

Battery Technology and Amateur Radio

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BY TONY GAWEL W6TNY

Batteries

What type of batteries do I need for Amateur Radio?

Do I need an emergency Battery Go-Box?

How long will my battery last?

Is it safe to work with batteries, or can I get shocked?



Be Safe

Safety First

- ▶ Safety Glasses
- ▶ Gloves

<https://youtu.be/VswaFOrVM6I>

Any Lawyers in the room?



Safety

- ▶ **Do this at your own risk?**
- ▶ Never disassemble a battery under any circumstances. The materials in a battery are often toxic and can cause severe burns and can damage your clothing.
- ▶ **Red wire goes to the Positive + Black wire goes to the Negative -**
- ▶ Never use a fuse larger than one that is rated or recommended for your device
- ▶ Do not short circuit a battery by crossing the positive and negative terminals as you can damage the battery and other electrical equipment components. This can cause burns and/or injury to you and those around you.
- ▶ Never throw batteries into a fire as they can split, cause toxic fumes and leak acid.
- ▶ Don't reverse the polarity of the battery or you may damage your equipment and the battery.
- ▶ Don't use old and new batteries together. This can degrade the batteries.
- ▶ **"Always"** charge the battery at the correct voltage and amperage after each use.
- ▶ Don't over-charge the battery as this can damage the battery and cause it to leak.
- ▶ Follow the manufacturers charging procedures.
- ▶ Store batteries in a sealed, cool, dry place when not in use.

Rules

- ▶ Note:
 - ▶ With many rules - there are always exceptions.
 - ▶ There are hybrids and exceptions to all of the examples I am showing in this presentation, but the concepts and information is based on the more common battery types available.

Battery Types

- ▶ Cranking
 - ▶ High current output
 - ▶ Shorter discharge duration
 - ▶ Thinner plates
- ▶ Deep Cycle
 - ▶ Lower current output
 - ▶ Longer duration
 - ▶ Thicker plates
- ▶ Hybrid
 - ▶ This is a balance of the two technologies
 - ▶ Slightly thicker plates
 - ▶ Slightly longer output duration



WHAT IS A CRANKING BATTERY?

- ▶ A cranking battery is the battery that allows a vehicle to start, sending power to the engine starter when the ignition switch is activated.
- ▶ These are also known as starting batteries.
- ▶ These are designed for high current in short bursts of energy.
- ▶ These have many thin plates to increase the surface area for the high current demands.
- ▶ The thin plates are a poor choice for continuous discharge loads.

WHAT IS A DEEP CYCLE BATTERY?

- ▶ This type of battery is designed to provide **continuous**, reliable power.
- ▶ Some times referred as a golf cart, trolling, or RV battery.
- ▶ A deep cycle battery, consists of fewer plates, but those plates are thicker.
- ▶ This allows the battery to provide continuous power output over longer periods of time.
- ▶ It also means that the battery can be entirely drained (not recommended) and recharged many times over, which is not the case with cranking batteries.
- ▶ Deep cycle batteries are also much less likely to overheat since their thicker plate construction can withstand high temperatures during heavy currents.

www.crownbattery.com

DUAL PURPOSE MARINE BATTERIES

- ▶ With many rules - there are always exceptions.
- ▶ There are dual purpose batteries can that can work for both cranking and trolling.
- ▶ Some smaller RV and boats will use these batteries to save space and weight.
- ▶ However, these dual purpose batteries are not necessarily the right solution for most applications.
- ▶ Although they do serve the purpose of reducing maintenance, space, weight, and the number of batteries you need to purchase.
- ▶ Deep cycle batteries are built to withstand many deep discharges and recharges while cranking batteries are not.
- ▶ The compromise is a dual purpose battery, therefore, falls somewhere in between the cranking and deep cycle.
- ▶ Many do not stand up well to total discharges (discharge beyond 50% of usable capacity).

www.crownbattery.com

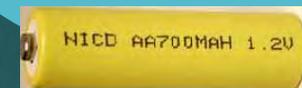
Battery Categories

- ▶ The categories of batteries we use more frequently in Amateur Radio are
 - ▶ Flashlight (Primary Cell)
 - ▶ Rechargeable
 - ▶ High Capacity (Lithium Ion)
 - ▶ Large High Capacity
 - ▶ SLA
 - ▶ LIPO4
 - ▶ Lead Acid Float



