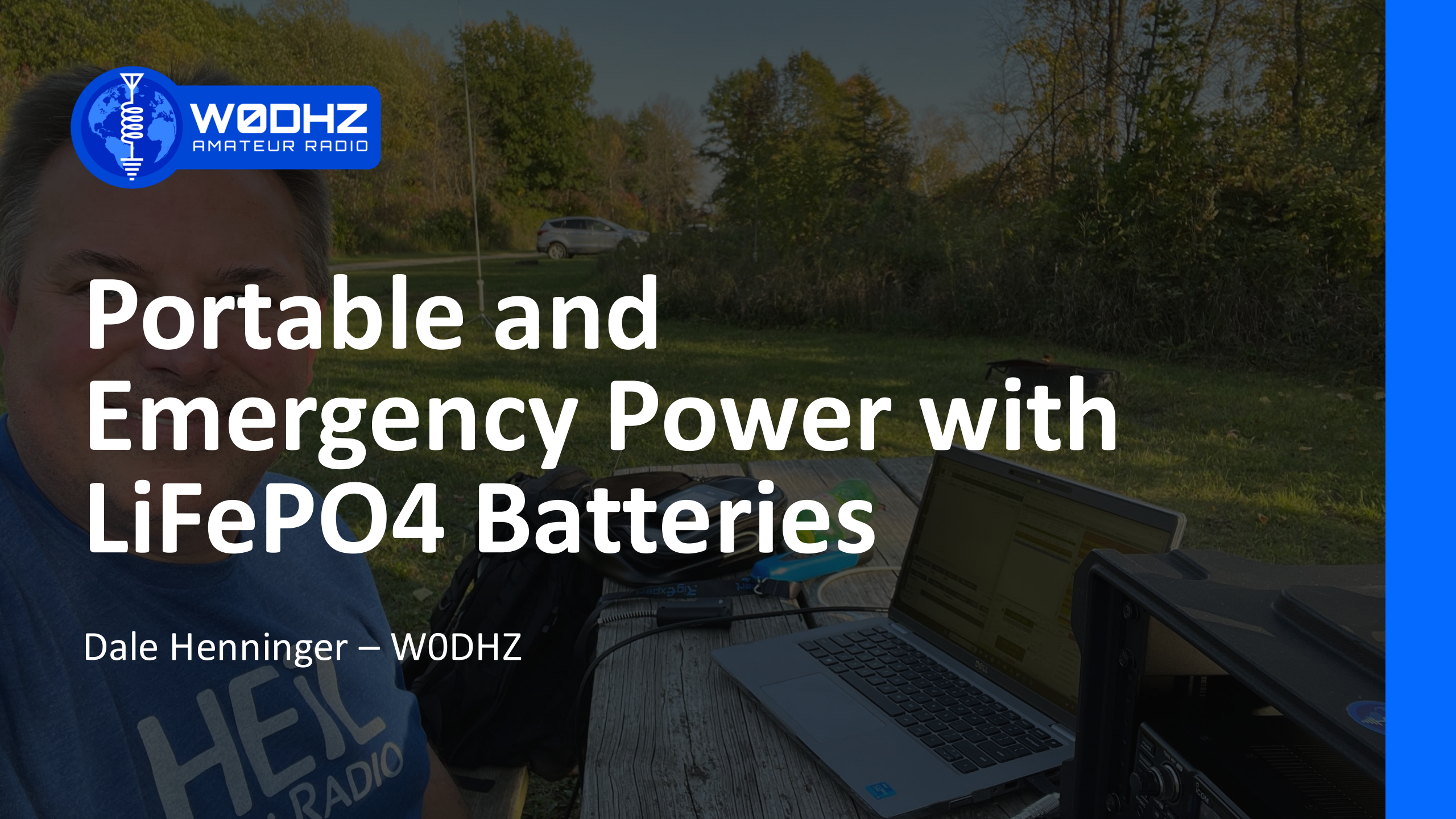




# Portable and Emergency Power with LiFePO4 Batteries

Dale Henninger – W0DHz



# Before we start...

I am a hobbyist... Not an electrical engineer.

Be Safe!

- Wear eye protection
- Invest in non-conductive tools
- Use Kapton/Polyimide Insulating Tape  
(heat resistant / non-conductive)

Read manufacturer data sheets!

Use fuses! High quality fuses!



# Disclaimer

Bioenno Power has donated batteries to the convention as door prizes.

They did not ask for me to promote their batteries and were not aware that I am doing this presentation.

I personally use Bioenno Power batteries as well as other brands of LiFePO4 batteries.

Bioenno Power has been very gracious to the amateur radio hobby, and I have received excellent customer service, which is why I continue to use their products.





# Ham Radio and Batteries

Direct Current!

RF Quiet

Emergency Communications

Off Grid Operations

Great for portable use (POTA/SOTA)



By Towel401 (talk) (Transferred by terrafloorin/Originally uploaded by Towel401) - self-made (Originally uploaded on en.wikipedia), Public Domain, <https://commons.wikimedia.org/w/index.php?curid=18314016>



# Ham Radio and Batteries

Your rig is only as good as your power source!

Radios require a 13.8 v power source (+/- 15%)

11.73 v - 15.87 v

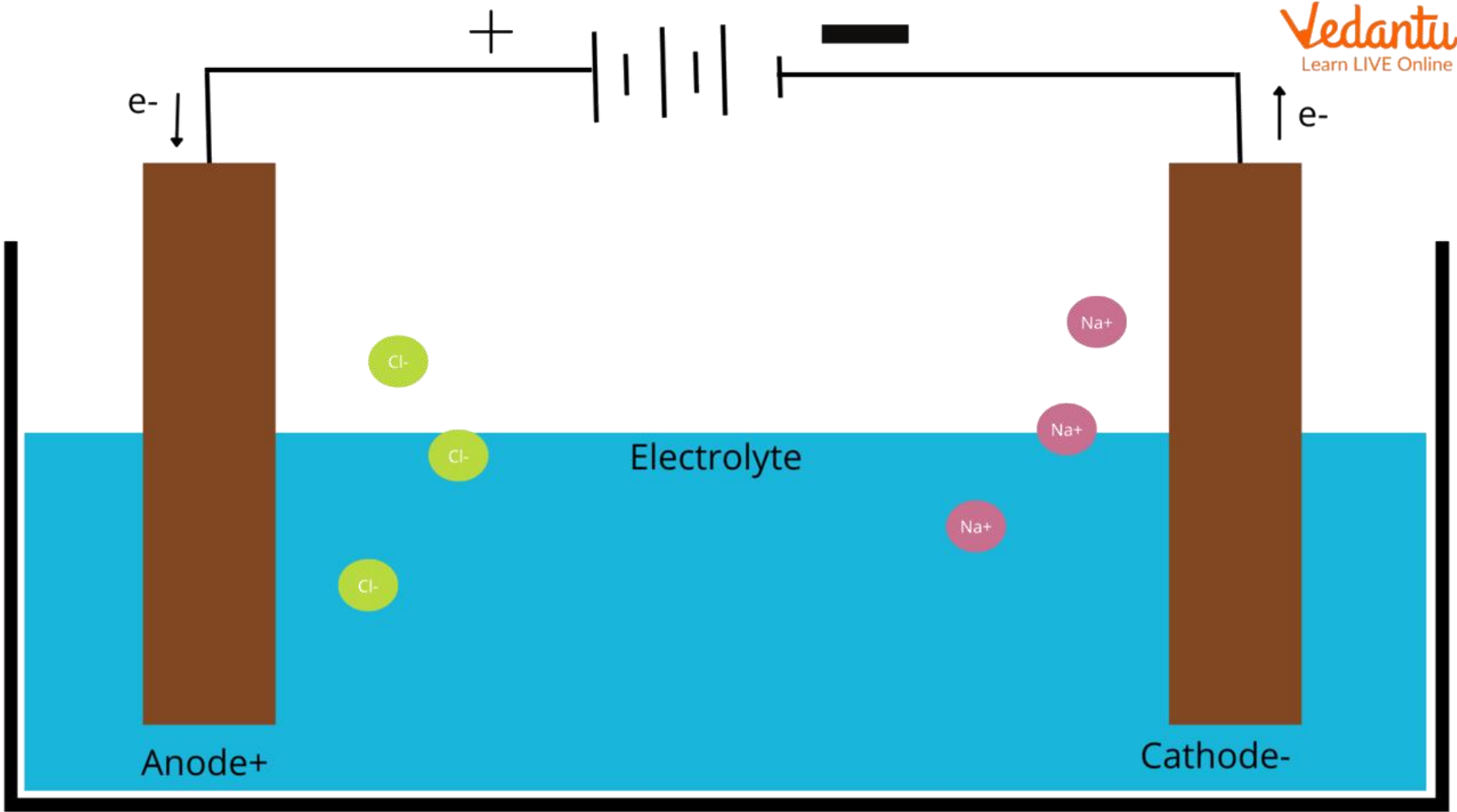
Battery needs to deliver a current that can sustain the power level you are trying to operate at, with no reduction in voltage.

