Lithium Iron Phosphate (LiFePO₄) Battery Charge Management Controller with Input Overvoltage Protection

**Features:**
- Complete Linear Charge Management Controller:
  - Integrated Input Overvoltage Protection (OVP)
  - Integrated Pass Transistor
  - Integrated Current Sense
  - Integrated Reverse Discharge Protection
- Constant Current/Constant Voltage Operation with Thermal Regulation
- 4.15V Undervoltage Lockout (UVLO)
- 18V Absolute Maximum Input with OVP:
  - 6.5V - MCP73123
  - 13V - MCP73223
- High Accuracy Preset Voltage Regulation Through Full Temperature Range (-5°C to +55°C):
  - ±0.5% - MCP73123
  - ±0.6% - MCP73223
- Battery Charge Voltage Options:
  - 3.6V - MCP73123
  - 7.2V - MCP73223
- Resistor Programmable Fast Charge Current:
  - 130 mA - 1100 mA
- Preconditioning of Deeply Depleted Cells:
  - Available Options: 10% or Disable
- Integrated Precondition Timer:
  - 32 Minutes or Disable
- Automatic End-of-Charge Control:
  - Selectable Minimum Current Ratio:
    - 5%, 7.5%, 10% or 20%
  - Elapse Safety Timer: 4 HR, 6 HR, 8 HR or Disable
- Automatic Recharge:
  - Available Options: 95% or Disable
- Factory Preset Charge Status Output:
  - On/Off or Flashing
- Soft Start
- Temperature Range: -40°C to +85°C
- Packaging: DFN-10 (3 mm x 3 mm)

**Applications:**
- Low-Cost LiFePO₄ Battery Chargers
- Power Tools
- Toys
- Backup Energy Storage Solutions

**Description:**

The MCP73123/223 is a highly integrated Lithium Iron Phosphate (LiFePO₄) battery charge management controller for use in space-limited and cost-sensitive applications. The MCP73123/223 provides specific charge algorithms for LiFePO₄ batteries to achieve optimal capacity and safety in the shortest charging time possible. Along with its small physical size, the low number of external components makes the MCP73123/223 ideally suitable for various applications. The absolute maximum voltage, up to 18V, allows the use of MCP73123/223 in harsh environments, such as low cost AC adapter or voltage spikes from plugging/unplugging.

The MCP73123/223 employs a constant current/constant voltage charge algorithm. The 3.6V per cell factory preset reference voltage simplifies design with 2V preconditioning threshold. The fast charge, constant current value is set with one external resistor from 130 mA to 1100 mA. The MCP73123/223 also limits the charge current based on die temperature during high power or high ambient conditions. This thermal regulation optimizes the charge cycle time while maintaining device reliability.

The PROG pin of the MCP73123/223 also serves as the enable pin. When high impedance is applied, the MCP73123/223 will be in Standby mode.

The MCP73123/223 is fully specified over the ambient temperature range of -40°C to +85°C. The MCP73123/223 is available in a 10 lead DFN package.

**Package Types (Top View)**

```
MCP73123/223
3x3 DFN *

VDD 0
10 PROG
VDD 2
9 VSS
V_BAT 3 11 EP 8 VSS
V_BAT 4 STAT
NC 5 6 NC
```

* Includes Exposed Thermal Pad (EP); see Table 3-1.


**TABLE 1: AVAILABLE FACTORY PRESET OPTIONS**

<table>
<thead>
<tr>
<th>Charge Voltage</th>
<th>OVP</th>
<th>Preconditioning Charge Current</th>
<th>Preconditioning Threshold</th>
<th>Precondition Timer</th>
<th>Elapse Timer</th>
<th>End-of-Charge Control</th>
<th>Automatic Recharge</th>
<th>Output Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.6V</td>
<td>6.5V</td>
<td>Disable/10%</td>
<td>Disable/32 Minimum</td>
<td>Disable / 32 Minimum</td>
<td>Disable/4 hr./6 hr./8 hr.</td>
<td>5%/7.5%/10%/20%</td>
<td>No / Yes</td>
<td>Type 1 / Type 2</td>
</tr>
<tr>
<td>7.2V</td>
<td>13V</td>
<td>Disable/10%</td>
<td>Disable/32 Minimum</td>
<td>Disable / 32 Minimum</td>
<td>Disable/4 hr./6 hr./8 hr.</td>
<td>5%/7.5%/10%/20%</td>
<td>No / Yes</td>
<td>Type 1 / Type 2</td>
</tr>
</tbody>
</table>

**Note 1:**
1. \( I_{\text{REG}} \): Regulated fast charge current.
2. \( V_{\text{REG}} \): Regulated charge voltage.
3. \( I_{\text{PREG}}/I_{\text{REG}} \): Preconditioning charge current; ratio of regulated fast charge current.
4. \( I_{\text{TERM}}/I_{\text{REG}} \): End-of-Charge control; ratio of regulated fast charge current.
5. \( V_{\text{RTH}}/V_{\text{REG}} \): Recharge threshold; ratio of regulated battery voltage, 0% or 95%. 0% = Disabled.
6. \( V_{\text{PTH}}/V_{\text{REG}} \): Preconditioning threshold voltage.
7. Type 1: On/Off; Type 2: Flashing. Please refer to Table 5-2.

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**TABLE 2: STANDARD SAMPLE OPTIONS**

<table>
<thead>
<tr>
<th>Part Number</th>
<th>( V_{\text{REG}} )</th>
<th>OVP</th>
<th>( I_{\text{PREG}}/I_{\text{REG}} )</th>
<th>Precharge Timer</th>
<th>Elapse Timer</th>
<th>( I_{\text{TERM}}/I_{\text{REG}} )</th>
<th>Auto Recharge Threshold (0% = Disabled)</th>
<th>( V_{\text{PTH}}/V_{\text{REG}} )</th>
<th>Output Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>MCP73123-22S/MF</td>
<td>3.6V</td>
<td>6.5V</td>
<td>10%</td>
<td>32 Min.</td>
<td>6 hr.</td>
<td>10%</td>
<td>95%</td>
<td>2V</td>
<td>Type 1</td>
</tr>
<tr>
<td>MCP73123-22A/MF</td>
<td>3.6V</td>
<td>6.5V</td>
<td>10%</td>
<td>32 Min.</td>
<td>6 hr.</td>
<td>10%</td>
<td>95%</td>
<td>2V</td>
<td>Type 1</td>
</tr>
<tr>
<td>MCP73223-C2S/MF</td>
<td>7.2V</td>
<td>13V</td>
<td>10%</td>
<td>32 Min.</td>
<td>6 hr.</td>
<td>10%</td>
<td>95%</td>
<td>4V</td>
<td>Type 1</td>
</tr>
<tr>
<td>MCP73223-C2A/MF</td>
<td>7.2V</td>
<td>13V</td>
<td>10%</td>
<td>32 Min.</td>
<td>6 hr.</td>
<td>10%</td>
<td>0%</td>
<td>4V</td>
<td>Type 1</td>
</tr>
</tbody>
</table>

**Note 1:** Customers should contact their distributor, representatives or field application engineer (FAE) for support and samples. Local sales offices are also available to help customers. A listing of sales offices and locations is included in the back of this document. Technical support is available through the web site at: http://support.microchip.com.

