Review of Energy Storage Solutions for IoT Edge Nodes

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APEC Industry Session
10 June 2021
Ilika Solid State Batteries

**Stereax**  
Miniature battery technology for MedTech and Industrial IoT

**Goliath**  
Large format battery technology for Electric Vehicles, Consumer Electronics, Aerospace, Military
Requirements for Edge Nodes Connectivity

- **Cabling:** costly and heavy
- **High and low temperature environments**
- **Small-size unobtrusive, “invisible”, beacons for hard-to-reach places**
- **Low cost of ownership**
- **Reliability**
- **Bio-compatibility**
- **Safety**
Perpetual Beacons

Efficient energy harvesters

Ultra low power electronics, sensors, communication and PMIC

Source: Ref 1

Source: Ref 2

Source: Ref 3
Energy Storage Solutions

Primary batteries
- Li/CFₓ, Li/MnO₂, Li/SOCl₂, Zn air
- Single discharge
- Large capacity to Ah
- Prismatic, D-shaped, Cylindrical
- Highly packaged

Secondary batteries
- Li-metal oxide
- 500-1000 cycles
- 2-5 years life
- To 100s mAh
- Smaller size than primary
- Need packaging

Li polymer
- Primary or secondary
- Gel/Polymer electrolyte
- Footprint in²/cm²
- Thin, Flexible
- Higher cost-to-energy ratio than lithium-ion

Supercaps (battery-free)
- Electric Double Layer
- Very thin (mm)
- Many cycles (>100,000)
- High power
- Low energy density

Solid State Batteries
Rechargeable SOLID STATE
Li-ion Chemistry

No liquid or polymer electrolyte
Won’t leak or explode!

Fabricated using equipment from semi-conductor and MEMS industry

*Deposited by single-step co-evaporation;*
*Patterned by photolithography and etching*

Advantages

- Predictable cycle life; high C-rate
- Single-step, low temperature process
- No need for additional post-anneal
- Dense, columnar crystals, with high Li diffusion
  - Stackable cells
Design Considerations

Size and shape

- Device size often dominated by size of battery
- Shapes standardized
- Miniaturisation limited by casing/packaging
- Flexibility: LiPo pouches
- Some customisation:

  **Cylindrical**
  - Min 2.9 mm dia
  - 1.6 mm thick

  **Coin**
  - Min 2mm dia
  - 1.6 mm thick

  **Pouch**
  - LiPo ~500um thick

  **SSB**
  - ~150um thick

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[Image of diagram showing components: Antenna, Solid state batteries, Sensor, Processor, Induction charging bands, and Optimized microfabrication with different area efficiencies.]
Design Considerations

Energy

- Choice between Primary and Secondary
- “Accumulated Energy” = Capacity for one cycle x number of cycles

Primary
- Large size
- Higher cost
- Large capacity
- No need for charging

Secondary
- Small size
- Lower cost
- Lower capacity
- Need wireless charging or EH
Design Considerations

Power / Rate Capability

- Power capability linked to internal resistance
- Power hungry components
  - Communications module
  - Sensors
- Remember quiescent current

Internal Resistance of a Mobile Phone Battery

<table>
<thead>
<tr>
<th>Component</th>
<th>Resistance (Ω)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cell, single, high capacity prismatic</td>
<td>50mΩ</td>
</tr>
<tr>
<td>Connection, welded</td>
<td>1mΩ</td>
</tr>
<tr>
<td>PTC, welded to cable, cell</td>
<td>25mΩ</td>
</tr>
<tr>
<td>Protection circuit, PCB</td>
<td>50mΩ</td>
</tr>
<tr>
<td>Total internal resistance</td>
<td>~130mΩ</td>
</tr>
</tbody>
</table>
Design Considerations

Power management

- Increasing number of off-the-shelf ultra low power PMIC
  - Texas Instruments bq25570
  - Analog Devices ADP5091
  - E-peas AEM10941

- Some OEM prefer to design their own ASIC including such functions
  - MICRODUL MA198

<table>
<thead>
<tr>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Battery protection (operational voltage window)</td>
</tr>
<tr>
<td>Output voltage conversion: 3-4V → useful voltage</td>
</tr>
<tr>
<td>Regulate input current and voltage (Energy Harvester)</td>
</tr>
<tr>
<td>Mm-scale footprint</td>
</tr>
<tr>
<td>Low quiescent currents</td>
</tr>
</tbody>
</table>

100 μAh SSB @ 3.5V

+40% @ 1.8V
Design Considerations

Packaging and PCB mounting

- Conventional batteries need holders and connectors
- SMD solder-reflowable components: MLCC-type
- Other methods:

  **SSB**
  - Conductive epoxy
    (Ag / Carbon; room temperature)
  - Wire-bonding
    (room temperature; Ag/Pt)

**In test:**
- Anisotropic Conductive Films
  (acrylic resins <160°C)
- Hi-res Printed Inks
  (low heat)
Design Considerations

Operational Life

- Design battery around cycle life requirements and Depth of Discharge
  - Over-design of battery if possible
  - Reduce use case (smaller DoD; frequent recharges)
  - Low-power electronics
  - Trickle charge via energy harvesting for max life cycle
  - Depends on temperature
  - Depends on C-rate

- Conventional LIB: 500-1000 cycles
- SSB: 1000-2000 cycles
- Supercaps: 10,000s
Energy storage components self-discharge via leakage current – Only partially recoverable

During unused periods; Non-Zero loads and switches; Shorts

Quiescent current contributions:
- **Communications**
- **Sensors**
- **MCU sleep mode**
- **PMIC**

Medical cylindrical batteries have Zero-volt technology

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### Energy source

<table>
<thead>
<tr>
<th>Energy source</th>
<th>Leakage current level</th>
<th>Yearly loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solid state batteries</td>
<td>1nA</td>
<td>10μAh</td>
</tr>
<tr>
<td>Pulse caps</td>
<td>10nA</td>
<td>100μAh</td>
</tr>
<tr>
<td>PMIC</td>
<td>100nA</td>
<td>1mAh</td>
</tr>
<tr>
<td>Supercaps, coin cells</td>
<td>1μA</td>
<td>10mA</td>
</tr>
</tbody>
</table>

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*Ref 1*
Call to action

**EVALUATION**
Evaluate Stereax standard products

**CUSTOMISATION**
Ilika can design a battery to fit your requirements

**PROTOTYPING**
Ilika can provide low volumes of batteries for prototyping, internal testing, field trials
Or you can take a license to have the batteries manufactured

**MANUFACTURING**
Ilika is transferring its solid state battery technology to foundries
Thanks a lot for your time and attention!

Any questions and/or comments?

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