100w = ~ 17 Amps



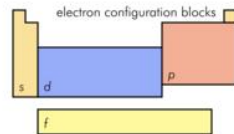
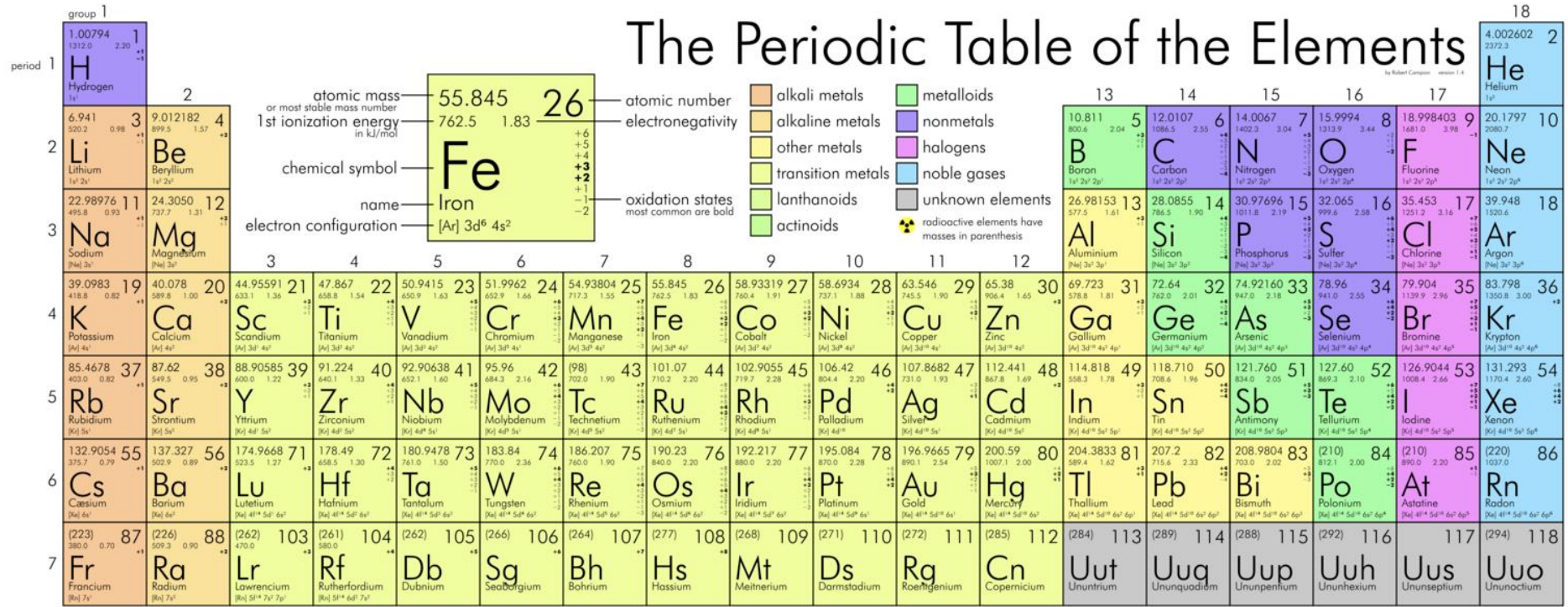
By Towel401 (talk) (Transferred by terrafloirin/Originally uploaded by Towel401) - self-made (Originally uploaded on en.wikipedia), Public Domain, <https://commons.wikimedia.org/w/index.php?curid=18314016>

# Battery Review





# Battery Chemistries



**notes**

- as of yet, elements 113-118 have no official name designated by the IUPAC.
- 1 kJ/mol = 96.485 eV.
- all elements are implied to have an oxidation state of zero.

138.9054 57 Lanthanum [Xe] 5d <sup>1</sup> 6s <sup>2</sup>	140.116 58 Cerium [Xe] 4f <sup>1</sup> 5d <sup>1</sup> 6s <sup>2</sup>	140.9076 59 Praseodymium [Xe] 4f <sup>3</sup> 6s <sup>2</sup>	144.242 60 Neodymium [Xe] 4f <sup>4</sup> 6s <sup>2</sup>	(145) 61 Promethium [Xe] 4f <sup>5</sup> 6s <sup>2</sup>	150.36 62 Samarium [Xe] 4f <sup>6</sup> 6s <sup>2</sup>	151.964 63 Europium [Xe] 4f <sup>7</sup> 6s <sup>2</sup>	157.25 64 Gadolinium [Xe] 4f <sup>7</sup> 5d <sup>1</sup> 6s <sup>2</sup>	158.9253 65 Terbium [Xe] 4f <sup>9</sup> 6s <sup>2</sup>	162.500 66 Dysprosium [Xe] 4f <sup>10</sup> 6s <sup>2</sup>	164.9303 67 Holmium [Xe] 4f <sup>11</sup> 6s <sup>2</sup>	167.259 68 Erbium [Xe] 4f <sup>12</sup> 6s <sup>2</sup>	168.9342 69 Thulium [Xe] 4f <sup>13</sup> 6s <sup>2</sup>	173.054 70 Ytterbium [Xe] 4f <sup>14</sup> 6s <sup>2</sup>
(227) 89 Actinium [Rn] 6d <sup>1</sup> 7s <sup>2</sup>	232.0380 90 Thorium [Rn] 6d <sup>2</sup> 7s <sup>2</sup>	231.0358 91 Protactinium [Rn] 5f <sup>2</sup> 6d <sup>1</sup> 7s <sup>2</sup>	238.0289 92 Uranium [Rn] 5f <sup>3</sup> 6d <sup>1</sup> 7s <sup>2</sup>	(237) 93 Neptunium [Rn] 5f <sup>4</sup> 6d <sup>1</sup> 7s <sup>2</sup>	(244) 94 Plutonium [Rn] 5f <sup>6</sup> 7s <sup>2</sup>	(243) 95 Americium [Rn] 5f <sup>7</sup> 7s <sup>2</sup>	(247) 96 Curium [Rn] 5f <sup>8</sup> 7s <sup>2</sup>	(247) 97 Berkelium [Rn] 5f <sup>9</sup> 7s <sup>2</sup>	(251) 98 Californium [Rn] 5f <sup>10</sup> 7s <sup>2</sup>	(252) 99 Einsteinium [Rn] 5f <sup>11</sup> 7s <sup>2</sup>	(257) 100 Fermium [Rn] 5f <sup>12</sup> 7s <sup>2</sup>	(258) 101 Mendelevium [Rn] 5f <sup>13</sup> 7s <sup>2</sup>	(259) 102 Nobelium [Rn] 5f <sup>14</sup> 7s <sup>2</sup>



# Battery Chemistries – Lead Acid



Lead (Pb)

Sulfuric Acid (H / S / O)

AGM – Improves the design – increases the costs

The Periodic Table of the Elements

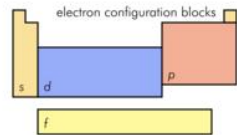
1																	17	18
1																	He	2
2	Li	Be											B	C	N	O	F	Ne
3	Na	Mg											Al	Si	P	S	Cl	Ar
4	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
5	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
6	Cs	Ba	Lu	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
7	Fr	Ra	Lr	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Uut	Uuq	Uup	Uuh	Uus	Uuo

Legend:

- alkali metals (orange)
- alkaline metals (yellow)
- other metals (light green)
- transition metals (green)
- lanthanoids (light blue)
- actinoids (dark blue)
- metalloids (light purple)
- nonmetals (purple)
- halogens (pink)
- noble gases (light blue)
- unknown elements (grey)
- radioactive elements have masses in parenthesis (grey with radiation symbol)

Example Element: Iron (Fe)

- atomic mass: 55.845
- 1st ionization energy: 762.5 kJ/mol
- atomic number: 26
- electronegativity: 1.83
- chemical symbol: Fe
- name: Iron
- electron configuration: [Ar] 3d<sup>6</sup> 4s<sup>2</sup>
- oxidation states: +2, +3, +6



notes

- as of yet, elements 113-118 have no official name designated by the IUPAC.
- 1 kJ/mol = 96.485 eV
- all elements are implied to have an oxidation state of zero.