2: Contact your local Microchip sales office for alternative device options.
MCP73123/223

Functional Block Diagram

- **VDD**
- **VBAT**
- **VSS**
- **VO_REG**
- **VREF (1.21V)**
- **INPUT OVERVP**
- **THERMAL REGULATION**
- **6.5V/13V**
- **110°C**
- **TSD**
- **PRECONDITION**
- **CURRENT LIMIT**
- **CHARGE**
- **CHARGE CONTROL, TIMER, AND STATUS LOGIC**
- **REFERENCE, BIAS, UVLO, AND SHDN**
- **REFERENCE, BIAS, UVLO, AND SHDN**
- **VDD**
- **G=0.001**

*Only available on selected options*
1.0 ELECTRICAL CHARACTERISTICS

Absolute Maximum Ratings†

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Units</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>VDD</td>
<td>4</td>
<td>—</td>
<td>16</td>
<td>V</td>
<td>MCCP73123</td>
</tr>
<tr>
<td>VPROG</td>
<td>4.2</td>
<td>—</td>
<td>6.5</td>
<td>V</td>
<td>MCCP73223</td>
</tr>
<tr>
<td>Maximum Junction Temperature, TJ</td>
<td>—</td>
<td>—</td>
<td>13.0</td>
<td>V</td>
<td>MCCP73223</td>
</tr>
<tr>
<td>Storage temperature</td>
<td>—</td>
<td>—</td>
<td>1500</td>
<td>µA</td>
<td>Shutdown (VDD ≤ VBAT - 150 mV)</td>
</tr>
<tr>
<td></td>
<td>—</td>
<td>30</td>
<td>100</td>
<td>µA</td>
<td>Charging</td>
</tr>
<tr>
<td></td>
<td>—</td>
<td>50</td>
<td>150</td>
<td>µA</td>
<td>Charge Complete; No Battery; VDD ≤ VSTOP</td>
</tr>
<tr>
<td>Battery Discharge Current</td>
<td>—</td>
<td>0.5</td>
<td>2</td>
<td>µA</td>
<td>Standby (PROG Floating)</td>
</tr>
<tr>
<td></td>
<td>—</td>
<td>0.5</td>
<td>2</td>
<td>µA</td>
<td>Shutdown (VDD ≤ VBAT or VDD ≤ VSTOP)</td>
</tr>
<tr>
<td></td>
<td>—</td>
<td>6</td>
<td>17</td>
<td>µA</td>
<td>Charge Complete; VDD is present</td>
</tr>
<tr>
<td>Undervoltage Lockout</td>
<td>—</td>
<td>100</td>
<td>—</td>
<td>mV</td>
<td></td>
</tr>
<tr>
<td></td>
<td>—</td>
<td>6.4</td>
<td>6.5</td>
<td>6.6</td>
<td>MCCP73123</td>
</tr>
<tr>
<td></td>
<td>—</td>
<td>12.8</td>
<td>13</td>
<td>13.2</td>
<td>MCCP73223</td>
</tr>
<tr>
<td></td>
<td>—</td>
<td>150</td>
<td>—</td>
<td>mV</td>
<td></td>
</tr>
<tr>
<td>Overvoltage Protection</td>
<td>—</td>
<td>3.582</td>
<td>3.60</td>
<td>3.618</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td>—</td>
<td>—</td>
<td>+0.5</td>
<td>%</td>
<td>Tj = -5°C to +55°C, IOUT = 50 mA</td>
</tr>
<tr>
<td></td>
<td>—</td>
<td>7.157</td>
<td>7.20</td>
<td>7.243</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td>—</td>
<td>+0.5</td>
<td>+0.6</td>
<td>%</td>
<td>Tj = -5°C to +55°C, IOUT = 50 mA</td>
</tr>
</tbody>
</table>

† Notice: Stresses above those listed under “Maximum Ratings” may cause permanent damage to the device. This is a stress rating only and functional operation of the device at those or any other conditions above those indicated in the operational listings of this specification is not implied. Exposure to maximum rating conditions for extended periods may affect device reliability.

DC CHARACTERISTICS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Sym.</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Units</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply Input</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Input Voltage Range</td>
<td>VDD</td>
<td>4</td>
<td>—</td>
<td>16</td>
<td>V</td>
<td>MCCP73123</td>
</tr>
<tr>
<td>Operating Supply Voltage</td>
<td>VDD</td>
<td>4.2</td>
<td>—</td>
<td>6.5</td>
<td>V</td>
<td>MCCP73223</td>
</tr>
<tr>
<td>Operating Supply Voltage</td>
<td>VDD</td>
<td>4.2</td>
<td>—</td>
<td>13.0</td>
<td>V</td>
<td>MCCP73223</td>
</tr>
<tr>
<td>Supply Current</td>
<td>ISS</td>
<td>—</td>
<td>4</td>
<td>5.5</td>
<td>µA</td>
<td>Shutdown (VDD ≤ VBAT - 150 mV)</td>
</tr>
<tr>
<td></td>
<td>—</td>
<td>700</td>
<td>1500</td>
<td>µA</td>
<td>Charging</td>
<td></td>
</tr>
<tr>
<td></td>
<td>—</td>
<td>30</td>
<td>100</td>
<td>µA</td>
<td>Standby (PROG Floating)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>—</td>
<td>50</td>
<td>150</td>
<td>µA</td>
<td>Charge Complete; No Battery; VDD ≤ VSTOP</td>
<td></td>
</tr>
</tbody>
</table>

Battery Discharge Current

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Sym.</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Units</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output Reverse Leakage</td>
<td>I_DISCHARGE</td>
<td>—</td>
<td>0.5</td>
<td>2</td>
<td>µA</td>
<td>Standby (PROG Floating)</td>
</tr>
<tr>
<td>Current</td>
<td></td>
<td>—</td>
<td>0.5</td>
<td>2</td>
<td>µA</td>
<td>Shutdown (VDD ≤ VBAT or VDD ≤ VSTOP)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>—</td>
<td>6</td>
<td>17</td>
<td>µA</td>
<td>Charge Complete; VDD is present</td>
</tr>
</tbody>
</table>

Undervoltage Lockout

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Sym.</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Units</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>UVLO Start Threshold</td>
<td>VSTART</td>
<td>4.10</td>
<td>4.15</td>
<td>4.25</td>
<td>V</td>
<td>MCCP73123</td>
</tr>
<tr>
<td>UVLO Stop Threshold</td>
<td>VSTOP</td>
<td>4.00</td>
<td>4.05</td>
<td>4.15</td>
<td>V</td>
<td>MCCP73223</td>
</tr>
<tr>
<td>UVLO Hysteresis</td>
<td>V_HYS</td>
<td>—</td>
<td>100</td>
<td>—</td>
<td>mV</td>
<td></td>
</tr>
</tbody>
</table>

Overvoltage Protection

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Sym.</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Units</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>OVP Start Threshold</td>
<td>V_OVP</td>
<td>6.4</td>
<td>6.5</td>
<td>6.6</td>
<td>V</td>
<td>MCCP73123</td>
</tr>
<tr>
<td>OVP Start Threshold</td>
<td>V_OVP</td>
<td>12.8</td>
<td>13</td>
<td>13.2</td>
<td>V</td>
<td>MCCP73223</td>
</tr>
<tr>
<td>OVP Hysteresis</td>
<td>V_OVP</td>
<td>—</td>
<td>150</td>
<td>—</td>
<td>mV</td>
<td></td>
</tr>
</tbody>
</table>

