Lithium Ion Batteries for You

Things to consider to be successful with Lithium Ion systems

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What is Lithium Ion About?

Getting light weight, smaller volume, higher power sources

- Lithium Iron Phosphate Chemistry
  LiFePo4 cells are the most commonly found lithium ion battery technology in consumer devices. They don't work 'well' in extreme cold, and like all lithium ion chemistries will degrade in very high heat environments. They have a higher range of temperatures, and they do not decay very fast when being kept at 100% charge capacity. That makes them very attractive for general use. This is what you most likely want to use.

- Nickel-Manganese-Cobalt (NMC) and Nickel-Cobalt-Aluminum (NCA) Chemistries
  These chemistries are found in higher current use environments. Performance Lithium Ion battery systems are in higher performance EVs and in some types of power brick applications. These do not like to be kept outside of a 20% to 80% charge state without some decay in capacity over time.

- Your Cell phones will have NMC/NCA batteries due to higher power densities. Some devices don't charge to 100% unless you request it because they are these chemistries that don't like 100% charge.

What about NiCd and NiMH?

Do you still use old rechargeable batteries?

- NiCd (high current in and out) and NiMH (no memory like NiCd) batteries still have some uses because they have charge and discharge curves that are applicable to specific uses.

- Toyota and Honda use NiMH in some of their base Hybrids.

Feature	NiCd	NiMH
Durability	Very high	High
Temperature Tolerance	Excellent (cold + hot)	Good
Cost	Low	Moderate
Charging Simplicity	Robust to overcharging	Better than Li-ion
Memory Effect	Present	Less than NiCd
Cycle Life	1000+ cycles	500–1000 cycles
Self-Discharge	High	Moderate

What’s the real value here?

Higher Energy Density

- **More power in less space and weight**.
- Example: A Li-ion battery can offer **2–3x the runtime** of an equivalently sized NiMH or NiCd pack.
- Ideal for **cordless tools**, **portable devices**, **electric vehicles**, etc.

Lower Self-Discharge

- Holds a charge for **months**, even when idle.
- Compare:
  - **NiCd**: ~10–15% per month
  - **NiMH**: ~20–30% per month (standard)
  - **Li-ion**: ~2–5% per month
- Perfect for **standby**, **emergency gear**, or **infrequent-use tools**.

No Memory Effect

- Li-ion can be **recharged at any time**, without degrading capacity.
- NiCd and (to a lesser extent) NiMH **need full discharges** occasionally to prevent capacity loss.

Faster Charging

- Can charge in **half the time** or better, depending on the charger.
- Important for **production**, **service**, or **field-use cycles**.

What Is Really Better?

Smart Battery Features

- Built-in Battery Management Systems (BMS) allow:
  - Overcharge/discharge protection
  - Temperature monitoring
  - Cell balancing
  - Health/status reporting
- Improves safety and extends life.

Better Long-Term Cost

- **Higher up-front**, but **lower total cost of ownership** due to:
  - Longer cycle life
  - Reduced replacements
  - Lower energy loss
- In many applications, you can **downsize the battery** because of better energy density.

Regulatory and Environmental Compliance

- **No toxic cadmium** (as in NiCd)
- Easier to ship, recycle, and comply with global safety/environmental laws
- Increasingly **mandated** in certain industries and product categories

Lithium Ion Chemistry Comparison

Feature	**NiCd**	**$LiFePO_4$ (LFP)**	**NMC ($LiNiMnCoO_2$)**	**NCA ($LiNiCoAlO_2$)**
Energy Density (Wh/kg)	40–60	90–120	150–220	200–260
Cycle Life	1000–2000	2000–6000+	1000–20	500–100
Voltage per Cell (V)	1.2	3.2–3.3	3.6–3.7	3.6–3.7
Self-Discharge (per month)	10–20%	<2–3%	\~2–3%	\~2–3%
Temperature Tolerance	Excellent (-40°C to +60°C)	Good (-20°C to +60°C)	Moderate (-10°C to +50°C)	Moderate (-10°C to +50°C)
Safety	Good (can handle abuse)	Excellent (very stable, doesn’t burn)	Moderate (needs BMS)	Lower (needs robust BMS)
Memory Effect	Strong	None	None	None
Toxicity	**High (Cadmium is toxic)**	Non-toxic	Moderate (Cobalt use)	Moderate (Cobalt, Aluminum)
Cost per Wh	High	Low to moderate	Moderate	Moderate to high
Power Delivery	Excellent	Good	Very Good	Very Good
Applications	Legacy aviation, radios, tools	Solar, EVs, energy storage, marine	EVs, power tools, consumer devices	EVs (Tesla), aerospace

Battery Capacity and Power Rating

Stuff you probably already know about

- The power capacity of a battery is the wattage (amps * volts) that it can provide instantaneously.
  - An extended period of time at this wattage is sustainable.
  - Too much power out can create problems!
- The energy capacity of a battery is the kWh capacity. In small power systems, this is often just expressed as Ah of a particular voltage battery.
  - Amps * Volts = Watts of power.
  - Watts over a period of time is watt-hours or kWh for large systems where units of 1000 is a more convenient number to work with.
  - EVs batteries are expressed in kWh. The power used from the battery varies by what's using it. Voltage converters provide what's needed out of a 400v, 800v or higher battery system. Motors may be 400volts or 800volts while accessories are 12v (or 48v like Tesla is moving to for smaller wires and less copper).