138.9054	140.116	140.9076	144.242	(145)	150.36	151.964	157.25	158.9253	162.500	164.9303	167.259	168.9342	173.054
La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb
Lanthanum	Cerium	Praseodymium	Neodymium	Promethium	Samarium	Europium	Gadolinium	Terbium	Dysprosium	Holmium	Erbium	Thulium	Ytterbium
(227)	232.0380	231.0358	238.0289	(237)	(244)	(243)	(247)	(247)	(251)	(252)	(257)	(258)	(259)
Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No
Actinium	Thorium	Protactinium	Uranium	Neptunium	Plutonium	Americium	Curium	Berkelium	Californium	Einsteinium	Fermium	Mendelevium	Nobelium





# Battery Chemistries – Lithium Ion / Lithium Polymer



Lithium Ion (Li Co O<sub>2</sub>)

Cobalt

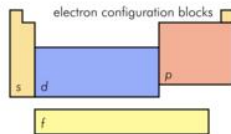
Lithium Polymer (LiPo)

(Lithium Ion variant)

### The Periodic Table of the Elements

by Robert Cawood version 1.4

group 1	2	13	14	15	16	17	18																									
period 1	1 H Hydrogen	2 He Helium						2 He Helium																								
	3 Li Lithium	4 Be Beryllium	5 B Boron	6 C Carbon	7 N Nitrogen	8 O Oxygen	9 F Fluorine	10 Ne Neon																								
	11 Na Sodium	12 Mg Magnesium	13 Al Aluminium	14 Si Silicon	15 P Phosphorus	16 S Sulfur	17 Cl Chlorine	18 Ar Argon																								
	19 K Potassium	20 Ca Calcium	21 Sc Scandium	22 Ti Titanium	23 V Vanadium	24 Cr Chromium	25 Mn Manganese	26 Fe Iron	27 Co Cobalt	28 Ni Nickel	29 Cu Copper	30 Zn Zinc	31 Ga Gallium	32 Ge Germanium	33 As Arsenic	34 Se Selenium	35 Br Bromine	36 Kr Krypton														
	37 Rb Rubidium	38 Sr Strontium	39 Y Yttrium	40 Zr Zirconium	41 Nb Niobium	42 Mo Molybdenum	43 Tc Technetium	44 Ru Ruthenium	45 Rh Rhodium	46 Pd Palladium	47 Ag Silver	48 Cd Cadmium	49 In Indium	50 Sn Tin	51 Sb Antimony	52 Te Tellurium	53 I Iodine	54 Xe Xenon														
	55 Cs Caesium	56 Ba Barium	57 La Lanthanum	58 Ce Cerium	59 Pr Praseodymium	60 Nd Neodymium	61 Pm Promethium	62 Sm Samarium	63 Eu Europium	64 Gd Gadolinium	65 Tb Terbium	66 Dy Dysprosium	67 Ho Holmium	68 Er Erbium	69 Tm Thulium	70 Yb Ytterbium	71 Lu Lutetium	72 Hf Hafnium	73 Ta Tantalum	74 W Tungsten	75 Re Rhenium	76 Os Osmium	77 Ir Iridium	78 Pt Platinum	79 Au Gold	80 Hg Mercury	81 Tl Thallium	82 Pb Lead	83 Bi Bismuth	84 Po Polonium	85 At Astatine	86 Rn Radon
	87 Fr Francium	88 Ra Radium	89 Ac Actinium	90 Th Thorium	91 Pa Protactinium	92 U Uranium	93 Np Neptunium	94 Pu Plutonium	95 Am Americium	96 Cm Curium	97 Bk Berkelium	98 Cf Californium	99 Es Einsteinium	100 Fm Fermium	101 Md Mendelevium	102 No Nobelium	103 Lr Lawrencium	104 Rf Rutherfordium	105 Db Dubnium	106 Sg Seaborgium	107 Bh Bohrium	108 Hs Hassium	109 Mt Meitnerium	110 Ds Darmstadtium	111 Rg Roentgenium	112 Cn Copernicium	113 Uut Ununtrium	114 Uuq Ununquadium	115 Uup Ununpentium	116 Uuh Ununhexium	117 Uus Ununseptium	118 Uuo Ununoctium



- notes
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138.9054 57 La Lanthanum	140.116 58 Ce Cerium	140.9076 59 Pr Praseodymium	144.242 60 Nd Neodymium	(145) 61 Pm Promethium	150.36 62 Sm Samarium	151.964 63 Eu Europium	157.25 64 Gd Gadolinium	158.9253 65 Tb Terbium	162.500 66 Dy Dysprosium	164.9303 67 Ho Holmium	167.259 68 Er Erbium	168.9342 69 Tm Thulium	173.054 70 Yb Ytterbium
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# Battery Chemistries – Lithium Iron Phosphate

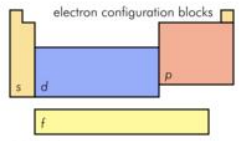


Lithium Iron Phosphate  
(Li Fe P O<sub>4</sub>)

### The Periodic Table of the Elements

by Robert Crampton, version 1.4

group 1	2	13	14	15	16	17	18												
period 1	1 H Hydrogen							2 He Helium											
	3 Li Lithium	4 Be Beryllium							10 Ne Neon										
	11 Na Sodium	12 Mg Magnesium							18 Ar Argon										
	19 K Potassium	20 Ca Calcium	21 Sc Scandium	22 Ti Titanium	23 V Vanadium	24 Cr Chromium	25 Mn Manganese	26 Fe Iron	27 Co Cobalt	28 Ni Nickel	29 Cu Copper	30 Zn Zinc	31 Ga Gallium	32 Ge Germanium	33 As Arsenic	34 Se Selenium	35 Br Bromine	36 Kr Krypton	
	37 Rb Rubidium	38 Sr Strontium	39 Y Yttrium	40 Zr Zirconium	41 Nb Niobium	42 Mo Molybdenum	43 Tc Technetium	44 Ru Ruthenium	45 Rh Rhodium	46 Pd Palladium	47 Ag Silver	48 Cd Cadmium	49 In Indium	50 Sn Tin	51 Sb Antimony	52 Te Tellurium	53 I Iodine	54 Xe Xenon	
	55 Cs Caesium	56 Ba Barium	57 La Lanthanum	71 Lu Lutetium	72 Hf Hafnium	73 Ta Tantalum	74 W Tungsten	75 Re Rhenium	76 Os Osmium	77 Ir Iridium	78 Pt Platinum	79 Au Gold	80 Hg Mercury	81 Tl Thallium	82 Pb Lead	83 Bi Bismuth	84 Po Polonium	85 At Astatine	86 Rn Radon
	87 Fr Francium	88 Ra Radium	89 Ac Actinium	103 Lr Lawrencium	104 Rf Rutherfordium	105 Db Dubnium	106 Sg Seaborgium	107 Bh Bohrium	108 Hs Hassium	109 Mt Meitnerium	110 Ds Darmstadtium	111 Rg Roentgenium	112 Cn Copernicium	113 Uut Ununtrium	114 Uuq Ununquadium	115 Uup Ununpentium	116 Uuh Ununhexium	117 Uus Ununseptium	118 Uuo Ununoctium