Voltage Regulation (Constant Voltage Mode)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Sym.</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Units</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regulated Output Voltage</td>
<td>V_REG</td>
<td>3.582</td>
<td>3.60</td>
<td>3.618</td>
<td>V</td>
<td>Tj = -5°C to +55°C, IOUT = 50 mA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>—</td>
<td>+0.5</td>
<td>%</td>
<td>Tj = -5°C to +55°C</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>7.157</td>
<td>7.20</td>
<td>7.243</td>
<td>V</td>
<td>Tj = -5°C to +55°C, IOUT = 50 mA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>+0.5</td>
<td>+0.6</td>
<td>%</td>
<td>Tj = -5°C to +55°C</td>
<td></td>
</tr>
</tbody>
</table>

Note 1: Not production tested. Ensured by design.
### DC CHARACTERISTICS (CONTINUED)

Electrical Specifications: Unless otherwise indicated, all limits apply for \( V_{DD} = [V_{REG}\text{(Typical)} + 0.3V] \) to 12V, \( T_A = -40°C \) to +85°C. Typical values are at +25°C, \( V_{DD} = [V_{REG}\text{(Typical)} + 1.0V] \)

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Sym.</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Units</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Line Regulation</td>
<td>( \frac{\Delta V_{BAT}}{V_{BAT}}/\Delta V_{DD} )</td>
<td>—</td>
<td>0.05</td>
<td>0.20</td>
<td>%/V</td>
<td>( V_{DD} = [V_{REG}\text{(Typical)} + 1V] ) to 6V</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>- MCP73123</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>( V_{DD} = [V_{REG}\text{(Typical)} + 1V] ) to 12V</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>- MCP73223</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>( I_{OUT} = 50 \text{ mA} )</td>
</tr>
<tr>
<td>Load Regulation</td>
<td>( \Delta V_{BAT}/V_{BAT} )</td>
<td>—</td>
<td>0.05</td>
<td>0.20</td>
<td>%</td>
<td>( I_{OUT} = 50 \text{ mA} - 150 \text{ mA} ) ( V_{DD} = [V_{REG}\text{(Typical)} + 1V] )</td>
</tr>
<tr>
<td>Supply Ripple Attenuation</td>
<td>PSRR</td>
<td>—</td>
<td>-46</td>
<td>—</td>
<td>dB</td>
<td>( I_{OUT} = 20 \text{ mA}, \text{10 Hz to 1 kHz} )</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-30</td>
<td>—</td>
<td>dB</td>
<td>( I_{OUT} = 20 \text{ mA}, \text{10 Hz to 10 kHz} )</td>
</tr>
<tr>
<td>Battery Short Protection</td>
<td>( V_{SHORT} )</td>
<td>—</td>
<td>1.45</td>
<td>—</td>
<td>V</td>
<td>MCP73123</td>
</tr>
<tr>
<td></td>
<td>( V_{SHORT} )</td>
<td>—</td>
<td>2.90</td>
<td>—</td>
<td>V</td>
<td>MCP73223</td>
</tr>
<tr>
<td></td>
<td>( V_{BSPHY} )</td>
<td>—</td>
<td>150</td>
<td>—</td>
<td>mV</td>
<td></td>
</tr>
<tr>
<td>Battery Short Protection Current</td>
<td>( I_{SHORT} )</td>
<td>—</td>
<td>25</td>
<td>—</td>
<td>mA</td>
<td></td>
</tr>
<tr>
<td>Current Regulation (Fast Charge, Constant-Current Mode)</td>
<td>( I_{REG} )</td>
<td>130</td>
<td>—</td>
<td>1100</td>
<td>mA</td>
<td>( T_{A} = -5°C ) to +55°C</td>
</tr>
<tr>
<td></td>
<td></td>
<td>130</td>
<td>—</td>
<td>—</td>
<td>mA</td>
<td>( \text{PROG = 10 k} \Omega )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1000</td>
<td>—</td>
<td>—</td>
<td>mA</td>
<td>( \text{PROG = 1.1 k} \Omega )</td>
</tr>
<tr>
<td>Preconditioning Current Regulation (Trickle Charge Constant Current Mode)</td>
<td>( I_{PREG}/I_{REG} )</td>
<td>—</td>
<td>10</td>
<td>—</td>
<td>%</td>
<td>( \text{PROG = 1 k} \Omega ) to 10 k( \Omega ) ( T_{A} = -5°C ) to +55°C</td>
</tr>
<tr>
<td></td>
<td></td>
<td>—</td>
<td>100</td>
<td>—</td>
<td>%</td>
<td>( \text{PROG = 1 k} \Omega ) to 10 k( \Omega ) ( T_{A} = -5°C ) to +55°C</td>
</tr>
<tr>
<td></td>
<td></td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>%</td>
<td>( \text{No Preconditioning} )</td>
</tr>
<tr>
<td></td>
<td>( V_{PTH} )</td>
<td>1.9</td>
<td>2.0</td>
<td>2.1</td>
<td>V</td>
<td>MCP73123, ( V_{BAT}) Low-to-High</td>
</tr>
<tr>
<td></td>
<td>( V_{PTH} )</td>
<td>3.8</td>
<td>4.0</td>
<td>4.2</td>
<td>V</td>
<td>MCP73223, ( V_{BAT}) Low-to-High</td>
</tr>
<tr>
<td></td>
<td>( V_{PHYS} )</td>
<td>—</td>
<td>100</td>
<td>—</td>
<td>mV</td>
<td>( V_{BAT}) High-to-Low (Note 1)</td>
</tr>
<tr>
<td>Charge Termination</td>
<td>( I_{TERM}/I_{REG} )</td>
<td>3.7</td>
<td>5</td>
<td>6.3</td>
<td>%</td>
<td>( \text{PROG = 1 k} \Omega ) to 10 k( \Omega ) ( T_{A} = -5°C ) to +55°C</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5.6</td>
<td>7.5</td>
<td>9.4</td>
<td>%</td>
<td>( \text{PROG = 1 k} \Omega ) to 10 k( \Omega ) ( T_{A} = -5°C ) to +55°C</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7.5</td>
<td>10</td>
<td>12.5</td>
<td>%</td>
<td>( \text{No Preconditioning} )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15</td>
<td>20</td>
<td>25</td>
<td>%</td>
<td>( \text{No Preconditioning} )</td>
</tr>
<tr>
<td>Automatic Recharge</td>
<td>( V_{RTH}/V_{REG} )</td>
<td>93</td>
<td>95</td>
<td>97</td>
<td>%</td>
<td>( V_{BAT}) High-to-Low (No Automatic Recharge)</td>
</tr>
<tr>
<td>ON-Resistance</td>
<td>( R_{DS\text{ON}} )</td>
<td>—</td>
<td>350</td>
<td>—</td>
<td>m( \Omega ) ( V_{DD} = 4.5V, T_{J} = 105°C ) (Note 1)</td>
<td></td>
</tr>
<tr>
<td>Status Indicator - STAT</td>
<td>( I_{SINK} )</td>
<td>—</td>
<td>20</td>
<td>35</td>
<td>mA</td>
<td></td>
</tr>
<tr>
<td></td>
<td>( V_{OL} )</td>
<td>—</td>
<td>0.2</td>
<td>0.5</td>
<td>V</td>
<td>( I_{SINK} = 4 \text{ mA} )</td>
</tr>
<tr>
<td></td>
<td>( I_{LK} )</td>
<td>—</td>
<td>0.001</td>
<td>1</td>
<td>\mu( \text{A} )</td>
<td>High Impedance, ( V_{DD} ) on pin</td>
</tr>
<tr>
<td>PROG Input</td>
<td>( R_{PROG} )</td>
<td>1</td>
<td>—</td>
<td>10</td>
<td>k( \Omega )</td>
<td></td>
</tr>
<tr>
<td></td>
<td>( R_{PROG} )</td>
<td>—</td>
<td>200</td>
<td>—</td>
<td>k( \Omega )</td>
<td>Impedance for Shutdown</td>
</tr>
<tr>
<td></td>
<td>( V_{PROG} )</td>
<td>0</td>
<td>—</td>
<td>5</td>
<td>V</td>
<td></td>
</tr>
</tbody>
</table>