Flashlight Battery Types

- ▶ Non Rechargeable
 - ▶ Carbon Zinc (heavy duty) 1.5 v
 - ▶ Alkaline 1.5 v
 - ▶ Lithium Primary 1.5 v (not rechargeable)
- ▶ Rechargeable
 - ▶ NiCad obsolete 1.2 v
 - ▶ Nickle Metal Hydride (NiMh) 1.2 v
 - ▶ Lithium rechargeable Li-ion (later section) 3.7v



Flashlight

- ▶ Non Rechargeable

- ▶ AAA

- ▶ AA

- ▶ C

- ▶ D

- ▶ CR123 Lithium Primary

- ▶ AA, AAA, Lithium Primary (Camera)

- ▶ Rechargeable

- ▶ NiCad

- ▶ NiMh

- ▶ Lithium Polymer (LiPo)

Lithium Rechargeable (LiPo)

- ▶ High energy density
 - ▶ Low internal resistance
 - ▶ Tiny memory
 - ▶ Low self-discharge
 - ▶ +3.6 to 3.7v vs 1.2 to 1.5 v for standard batteries
 - ▶ Requires voltage regulation (14-15 v vs 13.8)
-
- ▶ Lithium Cobalt (LCO) 3.6 v
 - ▶ Lithium Manganese Cobalt Oxide 3.7 v
 - ▶ Lithium Iron Phosphate 3.2 v

LiPo Batteries

- ▶ The batteries will hold their charge longer compared to other rechargeable batteries
- ▶ They only lose about 5 percent a month. (20 percent NiMh)
- ▶ They don't have the same memory like other rechargeable batteries
- ▶ They can handle hundreds of charge and discharge cycles.

Lithium Cobalt (LCO) (LiPO) 3.6 v

- ▶ RC drones, planes, laptops, smart devices
 - ▶ High energy (**Caution**)
 - ▶ Limited Load but higher current
 - ▶ Lower thermal stability (can catch fire) especially if damaged
 - ▶ Shorter lifespan
 - ▶ Li-cobalt should not be charged and discharged at a current higher than its C-rating
 - ▶ Being replaced by other chemistries

Lithium Cobalt

Lithium Cobalt Oxide: LiCoO_2 cathode (~60% Co), graphite anode
Short form: LCO or Li-cobalt.

Since 1991

| | |
|-----------------------------------|---|
| Voltages | 3.60V nominal; typical operating range 3.0–4.2V/cell |
| Specific energy (capacity) | 150–200Wh/kg. Specialty cells provide up to 240Wh/kg. |
| Charge (C-rate) | 0.7–1C, charges to 4.20V (most cells); 3h charge typical. Charge current above 1C shortens battery life. |
| Discharge (C-rate) | 1C; 2.50V cut off. Discharge current above 1C shortens battery life. |
| Cycle life | 500–1000, related to depth of discharge, load, temperature |
| Thermal runaway | 150°C (302°F). Full charge promotes thermal runaway |
| Applications | Mobile phones, tablets, laptops, cameras |
| Comments | Very high specific energy, limited specific power. Cobalt is expensive. Serves as Energy Cell. Market share has stabilized. |

Lithium Manganese Cobalt Oxide 3.7 v

- ▶ Low internal cell resistance
- ▶ Faster charging
- ▶ High discharge currents 20-30 A
- ▶ Power tools, medical equipment, and electric vehicles

Lithium Manganese Cobalt Oxide

Lithium Manganese Oxide: LiMn_2O_4 cathode, graphite anode
Short form: LMO or Li-manganese (spinel structure)

Since 1996

| | |
|-----------------------------------|---|
| Voltages | 3.70V (3.80V) nominal; typical operating range 3.0–4.2V/cell |
| Specific energy (capacity) | 100–150Wh/kg |
| Charge (C-rate) | 0.7–1C typical, 3C maximum, charges to 4.20V (most cells) |
| Discharge (C-rate) | 1C; 10C possible with some cells, 30C pulse (5s), 2.50V cut-off |
| Cycle life | 300–700 (related to depth of discharge, temperature) |
| Thermal runaway | 250°C (482°F) typical. High charge promotes thermal runaway |
| Applications | Power tools, medical devices, electric powertrains |
| Comments | High power but less capacity; safer than Li-cobalt; commonly mixed with NMC to improve performance. |

