Selection of Battery and Charging Algorithm to Extend Battery Life and Cycle Life

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Accelerating Product Focus

- CPU, PC
- Datacenter and Internet of Things
More Devices with Batteries

Consideration in selection (example)

- Rechargeable or non-rechargeable?
- Chemistry? (Li, NiMH, Alkaline, etc...)
- Cost + Longevity = Cost of Ownership
### Example of Batteries for CE/IOT

<table>
<thead>
<tr>
<th></th>
<th>Rechargeable</th>
<th>Non-Rechargeable</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Li-ion</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy density</td>
<td>Baseline (700+Wh/l)</td>
<td>½ of Li-ion</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nominal voltage</td>
<td>~3.8V</td>
<td>1.2V</td>
</tr>
<tr>
<td>Cycles</td>
<td>Several hundreds to thousands</td>
<td>Several hundreds to thousands</td>
</tr>
<tr>
<td>Self-discharge</td>
<td>0.3-1.2%/month</td>
<td>~3%/month</td>
</tr>
<tr>
<td>Cost (online volume price)</td>
<td>~$0.2 /Wh (*18650) + protection + charger</td>
<td>&lt;$1.0/Wh (*AA) + charger</td>
</tr>
</tbody>
</table>

**Li-based or rechargeable battery for high-power device**
**Non Li-based or non-rechargeable battery for low-power device.**
**How about “Normally low-power but sometimes high-power device”?**

* Data varies by manufacturer, model, size, temperature, etc...
Impedance Knows...

- Battery voltage drops under current because of impedance.

- Battery impedance increases as discharge continues.
  \[ R = R(\text{Ohmic}) + R(\text{Polarization}) \]

- System shuts down when dropped voltage hits system shutdown voltage.

- It’s a key to understand what is impedance/IR drop under pulse and continuous discharge.

Fig. Voltage reaction under various current
Impedance Depends on Models/Suppliers...

CR2450 (Li-coin cell, non-rechargeable)

Discharged at 32mA for 2sec and 50uA for 5 sec, repeated until voltage hits 2.2V.

Room temperature

- Even with same chemistry, usable capacity is very different by models/suppliers because of impedance difference.
- For battery selection, it’s important to understand its impedance for usage.
Longevity

- Expectations:
  - Longer battery life for rechargeable/non-rechargeable battery
  - Longer cycle life for rechargeable battery

- Less battery replacement = Lower Cost of Ownership
  (e.g. Li-ion rechargeable battery)
  - PC: 500~1000 cycles
  - IOT: more

- Solution:
  - New battery chemistry
  - Smart charging algorithm
Cycle Life Degradation

- Full-charge-capacity is decreased after repeating charge and discharge.
- Degradation is accelerated at
  - Higher temperature
  - Full charge (higher charge level)
  - Too fast charge/discharge current
  - etc...
- Mixing these factors degrades cycle life even worse.
- What can we do for cycle life extension to reduce Cost of Ownership?

Cycle test result at 45deg.C

- 100% (Fresh battery) e.g. 10hr run time
- 88% e.g. <9hr run time
Solution

“Adaptive Charging Algorithm”
Adaptive Charging by Scheduling Application

- Charge battery as needed by “scheduling application”.
- This avoids higher charge level which gives more degradation, extending longevity.
- This lowers Cost of Ownership as it requires less battery replacement.

(U.S. Patent 9041356, 8232774, 7852045)
Adaptive Charging by Scheduling Application

* Example: If a device needs 90%, charge to 90+α%.

* 25% cycle life improvement.

* Lower charge level, Better cycle life.

* Application: Autonomous driving, Cleaning robot, Sensors, etc...
Situational Charging

IOT devices may operate with a battery charged by solar cell.

Winter

Night
Day

Full charge is needed in winter.

Summer

Night
Day

Full charge is NOT needed in summer.

Avoiding full charge by situations (season, usage, etc...) extends battery cycle life.
Conclusion

• Understanding impedance by usage is important to know usable battery capacity.

• Longer cycle life is expected for CE/IOT devices to reduce Cost of Ownership.

• Extension of battery cycle life (longevity) is possible by “Adaptive Charging Algorithm”.

• If you are interested in implementation, please contact us. naoki.matsumura@intel.com