**Note 1:** Not production tested. Ensured by design.
### DC CHARACTERISTICS (CONTINUED)

#### Electrical Specifications:
Unless otherwise indicated, all limits apply for $V_{DD} = [V_{REG}(Typical) + 0.3V]$ to 12V, $T_A = -40^\circ C$ to $+85^\circ C$. Typical values are at $+25^\circ C$, $V_{DD} = [V_{REG}(Typical) + 1.0V]$.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Sym.</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Units</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Automatic Power Down</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Entry Threshold</td>
<td>$V_{PDENTRY}$</td>
<td>$V_{BAT} + 10$ mV</td>
<td>$V_{BAT} + 50$ mV</td>
<td>—</td>
<td>V</td>
<td>$V_{DD}$ Falling</td>
</tr>
<tr>
<td>Exit Threshold</td>
<td>$V_{PDEEXIT}$</td>
<td>—</td>
<td>$V_{BAT} + 150$ mV</td>
<td>$V_{BAT} + 250$ mV</td>
<td>V</td>
<td>$V_{DD}$ Rising</td>
</tr>
<tr>
<td><strong>Thermal Shutdown</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Die Temperature</td>
<td>$T_{SD}$</td>
<td>—</td>
<td>—</td>
<td>150</td>
<td>°C</td>
<td></td>
</tr>
<tr>
<td>Die Temperature Hysteresis</td>
<td>$T_{SDHYS}$</td>
<td>—</td>
<td>—</td>
<td>10</td>
<td>°C</td>
<td></td>
</tr>
</tbody>
</table>

**Note 1:** Not production tested. Ensured by design.

### AC CHARACTERISTICS

#### Electrical Specifications:
Unless otherwise specified, all limits apply for $V_{DD} = [V_{REG}(Typical) + 0.3V]$ to 6V, $T_A = -40^\circ C$ to $+85^\circ C$. Typical values are at $+25^\circ C$, $V_{DD} = [V_{REG}(Typical) + 1.0V]$.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Sym.</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Units</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Elapsed Timer</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Period</td>
<td>$t_{ELAPSED}$</td>
<td>—</td>
<td>0</td>
<td>—</td>
<td>Hours</td>
<td>Timer Disabled</td>
</tr>
<tr>
<td></td>
<td></td>
<td>—</td>
<td>3.6</td>
<td>4.0</td>
<td>4.4</td>
<td>Hours</td>
</tr>
<tr>
<td></td>
<td></td>
<td>—</td>
<td>5.4</td>
<td>6.0</td>
<td>6.6</td>
<td>Hours</td>
</tr>
<tr>
<td></td>
<td></td>
<td>—</td>
<td>7.2</td>
<td>8.0</td>
<td>8.8</td>
<td>Hours</td>
</tr>
<tr>
<td><strong>Preconditioning Timer</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Period</td>
<td>$t_{PRECHG}$</td>
<td>—</td>
<td>0</td>
<td>—</td>
<td>Hours</td>
<td>Disabled Timer</td>
</tr>
<tr>
<td></td>
<td></td>
<td>—</td>
<td>0.4</td>
<td>0.5</td>
<td>0.6</td>
<td>Hours</td>
</tr>
</tbody>
</table>

**Note 1:** Not production tested. Ensured by design.

### TEMPERATURE SPECIFICATIONS

#### Electrical Specifications:
Unless otherwise indicated, all limits apply for $V_{DD} = [V_{REG}(Typical) + 0.3V]$ to 6V. Typical values are at $+25^\circ C$, $V_{DD} = [V_{REG}(Typical) + 1.0V]$.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Sym.</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Units</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Temperature Ranges</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Specified Temperature Range</td>
<td>$T_A$</td>
<td>—</td>
<td>$-40$</td>
<td>—</td>
<td>$+85$</td>
<td>°C</td>
</tr>
<tr>
<td>Operating Temperature Range</td>
<td>$T_J$</td>
<td>—</td>
<td>$-40$</td>
<td>—</td>
<td>$+125$</td>
<td>°C</td>
</tr>
<tr>
<td>Storage Temperature Range</td>
<td>$T_A$</td>
<td>—</td>
<td>$-65$</td>
<td>—</td>
<td>$+150$</td>
<td>°C</td>
</tr>
<tr>
<td><strong>Thermal Package Resistances</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thermal Resistance, DFN-10 (3x3)</td>
<td>$\theta_{JA}$</td>
<td>—</td>
<td>64</td>
<td>—</td>
<td>°C/W</td>
<td>4-Layer JC51-7 Standard Board, Natural Convection</td>
</tr>
<tr>
<td></td>
<td></td>
<td>—</td>
<td>12</td>
<td>—</td>
<td>°C/W</td>
<td></td>
</tr>
</tbody>
</table>

**Note 1:** Not production tested. Ensured by design.
2.0 TYPICAL PERFORMANCE CURVES

**Note:** The graphs and tables provided following this note are a statistical summary based on a limited number of samples and are provided for informational purposes only. The performance characteristics listed herein are not tested or guaranteed. In some graphs or tables, the data presented may be outside the specified operating range (e.g., outside specified power supply range) and therefore outside the warranted range.

**Note:** Unless otherwise indicated, $V_{DD} = [V_{REG} \text{ (Typical)} + 1\text{V}]$, $I_{OUT} = 50$ mA and $T_A = +25^\circ\text{C}$, Constant Voltage mode.

**FIGURE 2-1:** Battery Regulation Voltage ($V_{BAT}$) vs. Supply Voltage ($V_{DD}$).

**FIGURE 2-2:** Battery Regulation Voltage ($V_{BAT}$) vs. Supply Voltage ($V_{DD}$).

**FIGURE 2-3:** Battery Regulation Voltage ($V_{BAT}$) vs. Supply Voltage ($V_{DD}$).

**FIGURE 2-4:** Battery Regulation Voltage ($V_{BAT}$) vs. Ambient Temperature ($T_A$).

**FIGURE 2-5:** Battery Regulation Voltage ($V_{BAT}$) vs. Ambient Temperature ($T_A$).

**FIGURE 2-6:** Charge Current ($I_{OUT}$) vs. Programming Resistor ($R_{PROG}$).
TYPICAL PERFORMANCE CURVES (CONTINUED)

Note: Unless otherwise indicated, $V_{DD} = [V_{REG} \text{ (Typical)} + 1V]$, $I_{OUT} = 10 \text{ mA}$ and $T_A = +25^\circ\text{C}$, Constant Voltage mode.