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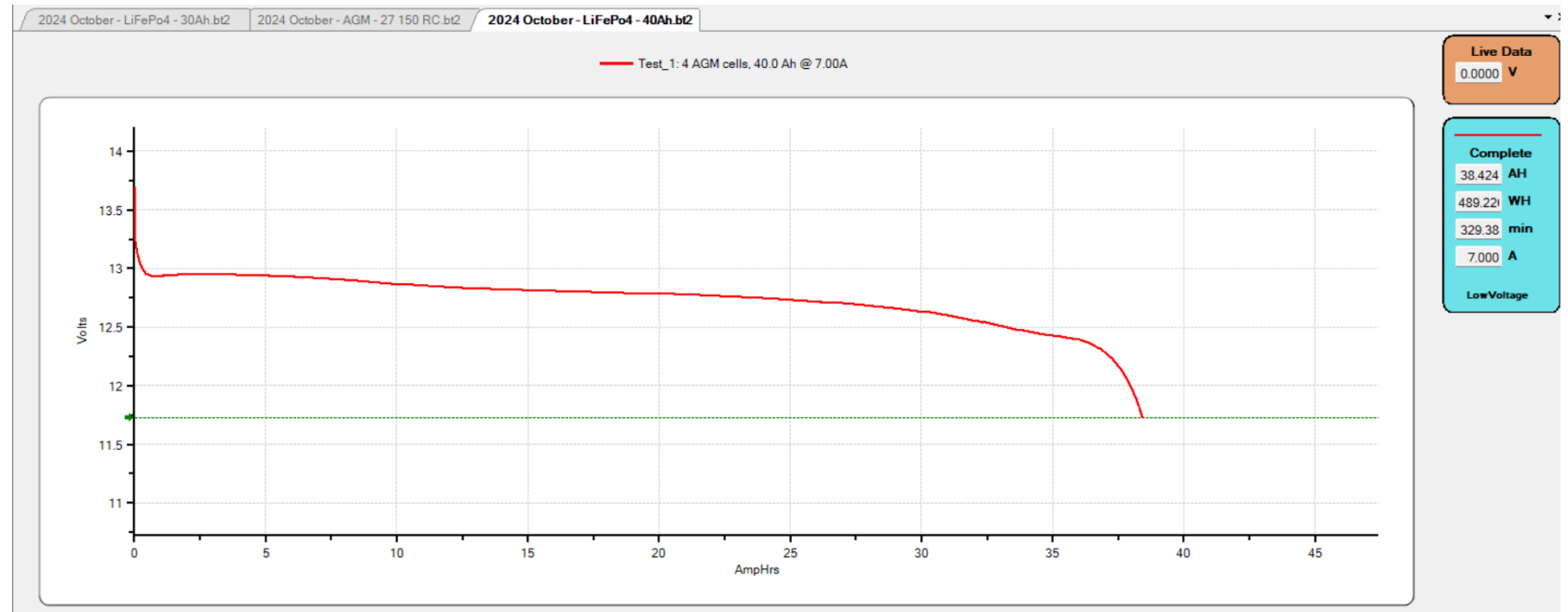








# My Test Suite





# Battery Measurement/Testing Terms

**Amateur Radio Effective Voltages – 11.73v minimum (-15% of 13.8v)**

All my tests are conducted with a shut off voltage of 11.73v

**Amp Hours (Ah) – Battery capacity measurement**

Amps \* Hours = Ah (30 Ah battery could deliver 1A for 30 hours or 30A for 1 Hour)

**State of Charge – Measurement of how much capacity is left in the battery**

0-100%

## Battery Technologies

# Lead Acid

### Pros

- Cheap / Durable (abuse may shorten life span)

### Cons

- Heavy (lowest energy density)
- Can only be discharged to about 50% of their rated capacity for peak life span (life span not that long)
- Voltage drops as you discharge
- Messy / Dangerous (AGM solves some of this)





Lead Acid / AGM Batteries

# Group 27 AGM Deep Cycle

## Specs

- 65 Pounds / 11" x 7.3" x 9.3"
- 150 Minutes of Reserve Capacity
- \$249.99
  
- Max/Peak Discharge: Hundreds of Amps



## Power Density

51.5 Ah of Capacity > 11.73 volts

.79 Ah / Pound Power Density

\$4.85 / Ah

## Deep Cycle Lead Acid / AGM Batteries

# Reserve Capacity vs Amp Hour

### Reserve capacity (RC)

Measures how long a battery can run before its voltage drops to a certain level. For example, a battery with a reserve capacity of 150 minutes can supply 25 amps for 150 minutes before the voltage drops to 10.5 volts. RC is a good indicator of how long a battery can power essential accessories if a vehicle's alternator fails.

### Amp hours (Ah)

Measures how many amps a battery can produce in one hour. One ampere-hour is the amount of electric charge transferred by a steady current of one ampere for one hour

12V Sealed Lead Acid Battery Voltage Chart		12V Flooded Lead Acid Battery Voltage Chart	
Voltage	Capacity	Voltage	Capacity
12.89V	100%	12.64V	100%
12.78V	90%	12.53V	90%
12.65V	80%	12.41V	80%
12.51V	70%	12.29V	70%
12.41V	60%	12.18V	60%
12.23V	50%	12.07V	50%
12.11V	40%	11.97V	40%
11.96V	30%	11.87V	30%
11.81V	20%	11.76V	20%
11.70V	10%	11.63V	10%
11.63V	0%	11.59V	0%

