## MPPT

- More expensive but more efficient
- Continuously varies load the panels see to extract maximum power for the given sunlight and temperature conditions
- Can be engineered to support hundreds of volts of solar input for very large arrays
- Solar panels actually work in reverse after dark - MPPT controllers prevent battery drainage
- Less RF noisy

# Charge controller recommendation

West Mountain Epic PWRgate

- Made specifically for hams (but great for any camping trailer)
- Covers both DC and solar battery charging
- 10A charger - plenty for 50-100Ah of battery storage
- 40A output capacity for the beefiest rigs
- Only 30V solar input so parallel wiring required for multiple panels
- Very RF quiet and there’s even a suspend button to pause battery charging for 30 minutes
- Uses Anderson Powerpoles we know and love
- Supports all battery chemistries via jumpers with fine parameter tuning / customizations via USB interface
- Optional temperature probe available if needed

# When to avoid Epic PWRgate

- More than 30V or 10A of solar (basically > 2 100 watt panels)
- More than about 100Ah of battery storage
- Current requirement exceeds 40A

# Charge controller alternatives

- Victron and Renogy both have extensive product lines for all kinds and sizes of systems.
- While PWM isn’t preferred, Renogy also has some low-cost PWM solutions if budget is tight.
- Know your way around a soldering iron? How about rolling your own MPPT controller? https://www.instructables.com/DIY-1kW-MPPT-Solar-Charge-Controller/
- Going the power station route? Check the owner’s manual. Some have on-board charge controllers that will work with any solar panel. Some require panels with built-in controllers and possibly proprietary connections.
- While Harbor Freight solar products aren’t generally competitively priced, they do have some portable folding panels with integrated PWM controllers that, with the right sale and infamous 25% coupon, might be compelling.

# Charge controller gotchas

- VERY few charge controllers support DC / grid charging like the Epic PWRgate. If you desire this functionality, additional hardware will be needed and it must play well together.

- Know your battery chemistry and charge requirements! Not all charge controllers - even expensive ones - support all chemistries, and marketing claims have been proven wrong many times. Don’t risk damaging your expensive battery investment. Double check all specifications!

- Never trust a wire color or connector polarity (unless it’s an Anderson). There are no real “standards” in solar and use of polarity flippers are common in connecting cross-vendor hardware. Always use a meter to verify positive to positive, negative to negative.

# Accessories

- Inverter - Noisy and inefficient. Avoid unless 120V is absolutely required. If used, watch your wire gauge! Inverters are power hungry beasts. A “small” 200 watt AC load will draw upwards of 20A off the battery.
- Fuse panel - Or consider a DC breaker panel. Spendy, but no more hunting for spare fuses. Blue Sea makes excellent DC fuse and breaker solutions.
- Breakers / cutoff switches MUST be DC rated. Don’t try to use AC safety equipment!
- Shunt - For accurate measurement of power in and out of the battery. Prices vary from $15 on Amazon to $100+ Bluetooth enabled Victron units.
- Wire - No copper clad!
- Consider going full DC in the shack; lighting, laptop, the works - Can’t be any power related QRM if the power frequency is zero!

# Thank you for your time!

Any Questions?