**FIGURE 2-7:** Charge Current ($I_{OUT}$) vs. Supply Voltage (V).

**FIGURE 2-8:** Charge Current ($I_{OUT}$) vs. Supply Voltage (V).

**FIGURE 2-9:** Charge Current ($I_{OUT}$) vs. Supply Voltage (V).

**FIGURE 2-10:** Charge Current ($I_{OUT}$) vs. Programming Resistor ($R_{PROG}$).

**FIGURE 2-11:** Charge Current ($I_{OUT}$) vs. Ambient Temperature ($T_A$).

**FIGURE 2-12:** Output Leakage Current ($I_{DISCHARGE}$) vs. Ambient Temperature ($T_A$).
TYPICAL PERFORMANCE CURVES (CONTINUED)

Note: Unless otherwise indicated, $V_{DD} = [V_{REG} \text{ (Typical)} + 1V]$, $I_{OUT} = 10 \text{ mA}$ and $T_A = +25^\circ C$, Constant Voltage mode.

FIGURE 2-13: Overvoltage Protection Start
(50 ms/Div).

FIGURE 2-14: Overvoltage Protection Stop
(50 ms/Div).

FIGURE 2-15: Load Transient Response
($I_{LOAD} = 50 \text{ mA}$, Output Ripple: 100 mV/Div,
Output Current: 50 mA/Div, Time: 100 $\mu s$/Div).

FIGURE 2-16: Complete Charge Cycle
(1100 mAh LiFePO$_4$ Battery).

FIGURE 2-17: Line Transient Response
($I_{LOAD} = 10 \text{ mA}$, Source Voltage: 2V/Div, Output Ripple: 100 mV/Div, Time: 100 $\mu s$/Div).

FIGURE 2-18: Line Transient Response
($I_{LOAD} = 100 \text{ mA}$, Source Voltage: 2V/Div, Output Ripple: 100 mV/Div, Time: 100 $\mu s$/Div).
3.0 PIN DESCRIPTION

The descriptions of the pins are listed in Table 3-1.

TABLE 3-1: PIN FUNCTION TABLE

<table>
<thead>
<tr>
<th>MCP73123/223</th>
<th>Symbol</th>
<th>I/O</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>DFN-10</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1, 2</td>
<td>$V_{DD}$</td>
<td>I</td>
<td>Battery Management Input Supply</td>
</tr>
<tr>
<td>3, 4</td>
<td>$V_{BAT}$</td>
<td>I/O</td>
<td>Battery Charge Control Output</td>
</tr>
<tr>
<td>5, 6</td>
<td>NC</td>
<td>—</td>
<td>No Connection</td>
</tr>
<tr>
<td>7</td>
<td>STAT</td>
<td>O</td>
<td>Battery Charge Status Output</td>
</tr>
<tr>
<td>8, 9</td>
<td>$V_{SS}$</td>
<td>—</td>
<td>Battery Management 0V Reference</td>
</tr>
<tr>
<td>10</td>
<td>PROG</td>
<td>I/O</td>
<td>Battery Charge Current Regulation Program and Charge Control Enable</td>
</tr>
<tr>
<td>11</td>
<td>EP</td>
<td>—</td>
<td>Exposed Pad</td>
</tr>
</tbody>
</table>

3.1 Battery Management Input Supply ($V_{DD}$)

A supply voltage of [$V_{REG}$ (Typical) + 0.3V] to 6.0V is recommended for MCP73123, while a supply voltage of [$V_{REG}$ (Typical) + 0.3V] to 12.0V is recommended for MCP73223. Bypass to $V_{SS}$ with a minimum of 1 µF. The $V_{DD}$ pin is rated 18V absolute maximum to prevent sudden rise of input voltage from spikes or low cost AC-DC wall adapter.

3.2 Battery Charge Control Output ($V_{BAT}$)

Connect to the positive terminal of the battery. Bypass to $V_{SS}$ with a minimum of 1 µF to ensure loop stability when the battery is disconnected. The MCP73123 is designed to provide 3.6V battery regulation voltage for LiFePO$_4$ batteries. Undercharge may occur if a typical Li-Ion or Li-Poly battery is used.

3.3 No Connect (NC)

No connect.

3.4 Status Output (STAT)

STAT is an open-drain logic output for connection to an LED for charge status indication in stand-alone applications. Alternatively, a pull-up resistor can be applied for interfacing to a host microcontroller. Refer to Table 5-1 for a summary of the status output during a charge cycle.

3.5 Battery Management 0V Reference ($V_{SS}$)

Connect to the negative terminal of the battery and input supply.

3.6 Current Regulation Set (PROG)

The fast charge current is set by placing a resistor from PROG to $V_{SS}$ during constant current (CC) mode.

The PROG pin also serves as a charge control enable pin. Allowing the PROG pin to float or connecting the pin to an impedance greater than 200 kΩ will disable the MCP73123/223 charger. Refer to Section 5.5, "Constant Current Mode – Fast Charge", for details.

3.7 Exposed Pad (EP)

The Exposed Thermal Pad (EP) shall be connected to the exposed copper area on the Printed Circuit Board (PCB) to enhance thermal power dissipation. Additional vias on the copper area under the MCP73123/223 device will improve the performance of heat dissipation and simplify the assembly process. Connecting EP to $V_{SS}$ is recommended.
4.0 DEVICE OVERVIEW

The MCP73123/223 are simple, but fully integrated linear charge management controllers. Figure 4-1 depicts the operational flow algorithm.

FIGURE 4-1: The MCP73123/223 Flow Chart.
5.0 DETAILED DESCRIPTION

5.1 Undervoltage Lockout (UVLO)
An internal undervoltage lockout (UVLO) circuit monitors the input voltage and keeps the charger in Shutdown mode until the input supply rises above the UVLO threshold. In the event a battery is present when the input power is applied, the input supply must rise approximately 150 mV above the battery voltage before the MCP73123/223 becomes operational.

The UVLO circuit places the device in Shutdown mode if the input supply falls to approximately 150 mV above the battery voltage. The UVLO circuit is always active. At any time, the input supply is below the UVLO threshold or approximately 150 mV of the voltage at the V\textsubscript{BAT} pin, the MCP73123/223 device is placed in a Shutdown mode.

5.2 Overvoltage Protection (OVP)
An internal OVP circuit monitors the input voltage and keeps the charger in Shutdown mode when the input supply rises above the OVP threshold. The hysteresis of OVP is approximately 150 mV for the MCP73123/223 device.

The MCP73123/223 device is operational between UVLO and OVP threshold. The OVP circuit is also recognized as an overvoltage lockout (OVLO).

5.3 Charge Qualification
When the input power is applied, the input supply must rise 150 mV above the battery voltage before the MCP73123/223 becomes operational.

The automatic power down circuit places the device in Shutdown mode if the input supply falls to within +50 mV of the battery voltage.

The automatic circuit is always active. At any time the input supply is within +50 mV of the voltage at the V\textsubscript{BAT} pin, the MCP73123/223 is placed in a Shutdown mode.

For a charge cycle to begin, the automatic power down conditions must be met and the charge enable input must be above the input high threshold.

Note: In order to extend the battery cycle life, the charge will initiate only when battery voltage is below 3.4V per cell.