Battery Charging and Output

Maximum rates are based on chemistry and temperature

- Battery charging in 1 hour is the 1C rating. If a battery can be charged in 30min, it would require a 2C power rate. Faster than that often requires intervention with active cooling. The output current available is 1C if the battery would last 1 hour at it's Ah rating. 10Ah battery should last 1 hour, providing 10amps out, for a 1C power output rate.

- Look for and pay attention to the maximum power rating out and into a battery. Large wattage in or out will require large conductors. Bus bars and/or large diameter wire are visible in large power systems.

- In an old telephone switching center, it was not unusual to see large scale 48v battery systems and 2" wide by 10" tall or larger copper bus bars running above switching equipment. The amount of current was large to power phones at everyones homes.

Solar Charging

Chargers are chemistry specific and the mode of charging is important!

- There are multiple types of Lithium Ion Solar powered chargers. MPPT (Maximum Power Point Tracking) chargers will try to draw constant power from solar cells by optimizing voltage and amperage drawn to be able to reach charging voltage, at whatever current is available, into the battery. MPPT takes whatever wattage it can pull, and then does voltage conversion to charging voltage and outputs that voltage with the resulting amount of current. This allows it to charge much of the time that a simple voltage bucking charger would not be at sufficient voltage to charge.

Lithium Ion Cells in Temperature Extremes

How do you keep your battery systems healthy

- Keeping your battery systems at reasonable temperatures of 40F to 110F is best for them.
- By Chemistry type, these are the ranges of temperatures to keep your battery
  - LiFePo4 = -20°C to +60°C ==> -4F to 140F
  - NMC = -10°C to +50°C ==> 14F to 122F
  - NCA = -10°C to +50°C ==> 14F to 122F
- Colder temperatures increase internal resistance. When you use batteries at these temperatures, you get less power out, and the resistance increases the total power used. Charging happens slower, and without adequate battery management systems, you need to be warming your battery before charging it yourself. The term lithium-plating is the mechanism where in extreme cold, the lithium metal will be transferred to the opposite poles of the battery instead of just electrons and this damages the battery.
- Hotter temperatures near 40C or 104F provide best performance of power transfer into and out of the batteries. Sustained higher temperatures do increase the rate of degradation of battery capacity.

Battery Management Systems

The BMS is your friend that can save your battery system

- The Battery Management System term refers to microcontroller/microprocessor technologies that are part of a the battery system operations.
- The consumer battery packages that are available as replacements for existing batteries in cars, boats and other related uses, have a BMS that provides safe, effective charging. The features of a BMS include
  1. Low temp. charging cut off (plugging in the charger results in no charging)
     - Power out will be reduced in colder temps due to increased resistance.
  2. High temp power out cut off (phone turns off in direct sun light)
     - High power draw may overheat battery
  3. Low charge state power out cut off (battery just turns off)
     - Charger needs to be able to meet the power draw plus additional power for charging if you want to create a UPS like function
  4. Automated battery heating in cold temperatures to maintain charging functionality and use without reduced power out.
  5. Automated battery cooling in high power draws or fast charging.

Battery System Prices and Features

Advertising is everywhere, beware of the details

- There are only a few lithium battery system companies selling “cells” to battery builders.
- Competition on price will happen based on “package” and “BMS” in general because everyone is buying cells for the same relative prices for any battery systems available at some moment in time.
- Tariffs are control availability and pricing because most battery cells are coming from overseas.
- Be wary of BMS features and “Bluetooth Accessibility” claims. Looks for people who are using the battery you are using. Save a copy of the description of your battery when you purchase it.

Battery Vendors

- There is a wide range of Battery companies world wide doing battery system construction using various battery cell companies products.

- I’ve started a ChatGPT session at this URL which has lots of information to read. You can also ask it more questions that you have to see what public information it has to share. The take away from using ChatGPT for things like this, is that you can get company names and some more technical information about battery chemistry attributes.

https://chatgpt.com/share/6875d5a4-0044-8000-aa0c-73957680d3f6

Links

1. General Lithium Ion Chemistry Details:
   - https://batteryuniversity.com/article/bu-205-types-of-lithium-ion
2. Lithium Plating
   - https://www.sciencedirect.com/science/article/abs/pii/S0360128521000514
3. Operating Temperatures
   - https://amprius.com/about/news-and-events/operating-temperature/
4. Charge Controllers:
   - https://www.youtube.com/watch?v=yLGHefSs5UA
5. Ham Radio Solutions:
   - https://www.westmountainradio.com/product_info.php?products_id=iso_pwr
   - https://www.westmountainradio.com/product_info.php?products_id=epic-pwrgate
   - https://www.westmountainradio.com/product_info.php?products_id=pg40s
   - https://www.westmountainradio.com/product_info.php?products_id=battery-boost
   - https://www.westmountainradio.com/product_info.php?products_id=pwr_guard
   - https://www.westmountainradio.com/product_info.php?products_id=pwrcheck
6. ChatGPT session on lithium ion battery details
   - https://chatgpt.com/share/6875d5a4-0044-8000-aa0c-73957680d3f6