Lithium Iron Phosphate

(LiFePO₄) LFP 3.2 v

- ▶ Li-phosphate offers good electrochemical performance with low resistance.
- ▶ The key benefits are high current rating and long cycle life, besides good thermal stability, enhanced safety and tolerance if abused.
- ▶ Li-phosphate is more tolerant to full charge conditions and is less stressed than other lithium-ion systems
- ▶ One important advantage over other lithium-ion chemistries is thermal and chemical stability, which improves battery safety
- ▶ As a trade-off, its lower nominal voltage of 3.2V/cell reduces the specific energy below that of cobalt-blended lithium-ion.
- ▶ Li-phosphate has a higher self-discharge than other Li-ion batteries, which can cause balancing issues with aging.

Lithium Iron Phosphate (LiFePO_4)

Lithium Iron Phosphate: LiFePO_4 cathode, graphite anode
Short form: LFP or Li-phosphate

Since 1996

| | |
|-----------------------------------|---|
| Voltages | 3.20, 3.30V nominal; typical operating range 2.5–3.65V/cell |
| Specific energy (capacity) | 90–120Wh/kg |
| Charge (C-rate) | 1C typical, charges to 3.65V; 3h charge time typical |
| Discharge (C-rate) | 1C, 25C on some cells; 40A pulse (2s); 2.50V cut-off (lower than 2V causes damage) |
| Cycle life | 1000–2000 (related to depth of discharge, temperature) |
| Thermal runaway | 270°C (518°F) Very safe battery even if fully charged |
| Cost | ~\$580 per kWh (Source: RWTH, Aachen) |
| Applications | Portable and stationary needing high load currents and endurance |
| Comments | Very flat voltage discharge curve but low capacity. One of safest Li-ions. Used for special markets. Elevated self-discharge. |

Higher Capacity Batteries

- ▶ Lead Float (car and marine)
- ▶ Gel Cell (aviation)
- ▶ Sealed Lead Acid (SLA/ AGM) (UPS and Alarm)
- ▶ Lithium Cobalt Phosphate (New)
- ▶ Lithium Iron Phosphate (New)

Battery Capacity Measurements

- ▶ Voltage
 - ▶ Can provide an estimate on how much charge is left in the battery
- ▶ Amperage or Milliamps (ma)
 - ▶ How much power is being drawn out of the battery
- ▶ Battery Capacity Rating
 - ▶ Amp Hour (ah)
 - ▶ Cold Cranking Amp (cca)
 - ▶ Now the industry is using a newer "C" rating
 - ▶ There is a C rating is for both Charge and discharge
 - ▶ Charge rates
 - ▶ Discharge rates

Important: for safety and longevity of the batteries

Do not exceed the C rating on charge or discharge

C Rate

- ▶ Battery manufacturers specification sheets and labeling often list a batteries C ratings.
- ▶ To calculate the charge and discharge rate you would multiply a batteries capacity by the C rate
- ▶ which multiply the battery's rated capacity. If a battery with a 3000mAh capacity has a 2C rating, you can discharge it at 6A, or twice its rated capacity. Discharging above the rated value or for an extended period can lead to reduced battery life or cell failure.

Lead Acid Charge Level

| Voltage | State of Charge |
|---------|-----------------|
| 12.6+ | 100% |
| 12.5 | 90% |
| 12.42 | 80% |
| 12.32 | 70% |
| 12.20 | 60% |
| 12.06 | 50% |
| 11.9 | 40% |
| 11.75 | 30% |
| 11.58 | 20% |
| 11.51 | 10% |
| 10.5 | 0% |

SLA Charge Level

| AGM BATTERY STATE OF CHARGE | |
|-----------------------------|---------|
| Level | Voltage |
| 100% | 13.00V |
| 90% | 12.75V |
| 80% | 12.50V |
| 70% | 12.30V |
| 60% | 12.15V |
| 50% | 12.05V |
| 40% | 11.95V |
| 30% | 11.81V |
| 20% | 11.66V |
| 10% | 11.51V |
| 0% | 10.50V |