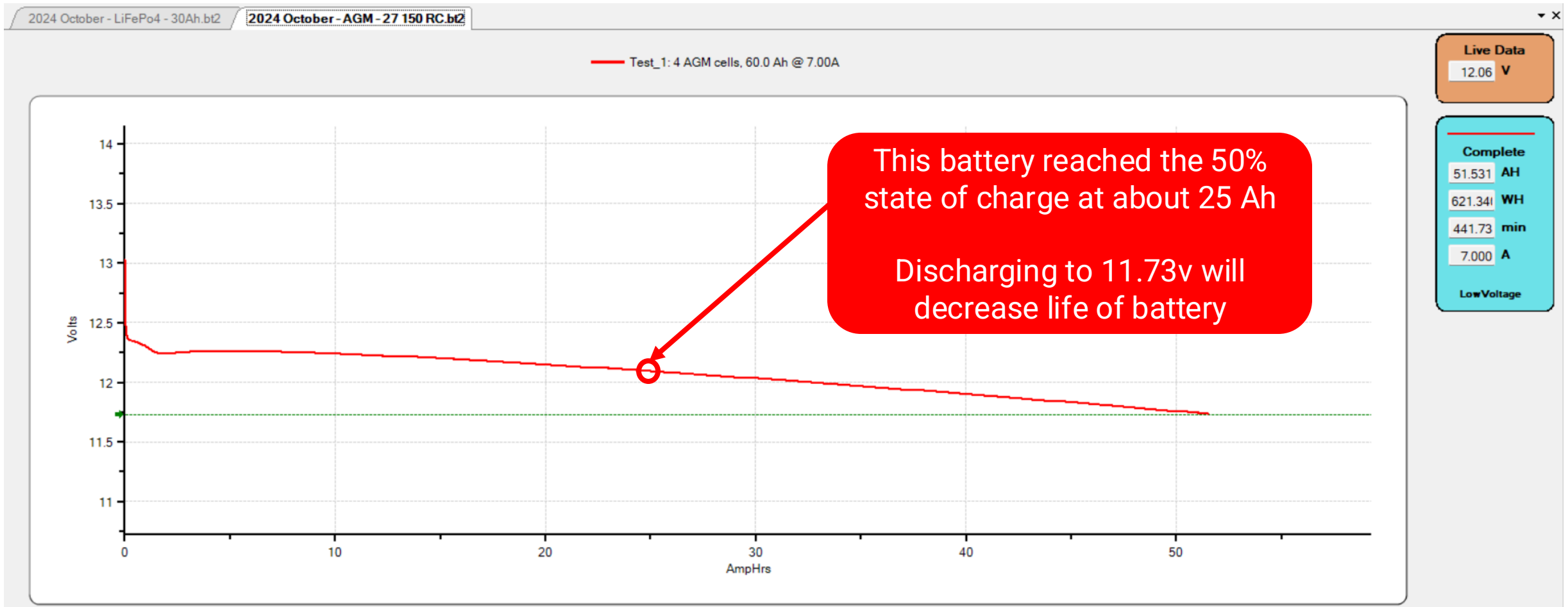
$$Ah = \frac{RC}{60} \times 25$$

$$62.5 Ah = \frac{150}{60} \times 25$$

I only measure 51.5 Ah as I cutoff testing when I pass below 11.73v



# Group 27 Discharge Curve = 7A Load



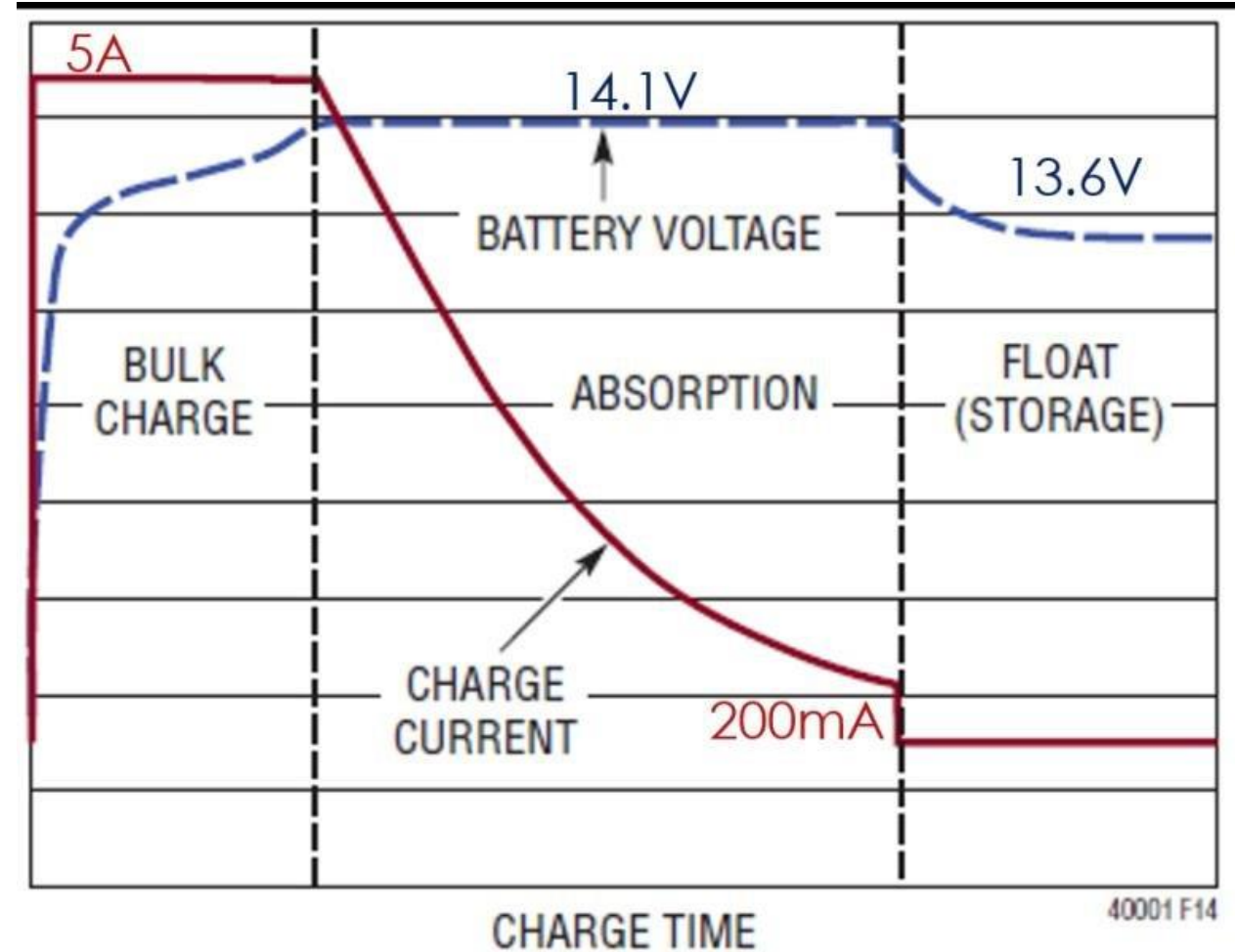
# Lead Acid Battery – Complex Charging Profile

Charging the battery to 80% happens quickly

The last 20% of the charge has to be done at a much slower rate to top off the battery

Specialized chargers are needed to effectively charge these batteries

Charging incorrectly will cause heat and you will boil your battery





## Battery Technologies

# Lithium Ion / Polymer

### Pros

- ~500 Discharge Cycle Lifespan
- Lightweight (high energy density)

### Cons

- Higher Cost
- Risk of Thermal Runaway / Swelling



## Battery Technologies

# Lithium Iron Phosphate

### Pros

- ~3000+ Discharge Cycle Lifespan
- Lightweight (high energy density)
- Able to utilize +90% of the stored energy
- Very Safe / Stable / Durable

### Cons

- Higher Cost





LiFePO4 Batteries

# Bioenno 40 Ah LiFePO4

## Specs

- 10.4 Pounds / 8.4" x 6.3" / 3.2"
- \$359.99
- 40A Max Continuous Discharge
- Peak Discharge 80A (5 seconds)



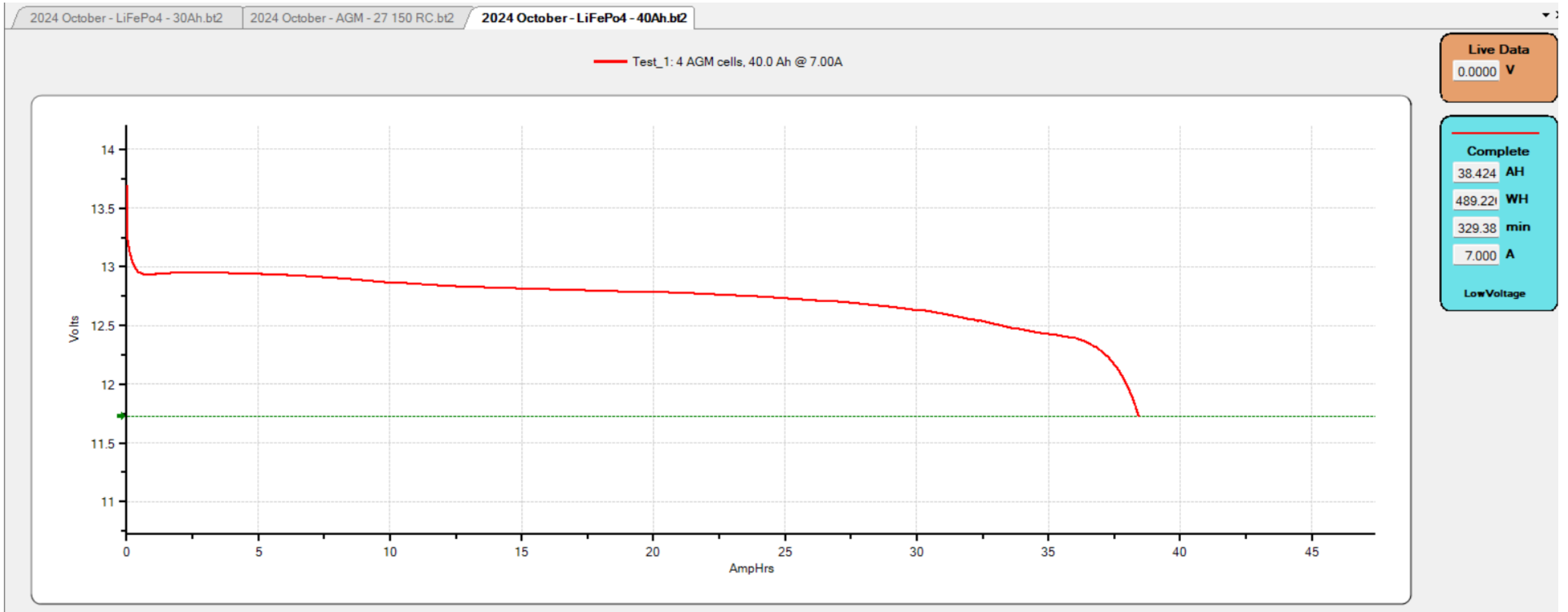
## Power Density

38.4 Ah of Capacity > 11.73 volts

3.7 Ah / Pound Power Density

\$9.38 / Ah

# 40Ah LiFePO4 = 7A Load





# Battery Discharge Curve Comparison

AGM / Lead Acid – Easier to determine State of Charge – Voltage varies throughout the discharge cycle

