Lithium Ion/Polymer Battery Assembly Design and Trends

Presented by Brion Munsey
Western Regional Sales Manager
○ Cell Types
○ Safety Circuits
○ Charging
○ Storage
○ Shipping/RoHs
○ Qualifying Assemblers
Cell Types:
- Cobalt based
- Manganese (Spinel)
- Nickel-Cobalt Manganese
- Polymer
- A123 Nanophosphate

New Developments:
- Capacity Improvements
- Lower Costs
- Hi Drain Cells
- Safer Cells
Lithium Ion Advantages

- High energy density - potential for yet higher capacities.
- Does not need prolonged priming when new. One regular charge is all that's needed.
- Relatively low self-discharge - self-discharge is less than half that of nickel-based batteries.
- Low Maintenance - no periodic discharge is needed; there is no memory.
- Specialty cells can provide very high current to applications such as power tools.
Lithium Ion Limitations

- Requires protection circuit to maintain voltage and current within safe limits.
- Subject to aging, even if not in use - storage in a cool place at 40% charge reduces the aging effect.
- Transportation restrictions - shipment of larger quantities may be subject to regulatory control.
- Expensive to manufacture - about 40 percent higher in cost than nickel-cadmium.
- Not fully mature - metals and chemicals are changing on a continuing basis.
Lithium Polymer Advantages

- Very low profile - batteries resembling the profile of a credit card are feasible.

- Flexible form factor - manufacturers are not bound by standard cell formats. With high volume, any reasonable size can be produced economically.

- Lightweight - gelled electrolytes enable simplified packaging by eliminating the metal shell.

- Improved safety - more resistant to overcharge; less chance for electrolyte leakage.
Lithium Polymer Limitations

- Lower energy density and decreased cycle count compared to lithium-ion.
- Expensive to manufacture.
- No standard sizes. Most cells are produced for high volume consumer markets.
- Higher cost-to-energy ratio than lithium-ion
○ Series:
  ● Up to four cells/groups in series (14.4V to 14.8V) standard. More than four cells custom requiring cell balancing.

○ Issues with 5S to 10S Cell Strings
  ● Cell balancing required
  ● Extra components and custom design increase cost and development time.

○ FIFO (stock rotation) of cells Important practice
  ● Cells lose capacity permanently if stored too long
Safety Circuit Features:

- **Overcharge Protection**
  - Limit the charge voltage to 4.30V/cell

- **Overdischarge Protection**
  - Designed to cut off the current path if the battery is discharged below 2.50V/cell

- **Overcurrent Protection**
  - Discharge is stopped when output terminals are shorted

- **Temperature Sensing**
  - Disconnects the charge if the cell temperature approaches 90°C (194°F)
Charging:

- Always use a CC/CV charger designed specifically for use with your particular Li-ion or Li-Poly battery
Storage:

- Batteries should be stored at room temperature at about 30% to 50% of capacity. Batteries should be charged about once a year to prevent over discharge if not being used.

<table>
<thead>
<tr>
<th>Storage Temperature</th>
<th>40% Charge</th>
<th>100% Charge</th>
</tr>
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<tbody>
<tr>
<td>0 °C (32 °F)</td>
<td>2% loss after 1 year</td>
<td>6% loss after 1 year</td>
</tr>
<tr>
<td>25 °C (77 °F)</td>
<td>4% loss after 1 year</td>
<td>20% loss after 1 year</td>
</tr>
<tr>
<td>40 °C (104 °F)</td>
<td>15% loss after 1 year</td>
<td>35% loss after 1 year</td>
</tr>
<tr>
<td>60 °C (140 °F)</td>
<td>25% loss after 1 year</td>
<td>40% loss after 3 months</td>
</tr>
</tbody>
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Performance:

- The life expectancy of batteries depends heavily on how the batteries are used.
- Different cells models are designed for specific benefits such as high capacity or long cycle life.

Cycle performance at various charge/discharge rates

![Graph showing cycle performance at various charge/discharge rates.](image)
Shipping:
Anyone shipping lithium-ion batteries in bulk is responsible to meet transportation regulations. This applies to domestic and international shipments by land, sea and air.

Lithium-ion batteries whose equivalent lithium content or Watt/Hour rating exceeds a certain amount must be shipped as Class 9 miscellaneous hazardous material depending on the method of shipment (air, ground, or sea). Cell capacity and the number of cells in a pack determine the lithium content and/or Watt/Hours.

All lithium-ion/polymer batteries must be tested and ship in accordance with the rules outlined in U.S. Hazardous Materials Regulations 49 CFR sub section 173.185 for lithium batteries and cells and/or meet the requirements for shipping according to the IATA Dangerous Good Regulations when applicable regardless of lithium content or Watt/Hour rating.

Cells & batteries must be separated to prevent short-circuiting and packaged in strong boxes.

The shipping regulations change from time to time, so keep up to date on all requirements.
Shipping:

*How do I know the lithium content of a lithium-ion battery?*

From a theoretical perspective, there is no metallic lithium in a typical lithium-ion battery. There is, however, equivalent lithium content that must be considered. For a lithium-ion cell, this is calculated at 0.3 times the rated capacity (in ampere-hours).

**Example:** A 2Ah 18650 Li-ion cell has 0.6 grams of lithium content. On a typical 60 Wh laptop battery with 8 cells (4 in series and 2 in parallel), this adds up to 4.8g. To stay under the 8-gram UN limit, the largest battery you can bring is 96 Wh. This pack could include 2.2Ah cells in a 12 cells arrangement (4s3p). If the 2.4Ah cell were used instead, the pack would need to be limited to 9 cells (3s3p).
Shipping:

Testing and Transportation Requirements

- All lithium and lithium ion/polymer cells and batteries must pass the following UN Tests prior to being transported:
  - Test 1: Altitude Simulation
  - Test 2: Extreme temperature changes
  - Test 3: Vibration
  - Test 4: Shock
  - Test 5: External Short Circuit
  - Test 6: Impact
  - Test 7: Overcharge
  - Test 8: Forced Discharge
Shipping:

- Packaging, marking, and shipping documentation requirements for shipments of lithium and lithium ion cells and batteries
  - Boxes must be marked appropriately
  - Shipments must be accompanied by proper documentation
  - Boxes must be able to pass drop test (must be certified)
  - Boxes may not exceed 30 kg gross mass
RoHs

- House of Batteries is fully committed to meeting the requirements of the European Union (RoHS) Directive.

- The RoHS directive specifically excludes cells & batteries.

- Legislation mandates specific recovery (recycling) programs for batteries and battery assemblies. Any potentially harmful waste stream (WEEE) is avoided.
Inexpensive, poorly designed, and cheaply built batteries are a source of trouble.

- Product and corporate reputation is compromised when problems occur in the field
- Public safety is threatened when poorly designed and built batteries malfunction to the point of presenting a hazard
- Product returns increase and extra demand is placed on customer service
- Many major manufacturers including Sony, Apple, Nikon, and Disney have had recalls on lithium rechargeable batteries due to quality issues
Pack design Best Practices

- **Qualified Cells:**
  - Avoid use of substandard cells with single layer separators or lightly processed cathode/anode material

- **Safety Circuit:**
  - Avoid use of substandard components on circuit
  - Ensure proper protection of circuit to prevent damage

- **Packaging:**
  - Plastic enclosure best. Careful layout in soft packs can be safe
  - Soft packs should not be user replaceable
Checklist:

- ISO Certified?
- Quality Department?
- Engineering Staff?
- Test Equipment?
- Hazmat Shipper?