5.3.1 Battery Management Input Supply (V\textsubscript{DD})
The V\textsubscript{DD} input is the input supply to the MCP73123/223. The MCP73123/223 automatically enters a Power-down mode if the voltage on the V\textsubscript{DD} input falls to within +50 mV of the battery voltage. This feature prevents draining the battery pack when the V\textsubscript{DD} supply is not present.

5.3.2 Battery Charge Control Output (V\textsubscript{BAT})
The battery charge control output is the drain terminal of an internal P-channel MOSFET. The MCP73123/223 provides constant current and voltage regulation to the battery pack by controlling this MOSFET in the linear region. The battery charge control output should be connected to the positive terminal of the battery pack.

5.3.3 Battery Detection
The MCP73123/223 detects the battery presence by monitoring the voltage at V\textsubscript{BAT}. The charge flow will initiate when the voltage on V\textsubscript{BAT} is below the V\textsubscript{RECHARGE} threshold. Refer to the Section 1.0, “Electrical Characteristics”, for V\textsubscript{RECHARGE} values.

When V\textsubscript{BAT} > V\textsubscript{REG} + Hysteresis, the charge will be suspended or not started, depending on the current charge status, to prevent overcharging.

5.4 Preconditioning
If the voltage at the V\textsubscript{BAT} pin is less than the preconditioning threshold, the MCP73123/223 device enters a Preconditioning mode. The preconditioning threshold is factory set. Refer to Section 1.0, “Electrical Characteristics”, for preconditioning threshold options.

In this mode, the MCP73123/223 device supplies 10% of the fast charge current (established with the value of the resistor connected to the PROG pin) to the battery. When the voltage at the V\textsubscript{BAT} pin rises above the preconditioning threshold, the MCP73123/223 device enters the Constant Current (Fast Charge) mode.

Note: The MCP73123/223 also offers options with no preconditioning.

5.4.1 Timer Expired During Preconditioning Mode
If the internal timer expires before the voltage threshold is reached for Fast Charge mode, a timer fault is indicated and the charge cycle terminates. The MCP73123/223 device remains in this condition until the battery is removed or input power is cycled. If the battery is removed, the MCP73123/223 device enters Standby mode, where it remains until a battery is reinserted.

Note: The typical preconditioning timer for MCP73123/223 is 32 minutes. The MCP73123/223 also offers options with no preconditioning timer.

5.5 Constant Current Mode – Fast Charge
During the Constant Current mode, the programmed charge current is supplied to the battery or load.
The charge current is established using a single resistor from PROG to V_{SS}. The program resistor and the charge current are calculated using Equation 5-1 and Equation 5-2.

**EQUATION 5-1:**

$$I_{REG} = 1104 \times R^{-0.93}$$

Where:

- $R_{PROG} = \text{kilo-ohms (kΩ)}$
- $I_{REG} = \text{milliampere (mA)}$

**EQUATION 5-2:**

$$R_{PROG} = 10^{\left(\log\left(I_{REG}/1104\right) \cdot (-0.93)\right)}$$

Where:

- $R_{PROG} = \text{kilo-ohms (kΩ)}$
- $I_{REG} = \text{milliampere (mA)}$

Table 5-1 provides commonly seen E96 (1%) and E24 (5%) resistors for various charge current to reduce design time.

<table>
<thead>
<tr>
<th>Charge Current (mA)</th>
<th>Recommended E96 Resistor (Ω)</th>
<th>Recommended E24 Resistor (Ω)</th>
</tr>
</thead>
<tbody>
<tr>
<td>130</td>
<td>10k</td>
<td>10k</td>
</tr>
<tr>
<td>150</td>
<td>8.45k</td>
<td>8.20k</td>
</tr>
<tr>
<td>200</td>
<td>6.20k</td>
<td>6.20k</td>
</tr>
<tr>
<td>250</td>
<td>4.99k</td>
<td>5.10k</td>
</tr>
<tr>
<td>300</td>
<td>4.02k</td>
<td>3.90k</td>
</tr>
<tr>
<td>350</td>
<td>3.40k</td>
<td>3.30k</td>
</tr>
<tr>
<td>400</td>
<td>3.00k</td>
<td>3.00k</td>
</tr>
<tr>
<td>450</td>
<td>2.61k</td>
<td>2.70k</td>
</tr>
<tr>
<td>500</td>
<td>2.32k</td>
<td>2.37k</td>
</tr>
<tr>
<td>550</td>
<td>2.10k</td>
<td>2.20k</td>
</tr>
<tr>
<td>600</td>
<td>1.91k</td>
<td>2.00k</td>
</tr>
<tr>
<td>650</td>
<td>1.78k</td>
<td>1.80k</td>
</tr>
<tr>
<td>700</td>
<td>1.62k</td>
<td>1.60k</td>
</tr>
<tr>
<td>750</td>
<td>1.50k</td>
<td>1.50k</td>
</tr>
<tr>
<td>800</td>
<td>1.40k</td>
<td>1.50k</td>
</tr>
<tr>
<td>850</td>
<td>1.33k</td>
<td>1.30k</td>
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<tr>
<td>900</td>
<td>1.24k</td>
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<tr>
<td>950</td>
<td>1.18k</td>
<td>1.20k</td>
</tr>
<tr>
<td>1000</td>
<td>1.10k</td>
<td>1.10k</td>
</tr>
<tr>
<td>1100</td>
<td>1.00k</td>
<td>1.00k</td>
</tr>
</tbody>
</table>

5.5.1 TIMER EXPIRED DURING CONSTANT CURRENT – FAST CHARGE MODE

If the internal timer expires before the recharge voltage threshold is reached, a timer fault is indicated and the charge cycle terminates. The MCP73123/223 device remains in this condition until the battery is removed. If the battery is removed or input power is cycled, the MCP73123/223 device enters the Standby mode, where it remains until a battery is reinserted.

5.6 Constant Voltage Mode

When the voltage at the V_{BAT} pin reaches the regulation voltage, V_{REG}, constant voltage regulation begins. The regulation voltage is factory set to 3.6V for a single cell, with a tolerance of ±0.5%; or 7.2V for dual cells, with a tolerance of ±0.6%.

5.7 Charge Termination

The charge cycle is terminated when, during Constant Voltage mode, the average charge current diminishes below a threshold established with the value of 5%, 7.5%, 10% or 20% of fast charge current or internal timer has expired. A 1 ms filter time on the termination comparator ensures that transient load conditions do not result in premature charge cycle termination. The timer period is factory set and can be disabled. Refer to Section 1.0, "Electrical Characteristics", for timer period options.

5.8 Automatic Recharge

The MCP73123/223 device continuously monitors the voltage at the V_{BAT} pin in the Charge Complete mode. If the voltage drops below the recharge threshold, another charge cycle begins and current is once again supplied to the battery or load. The recharge threshold is factory set. Refer to Section 1.0, "Electrical Characteristics", for recharge threshold options.

| Note: The MCP73123/223 also offer options with no automatic recharge. |

For the MCP73123/223 device with no recharge option, the MCP73123/223 will go into Standby mode when the termination condition is met. The charge will not restart until at least one of the following conditions have been met:

- The battery is removed from the system and inserted again
- $V_{DD}$ is removed and plugged in again
- $R_{PROG}$ is disconnected (or high impedance) and reconnected

Constant Current mode is maintained until the voltage at the V_{BAT} pin reaches the regulation voltage, V_{REG}. When Constant Current mode is invoked, the internal timer is reset.
5.9 Thermal Regulation

The MCP73123/223 limits the charge current, based on the die temperature. This thermal regulation optimizes the charge cycle time while maintaining device reliability. Figure 5-1 depicts the thermal regulation for the MCP73123/223 device. Refer to Section 1.0, "Electrical Characteristics", for thermal package resistances and Section 6.1.1.2 "Thermal Considerations", for calculating power dissipation.