LiFePO4 – Holds voltage until the end of the capacity



**SAFETY / DURABILITY**

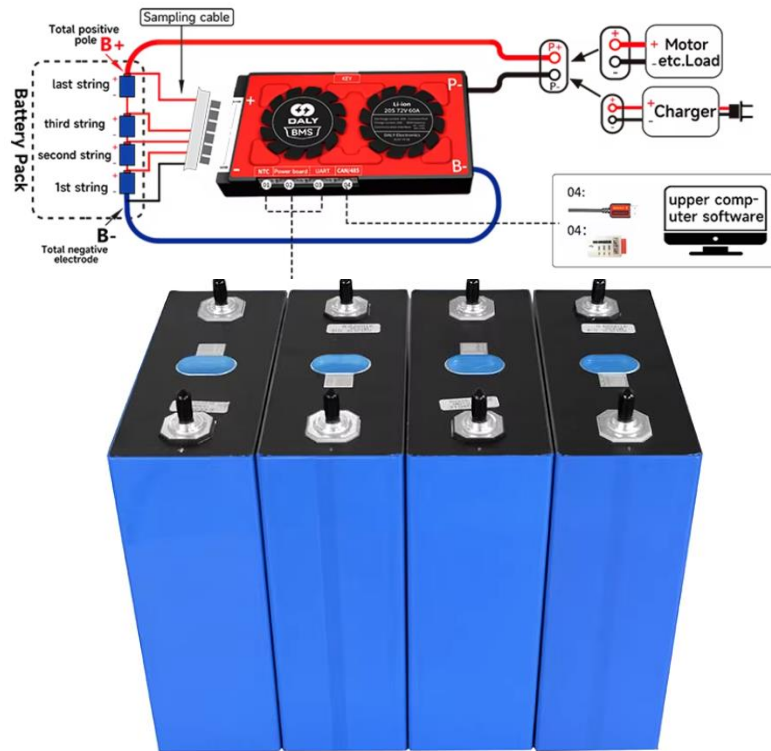


**Performance**



# Anatomy of a Lithium Iron Phosphate Battery

## Battery Management System (BMS)



**3.2V Prismatic Cells**  
**4x = 12.8V (Nominal)**  
**(13.6V-14.4V Fully Charged)**

## Load



## Charger



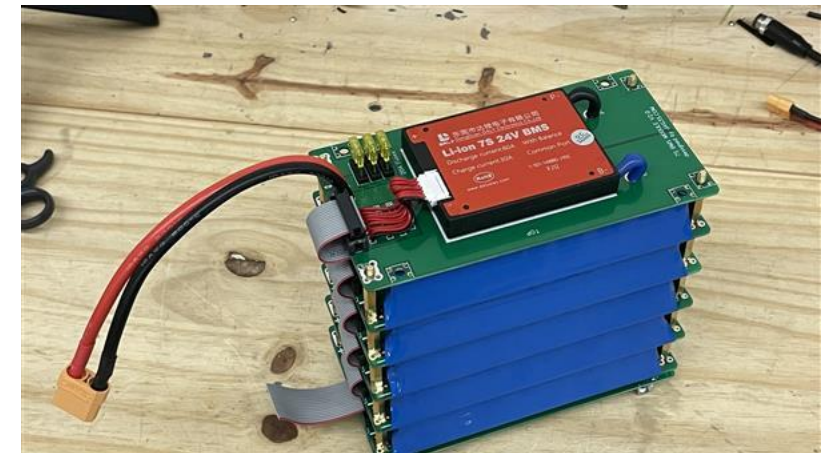
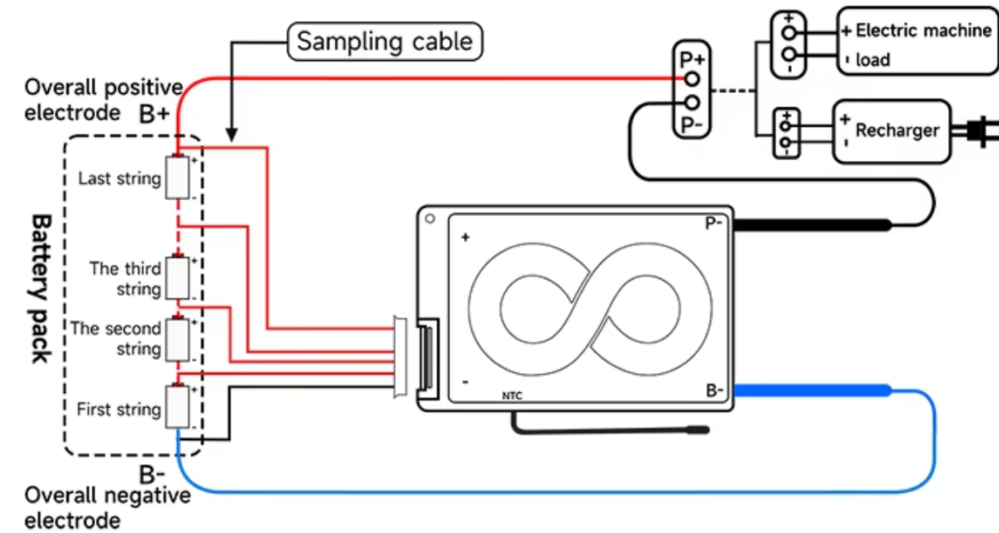
## Anatomy of a LiFePO4 Battery