LiPo Charge Level

- ▶ Depends on the type of BCM

| % Capacity | 1S Cell | 2S Pack | 3S Pack | 4S Pack | 5S Pack | 6S Pack |
|------------|---------|---------|---------|---------|---------|---------|
| 100 | 4.20 | 8.40 | 12.60 | 16.80 | 21.00 | 25.20 |
| 95 | 4.15 | 8.30 | 12.45 | 16.60 | 20.75 | 24.90 |
| 90 | 4.11 | 8.22 | 12.33 | 16.45 | 20.56 | 24.67 |
| 85 | 4.08 | 8.16 | 12.25 | 16.33 | 20.41 | 24.49 |
| 80 | 4.02 | 8.05 | 12.07 | 16.09 | 20.11 | 24.14 |
| 75 | 3.98 | 7.97 | 11.95 | 15.93 | 19.92 | 23.90 |
| 70 | 3.95 | 7.91 | 11.86 | 15.81 | 19.77 | 23.72 |
| 65 | 3.91 | 7.83 | 11.74 | 15.66 | 19.57 | 23.48 |
| 60 | 3.87 | 7.75 | 11.62 | 15.50 | 19.37 | 23.25 |
| 55 | 3.85 | 7.71 | 11.56 | 15.42 | 19.27 | 23.13 |
| 50 | 3.84 | 7.67 | 11.51 | 15.34 | 19.18 | 23.01 |
| 45 | 3.82 | 7.63 | 11.45 | 15.26 | 19.08 | 22.89 |
| 40 | 3.80 | 7.59 | 11.39 | 15.18 | 18.98 | 22.77 |
| 35 | 3.79 | 7.57 | 11.36 | 15.14 | 18.93 | 22.72 |
| 30 | 3.77 | 7.53 | 11.30 | 15.06 | 18.83 | 22.60 |
| 25 | 3.75 | 7.49 | 11.24 | 14.99 | 18.73 | 22.48 |
| 20 | 3.73 | 7.45 | 11.18 | 14.91 | 18.63 | 22.36 |
| 15 | 3.71 | 7.41 | 11.12 | 14.83 | 18.54 | 22.24 |
| 10 | 3.69 | 7.37 | 11.06 | 14.75 | 18.44 | 22.12 |
| 5 | 3.61 | 7.22 | 10.83 | 14.43 | 18.04 | 21.65 |
| 0 | 3.27 | 6.55 | 9.82 | 13.09 | 16.37 | 19.64 |

Stay in the white region for maximum pack longevity

Battery Charging

▶ Low and Slow (12-16 hours)

- ▶ Check manufacturer of the battery for
 - ▶ Charge
 - ▶ Discharge specifications
- ▶ Smart Chargers
 - ▶ Take much of the guess work out of using the correct charging voltage and amperage
 - ▶ They also have multiple charging levels to protect the battery from damage and provide long life
 - ▶ Some chargers come with a desulfation mode

Battery Charging

- ▶ Lead Acid (3 stage)

- ▶ Constant current, constant voltage Bulk (CC/CV)
- ▶ Float charge
- ▶ about 13.8 to 14.4 v Float 13.2 - 13.4
- ▶ 12 to 16 hours

- ▶ SLA /AGM

- ▶ Constant voltage variable current bulk (multi-stage)
- ▶ Absorption
- ▶ Float
- ▶ Sensitive to overcharging
- ▶ Multi stage charger to reduce over heating and prevent gassing (Optional disulfate)
- ▶ Charge 14.4 Float 13.5 - 13.8 v

(don't over charge)

- ▶ LiPo

- ▶ Constant Current Constant Voltage
- ▶ Some come with built in PCM protection circuit module in the battery to protect from over charging and discharging the battery along with equalizing the cells

▶ (don't over charge)

Charging

- ▶ Flooded Lead Acid
 - ▶ Constant current, constant voltage (CC/CV)
 - ▶ about 13.8 to 14.4 v Float 13.2 - 13.4
 - ▶ 12 to 16 hours
- ▶ AGM
 - ▶ Sensitive to overcharging
 - ▶ Multi stage charger to reduce over heating and prevent gassing
 - ▶ Charge 14.4 Float 13.5 - 13.8 v