5.10 Thermal Shutdown

The MCP73123/223 suspends charge if the die temperature exceeds +150°C. Charging will be resumed when the die temperature has cooled by approximately 10°C. This thermal shutdown is a secondary safety feature in the event that there is a failure within the thermal regulation circuitry.

5.11 Status Indicator

The charge status outputs are open-drain outputs with two different states: Low (L) and High Impedance (High-Z). The charge status outputs can be used to illuminate LEDs. Optionally, the charge status outputs can be used as an interface to a host microcontroller. Table 5-2 summarizes the state of the status outputs during a charge cycle.

<table>
<thead>
<tr>
<th>CHARGE CYCLE STATE</th>
<th>STAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shutdown</td>
<td>High-Z</td>
</tr>
<tr>
<td>Standby</td>
<td>High-Z</td>
</tr>
<tr>
<td>Preconditioning</td>
<td>L</td>
</tr>
<tr>
<td>Constant Current Fast</td>
<td>L</td>
</tr>
<tr>
<td>Charge</td>
<td></td>
</tr>
<tr>
<td>Constant Voltage</td>
<td>L</td>
</tr>
<tr>
<td>Charge Complete - Standby</td>
<td>High-Z</td>
</tr>
<tr>
<td>Temperature Fault</td>
<td>1.6 second 50% DC</td>
</tr>
<tr>
<td></td>
<td>Flashing (Type 2)</td>
</tr>
<tr>
<td></td>
<td>High-Z (Type 1)</td>
</tr>
<tr>
<td>Timer Fault</td>
<td>1.6 second 50% DC</td>
</tr>
<tr>
<td></td>
<td>Flashing (Type 2)</td>
</tr>
<tr>
<td></td>
<td>High-Z (Type 1)</td>
</tr>
<tr>
<td>Preconditioning Timer</td>
<td>1.6 second 50% DC</td>
</tr>
<tr>
<td>Fault</td>
<td>Flashing (Type 2)</td>
</tr>
<tr>
<td></td>
<td>High-Z (Type 1)</td>
</tr>
</tbody>
</table>

5.12 Battery Short Circuit Protection

When a lithium iron phosphate battery is detected, an internal battery short circuit protection circuit starts monitoring the battery voltage. When $V_{BAT}$ is below the typical 1.7V battery short circuit protection threshold voltage per cell, the charging behavior is postponed. A 25 mA (typical) detection current is supplied for recovering from the battery short circuit condition. Preconditioning mode resumes when $V_{BAT}$ rises above the battery short circuit protection threshold. The battery voltage must rise approximately 150 mV above the battery short circuit protection voltage before the MCP73123/223 device becomes operational.
6.0 APPLICATIONS

The MCP73123/223 is designed to operate with a host microcontroller or in stand-alone applications. The MCP73123/223 provides the preferred charge algorithm for lithium iron phosphate cells, Constant Current mode followed by Constant Voltage mode.

Figure 6-1 depicts a typical stand-alone application circuit, while Figure 6-2 depicts the accompanying charge profile.

**FIGURE 6-1:** Typical Application Circuit.

**FIGURE 6-2:** Typical Charge Profile for Single-Cell LiFePO$_4$ Battery.
6.1 Application Circuit Design

Due to the low efficiency of linear charging, the most important factors are thermal design and cost, which are a direct function of the input voltage, output current and thermal impedance between the battery charger and the ambient cooling air. The worst-case situation is when the device has transitioned from the Preconditioning mode to the Constant Current mode. In this situation, the battery charger has to dissipate the maximum power. A trade-off must be made between the charge current, cost, and thermal requirements of the charger.

6.1.1 COMPONENT SELECTION

Selection of the external components in Figure 6-1 is crucial to the integrity and reliability of the charging system. The following discussion is intended as a guide for the component selection process.

6.1.1.1 Charge Current

The recommended fast charge current should be obtained from the battery manufacturer. For example, a 1000 mAh battery pack with 2C preferred fast charge current has a charge current of 1000 mA. Charging at this rate provides the shortest charge cycle times without degradation of the battery pack performance or life.

**Note:** Please consult with your battery supplier or refer to the battery data sheet for the preferred charge rate.

6.1.1.2 Thermal Considerations

The worst-case power dissipation in the battery charger occurs when the input voltage is at the maximum and the device has transitioned from the Preconditioning mode to the Constant Current mode. In this case, the power dissipation is calculated using Equation 6-1.

**EQUATION 6-1:**

\[
Power\text{Dissipation} = (V_{\text{DDMAX}} - V_{\text{PTHMIN}}) \times I_{\text{REGMAX}}
\]

Where:
- \(V_{\text{DDMAX}}\) = the maximum input voltage
- \(I_{\text{REGMAX}}\) = the maximum fast charge current
- \(V_{\text{PTHMIN}}\) = the minimum transition threshold voltage

Power dissipation with a 5V, ±10% input voltage source, 500 mA ±10% and preconditioning threshold voltage at 2V is calculated using Equation 6-2.

**EQUATION 6-2:**

\[
Power\text{Dissipation} = (5.5V - 2V) \times 550mA = 1.925W
\]

This power dissipation with the battery charger in the DFN-10 package will raise the temperature approximately 83°C above room temperature.

6.1.1.3 External Capacitors

The MCP73123/223 is stable with or without a battery load. In order to maintain good AC stability in the Constant Voltage mode, a minimum capacitance of 1 µF is recommended to bypass the \(V_{\text{BAT}}\) pin to \(V_{\text{SS}}\). This capacitance provides compensation when there is no battery load. In addition, the battery and interconnections appear inductive at high frequencies. These elements are in the control feedback loop during Constant Voltage mode. Therefore, the bypass capacitance may be necessary to compensate for the inductive nature of the battery pack.

A minimum of 1 µF is recommended for the output capacitor, and a minimum of 1 µF is recommended for the input capacitor in typical applications.

**TABLE 6-1:** MLCC CAPACITOR EXAMPLE

<table>
<thead>
<tr>
<th>MLCC Capacitors</th>
<th>Temperature Range</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>X7R</td>
<td>-55°C to +125°C</td>
<td>±15%</td>
</tr>
<tr>
<td>X5R</td>
<td>-55°C to +85°C</td>
<td>±15%</td>
</tr>
</tbody>
</table>

Virtually any good quality output filter capacitor can be used, independent of the capacitor’s minimum Effective Series Resistance (ESR) value. The actual value of the capacitor (and its associated ESR) depends on the output load current. A 1 µF ceramic, tantalum, or aluminum electrolytic capacitor at the output is usually sufficient to ensure stability.

6.1.1.4 Reverse-Blocking Protection

The MCP73123/223 provides protection from a faulted or shorted input. Without the protection, a faulted or shorted input would discharge the battery pack through the body diode of the internal pass transistor.
6.2 PCB Layout Issues

For optimum voltage regulation, place the battery pack as close as possible to the device's $V_{BAT}$ and $V_{SS}$ pins to minimize voltage drops along the high-current-carrying PCB traces.