# Battery Management System

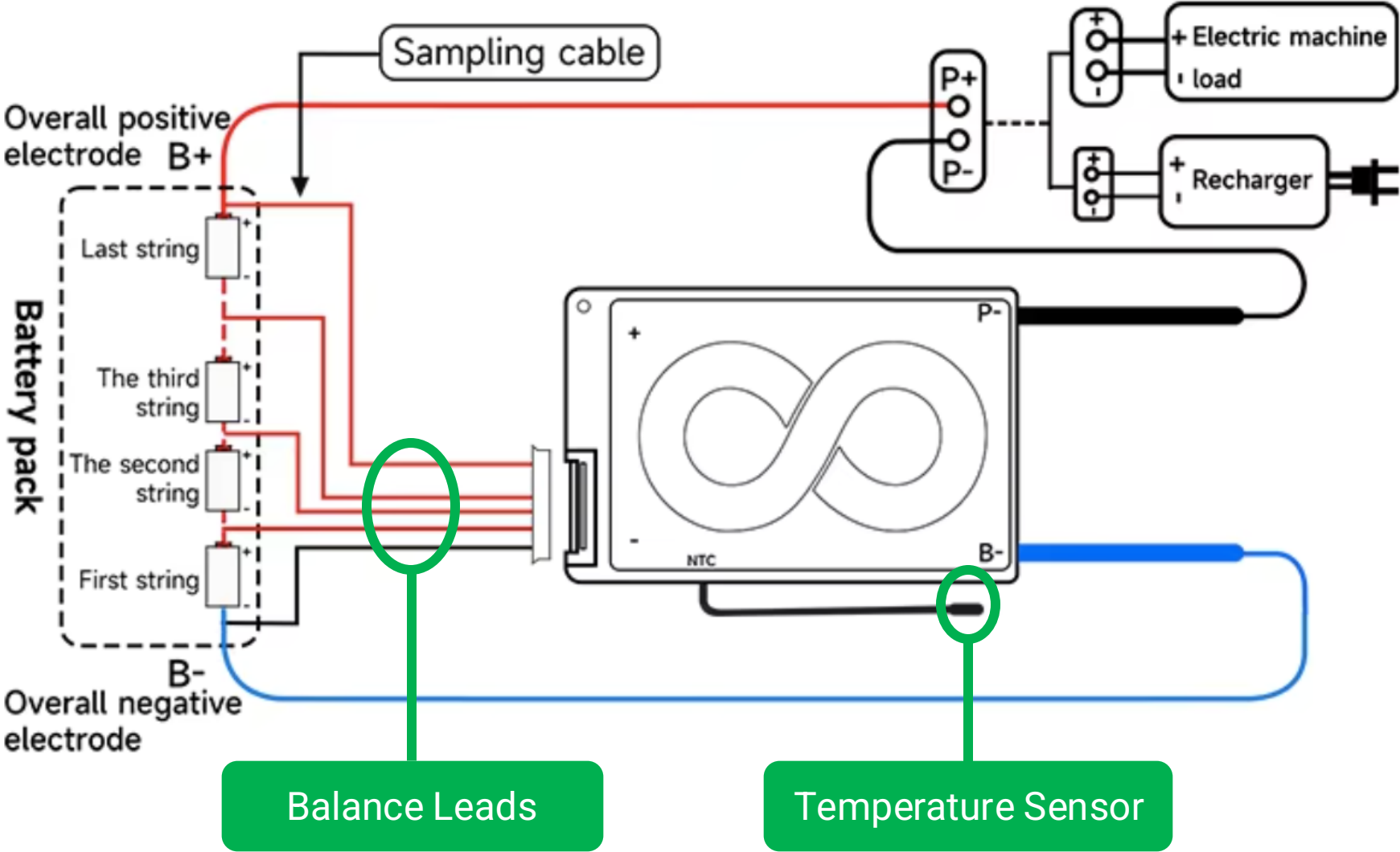
### BMS

- Protects cells against damage
- Protects against over discharge / over charging
- Provides low/high temperature protection
- Monitors operation of cells – Monitors individual cell voltages to try to protect cells and try to maintain consistent SoC (state of charge between all cells)
- Passive Balancing (most common) vs Active Balancing

## DALY BMS



# DALY BMS



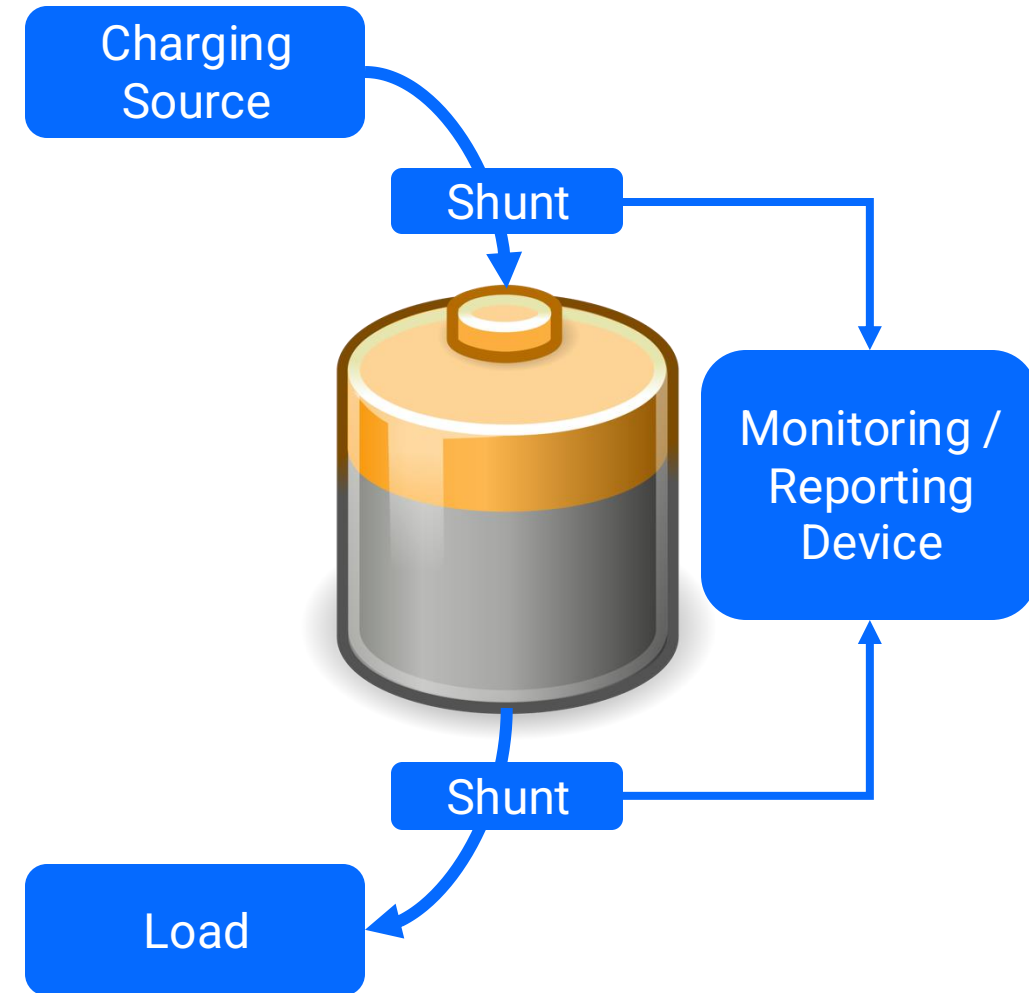


## State of Charge (SoC)

# Coulomb-Count Method

### Coulomb Counting

Provides a relative State of Charge by measuring how much current is put in and taken out of a battery.



## LiFePO4 Chargers

# How to Charge a LiFePO4

### Constant Current / Constant Voltage

LiFePO4 chargers provide a constant voltage of 14.2 to 14.5 volts

Constant current should be regulated based on the size of the battery. Although you can charge at higher rates, to maximize the life span of your battery, it is generally accepted that you should not charge at anything higher than .2C of the batteries rated Ah capacity.

Look for the recommendation of your manufacturer



### 40 Ah Battery

$40 * .2 = 8 \text{ A Charging}$   
Recommended @ 14.2 – 14.5v

Bioenno recommends 6 A charger (they do not have an 8 A model)

## LiFePO4 Chargers

# AC Chargers

### Manufacturer

Review the chargers that the manufacturer recommends for your battery and Ah rating.

### Desktop Power Supplies

Look for a model that can support constant voltage and constant current settings.





LiFePO4 Chargers

# DC-DC Chargers

Charing your LiFePO4 batteries on the go

Allows you to charge your battery while in your car

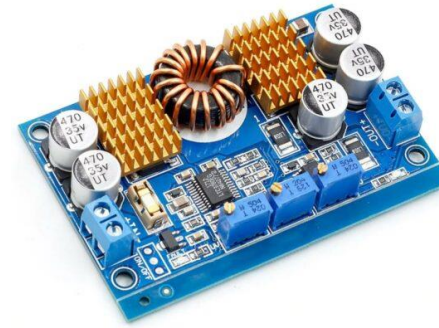


LiFePO4 Chargers

# DIY DC-DC Chargers

## Buck-Boost Converters

Provides a relative State of Charge by measuring how much current is put in and taken out of a battery.



Buck/Boost  
Input Voltage: 5-32V DC  
Output Current Continuous: 8A

\$15



Buck/Boost  
Input Voltage: 10-60V DC  
1800 Watts  
10A Output easy at 14.2 V

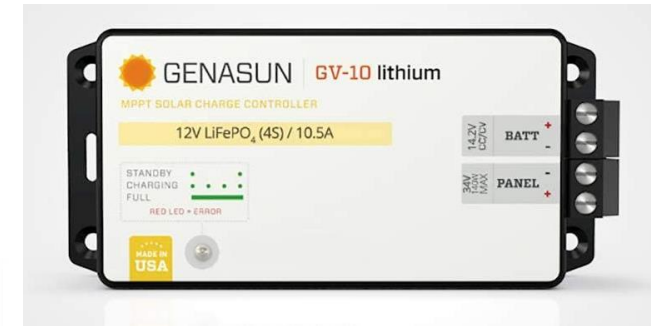
\$19

LiFePO4 Chargers

# Solar Chargers

Charge your battery for off grid use

Solar charge controllers can convert the power from a solar panel to a constant current/constant voltage that is compatible with your LiFePO4 battery



\$135



\$70



\$70



# What Battery is Right for You?

## QRP – 5w/10w



6Ah (3-6 Hours)

\$79.99



12Ah (6-12 Hours)

\$124.99

## QRO – 100w



30Ah (3-6 Hours)

\$279.99



100Ah (9-20 Hours)

\$203.99

# Form Factors – Go Boxes



# Key Take Aways

Do you research – look for reviews – cheap is not always bad...