Proper Charging

- ▶ Single stage charger
 - ▶ Single output charge voltage and no shut off when fully charged
 - ▶ Can overcharge battery
 - ▶ Cause overheating
 - ▶ Premature battery failure



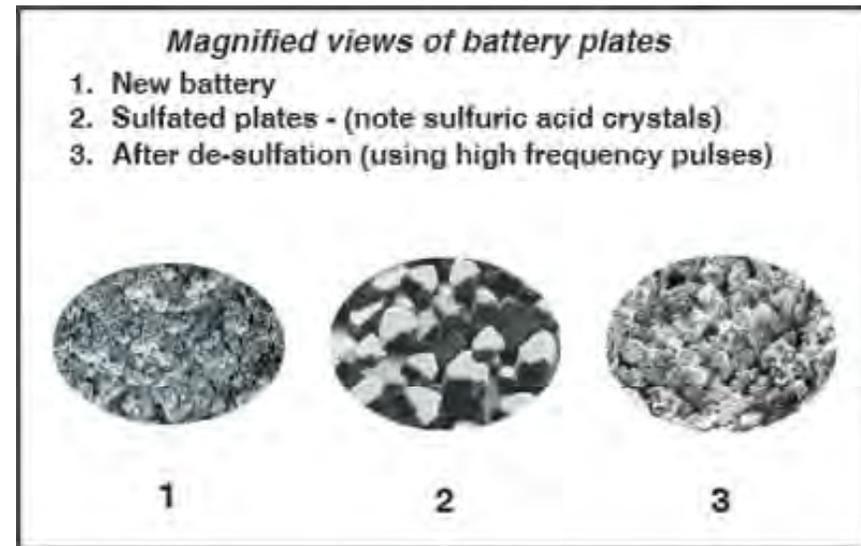
Charging

- ▶ Multistage Charger (Low and Slow)
 - ▶ Bulk
 - ▶ Additional Stages
 - ▶ Trickle
 - ▶ Float
 - ▶ De-sulfate



Sulfating/ Desulfating

- ▶ Batteries over time will sulfate and build up a layer of sulfur on the plates.
 - ▶ Causes
 - ▶ If they are not properly charged
 - ▶ Over charged
 - ▶ Under charged
 - ▶ Left uncharged
 - ▶ Age



Sulfating/ Desulfating

- ▶ This leads to
 - ▶ Loose of capacity
 - ▶ Taking longer to recharge
 - ▶ Battery discharges quicker
 - ▶ Battery gets hot during charges
- ▶ Smart charger often have a desulfating mode to recondition and remove the build up of sulfur on the plates by sending a pulse charge to the battery.

Battery Testing

- ▶ You only need to test your battery if
 - ▶ It begins to show signs of ageing
 - ▶ If you want to know how much life is left
 - ▶ If you pick up surplus batteries and don't know the age or capacity of the battery