If the PCB layout is used as a heat sink, adding multiple vias in the heat sink pad can help conduct more heat to the backplane of the PCB, thus reducing the maximum junction temperature. Figure 6-3, Figure 6-4 and Figure 6-5 depict a typical layout with PCB heatsinking.

**Figure 6-3:** Typical Layout (Top).

**Figure 6-4:** Typical Layout (Top Metal).

**Figure 6-5:** Typical Layout (Bottom).
# 7.0 PACKAGING INFORMATION

## 7.1 Package Marking Information

10-Lead DFN (3x3)

<table>
<thead>
<tr>
<th>XXXX</th>
<th>YYWW</th>
<th>NNN</th>
</tr>
</thead>
</table>

**Legend:**
- **XX...X** Customer-specific information
- **Y** Year code (last digit of calendar year)
- **YY** Year code (last 2 digits of calendar year)
- **WW** Week code (week of January 1 is week '01')
- **NNN** Alphanumeric traceability code
- **e3** Pb-free JEDEC designator for Matte Tin (Sn)
- ***** This package is Pb-free. The Pb-free JEDEC designator (e3) can be found on the outer packaging for this package.

**Note:** In the event the full Microchip part number cannot be marked on one line, it will be carried over to the next line, thus limiting the number of available characters for customer-specific information.

<table>
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<tr>
<th>Standard *</th>
<th></th>
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<tbody>
<tr>
<td>Part Number</td>
<td>Code</td>
</tr>
<tr>
<td>MCP73123-22SI/MF</td>
<td>77HI</td>
</tr>
<tr>
<td>MCP73223-C2SI/MF</td>
<td>X7HI</td>
</tr>
</tbody>
</table>

Example:

| 77HI |
| 1225 |
| 256  |

© 2009-2013 Microchip Technology Inc.
10-Lead Plastic Dual Flat, No Lead Package (MF) - 3x3x0.9mm Body [DFN]

Note: For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging

Microchip Technology Drawing No, C04-063C Sheet 1 of 2
MCP73123/223

10-Lead Plastic Dual Flat, No Lead Package (MF) - 3x3x0.9mm Body [DFN]

Note: For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging

![Image of package](image)

<table>
<thead>
<tr>
<th>Units</th>
<th>MILLIMETERS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimension Limits</td>
<td>MIN</td>
</tr>
<tr>
<td>Number of Pins</td>
<td>N</td>
</tr>
<tr>
<td>Pitch</td>
<td>e</td>
</tr>
<tr>
<td>Overall Height</td>
<td>A</td>
</tr>
<tr>
<td>Standoff</td>
<td>A1</td>
</tr>
<tr>
<td>Contact Thickness</td>
<td>A3</td>
</tr>
<tr>
<td>Overall Length</td>
<td>D</td>
</tr>
<tr>
<td>Exposed Pad Length</td>
<td>D2</td>
</tr>
<tr>
<td>Overall Width</td>
<td>E</td>
</tr>
<tr>
<td>Exposed Pad Width</td>
<td>E2</td>
</tr>
<tr>
<td>Contact Width</td>
<td>b</td>
</tr>
<tr>
<td>Contact Length</td>
<td>L</td>
</tr>
<tr>
<td>Contact-to-Exposed Pad</td>
<td>K</td>
</tr>
</tbody>
</table>

Notes:
1. Pin 1 visual index feature may vary, but must be located within the hatched area.
2. Package may have one or more exposed tie bars at ends.
3. Package is saw singulated.
4. Dimensioning and tolerancing per ASME Y14.5M.

BSC: Basic Dimension. Theoretically exact value shown without tolerances.
REF: Reference Dimension, usually without tolerance, for information purposes only.

Microchip Technology Drawing No. C04-063C Sheet 2 of 2
10-Lead Plastic Dual Flat, No Lead Package (MF) - 3x3x0.9mm Body [DFN]

**Note:** For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging

**RECOMMENDED LAND PATTERN**

<table>
<thead>
<tr>
<th>Units</th>
<th>MILLIMETERS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimension Limits</td>
<td>MIN</td>
</tr>
<tr>
<td>Contact Pitch</td>
<td>E</td>
</tr>
<tr>
<td>Optional Center Pad Width</td>
<td>W2</td>
</tr>
<tr>
<td>Optional Center Pad Length</td>
<td>T2</td>
</tr>
<tr>
<td>Contact Pad Spacing</td>
<td>C1</td>
</tr>
<tr>
<td>Contact Pad Width (X10)</td>
<td>X1</td>
</tr>
<tr>
<td>Contact Pad Length (X10)</td>
<td>Y1</td>
</tr>
<tr>
<td>Distance Between Pads</td>
<td>G</td>
</tr>
</tbody>
</table>

**Notes:**
1. Dimensioning and tolerancing per ASME Y14.5M
   BSC: Basic Dimension. Theoretically exact value shown without tolerances.
APPENDIX A: REVISION HISTORY

Revision E (February 2013)
The following is the list of modifications:
1. Updated the Functional Block Diagram.
2. Updated the Temperature Specifications table.
3. Updated Section 3.6 “Current Regulation Set (PROG)”.
4. Updated Section 5.3.3 “Battery Detection”.
5. Updated Equation 5-2.

Revision D (June 2011)
The following is the list of modifications:
1. Updated the land pattern drawing of the 3x3 DFN package on page 27.

Revision C (January 2011)
The following is the list of modifications:
1. Added two more part numbers in Table 2.
2. Updated the flowchart in Figure 4-1.

Revision B (January 2010)
The following is the list of modifications:
1. Updated the OVP value for MCP73223-C2S/MF in Table 2.
2. Updated the Battery Short Protection values in the DC Characteristics table.

Revision A (July 2009)
• Original Release of this Document.
PRODUCT IDENTIFICATION SYSTEM

To order or obtain information, e.g., on pricing or delivery, contact your local Microchip sales office.

<table>
<thead>
<tr>
<th>PART NO.</th>
<th>X</th>
<th>XX</th>
</tr>
</thead>
<tbody>
<tr>
<td>Device</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MCP73123: Single Cell Lithium Iron Phosphate Battery Device</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MCP73123T: Single Cell Lithium Iron Phosphate Battery Device, Tape and Reel</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MCP73223: Dual Cell Lithium Iron Phosphate Battery Device</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MCP73223T: Dual Cell Lithium Iron Phosphate Battery Device, Tape and Reel</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temperature Range:</td>
<td>I = -40°C to +85°C (Industrial)</td>
<td></td>
</tr>
<tr>
<td>Package:</td>
<td>MF = Plastic Dual Flat No Lead, 3x3 mm Body (DFN), 10-Lead</td>
<td></td>
</tr>
</tbody>
</table>

Examples:

a) MCP73123-22SI/MF: Single Cell Lithium Iron Phosphate Battery Device
b) MCP73123T-22SI/MF: Tape and Reel, Single Cell Lithium Iron Phosphate Battery Device
a) MCP73223-C2SI/MF: Dual Cell Lithium Iron Phosphate Battery Device
a) MCP73223T-C2SI/MF: Tape and Reel, Dual Cell Lithium Iron Phosphate Battery Device

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