Look for a battery with the following features

- Low Temperature Disconnect (if you can't get this, never charge when your battery is below 32F)

Charge your battery at .2c when possible

Store your battery for long periods at around 60% State of Charge



# Batteries I have experience with (positive)



**Dakota Lithium**

<https://www.dakotalithium.com>



**Bioenno Power**

<https://www.bioennopower.com>



**Li Time**

<https://www.litime.com>



**CHINS**

**Amazon**

- Made (mostly) in the USA
- Best selection of sizes and form factors
- Lowest cost by a longshot
- Options for batteries with internal heaters for cold climates

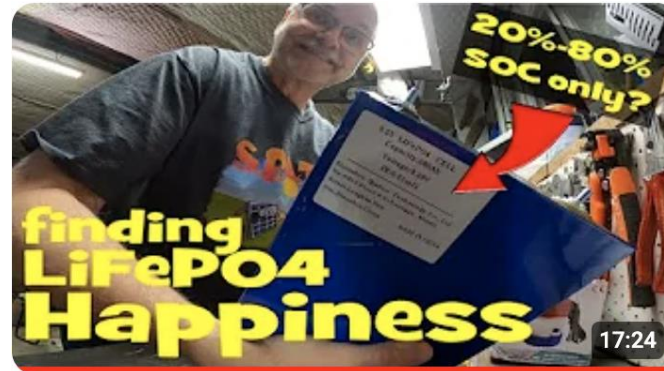
# YouTube Resources



**DIY Solar with Will Prowse**

<https://www.youtube.com/>

[@WillProwse](https://www.youtube.com/@WillProwse)



**Off-Grid Garage**

<https://www.youtube.com/>

[@OffGridGarageAustralia](https://www.youtube.com/@OffGridGarageAustralia)



**Ray Builds Cool Stuff**

<https://www.youtube.com/>

[@RayBuildsCoolStuff](https://www.youtube.com/@RayBuildsCoolStuff)

# Other Resources



**DC-DC Buck/Boost SEPIC Converter**

<https://universal-solder.ca/automatic-dc-dc-sepic-converter-10a/>



**DC-DC Buck/Boost Converter – 1800w**

<https://www.qskj.cc/shop/1941708-dc-dc-converter-1800w-30a-cc-cv-step-up-power-supply-module-qs-4884cccv-1800w-6704>

## Other Companies to Look At

**Victron Energy**

**Renogy**



**Genasun Solar Charge Controllers**

<https://sunforgellc.com/product/gv-10/>

# Other Resources

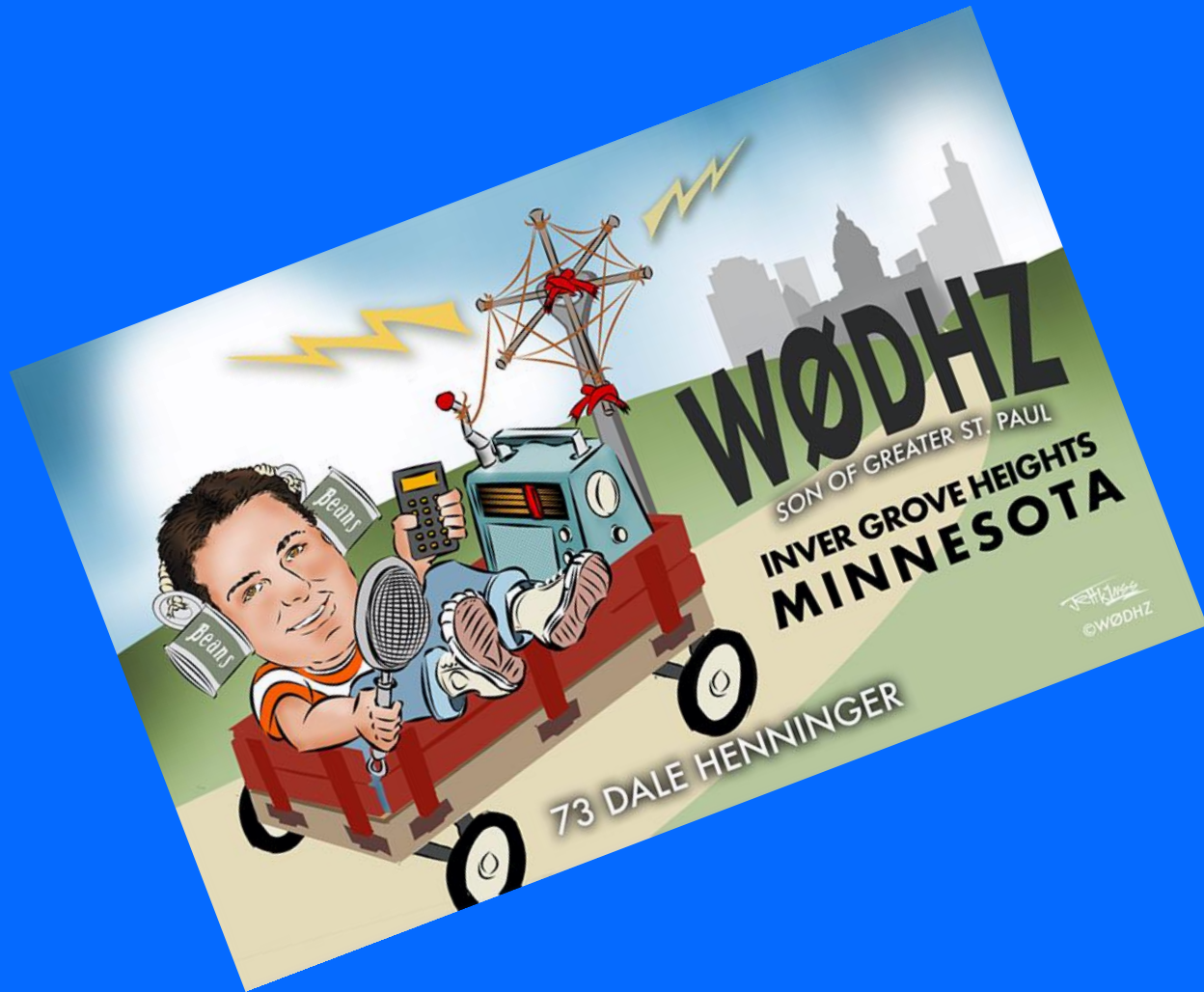
Want to build your own battery?

<https://shop.denco.enterprises/>

The screenshot shows the DenCo Enterprises website. At the top left is the logo for DenCo Enterprises. To the right is a search bar with the text "Search...". Further right are icons for a heart, a person, and a shopping bag. Below the logo is a navigation menu with "All Categories" and links for "Home", "About", "My Account", "Contact Us", "Wishlist", "Cart", and "FAQ". A breadcrumb trail reads "Home / Products / Batteries / DenCo 12V 5.5Ah Flat Pack LiFePO4 Battery". The product page features a "Sale" badge, a "DenCo 12V 5.5Ah Flat Pack LiFePO4 Battery" title, a price of \$84.99 (down from \$104.99), and a description: "Whether it's powering a QRP transceiver, or a 50W VHF/UHF mobile transceiver, this is the battery for you! This unit is a 12-volt 5.5 amp-hour custom hand-built DenCo Battery comprised of four 32650 LiFePO4 cells and a DenCo/Daly common port 20A BMS." The page also indicates "Out of stock" and includes social sharing buttons for Facebook, Twitter, Pinterest, and LinkedIn. A large image shows three batteries on a wooden surface with a soldering iron and a multimeter. Below the main image are three smaller thumbnail images of the battery.



# Thank You!



I hope to see you in my log!

Twitter: [@WØDHZ](https://twitter.com/WØDHZ)

<https://www.youtube.com/@WØDHZ>

<https://www.w0dhz.com>