Battery Testers

▶ Battery Tester

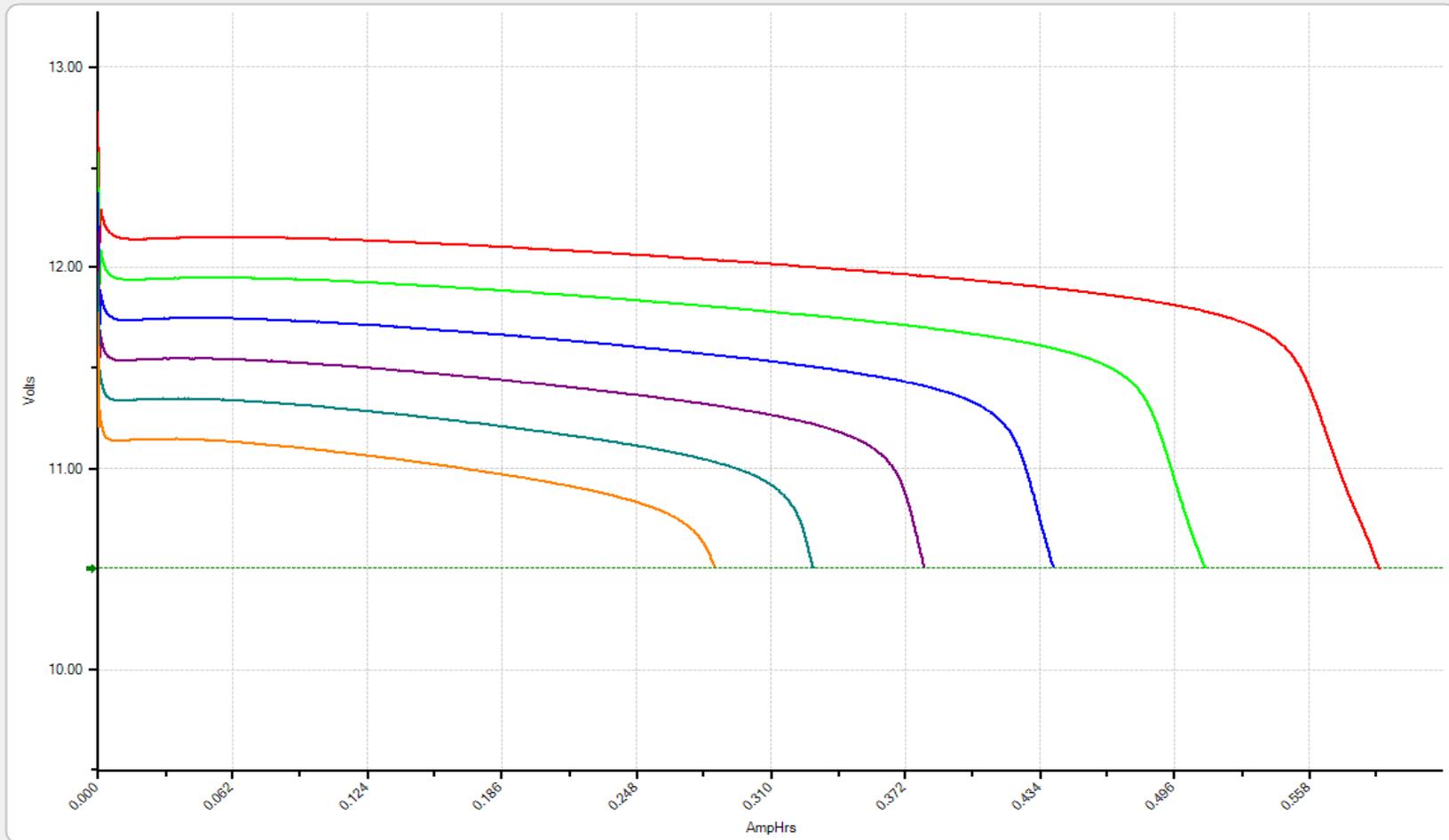
▶ West Mountain



West Mountain CBA

West Mountain Radio - Computerized Battery Analyzer (CBA)

Fresh: 6 Lead Acid cells, 1.0 Ah @ 0.40A Run2: 6 Lead Acid cells, 1.0 Ah @ 0.40A Run3: 6 Lead Acid cells, 1.0 Ah @ 0.40A
Run4: 6 Lead Acid cells, 1.0 Ah @ 0.40A Run5: 6 Lead Acid cells, 1.0 Ah @ 0.40A Run6: 6 Lead Acid cells, 1.0 Ah @ 0.40A



Battery Sources

- ▶ Amazon
- ▶ Electronic Surplus
- ▶ Alarm Companies
- ▶ Companies with Large UPS systems
- ▶ Telephone companies
- ▶ Government agencies
- ▶ Motorcycle LiPo
- ▶ Golf Carts for the larger batteries
 - ▶ Careful some batteries are higher voltage

LiPo Suppliers

- ▶ Bioenno LiPo4
 - ▶ <https://www.bioennopower.com/>
 - ▶ Amazon
 - ▶ HRO
- ▶ Zippy LiFe
 - ▶ ZIPPY Flightmax 8400mAh 4S2P LiFePo4 Pack
- ▶ K2 Energy LiFe ?
 - ▶ <https://k2battery.com/product/k2-lithium-ion-energy-battery-2/>
- ▶ Shorai Power Powersports Batteries
 - ▶ <https://shorai.com/batteries-c41>
- ▶ Western Power Sports
 - ▶ <https://www.wps-inc.com/>
- ▶ Relion
 - ▶ <http://relionbattery.com/products/lithium>



Questions?

THANK YOU