MCP73853/55

USB Compatible Li-Ion/Li-Polymer Charge Management Controllers

Features
• Linear Charge Management Controllers
  - Integrated Pass Transistor
  - Integrated Current Sense
  - Reverse Blocking Protection
• High-Accuracy Preset Voltage Regulation: ± 0.5%
• Two Selectable Voltage Regulation Options:
  - 4.1V, 4.2V
• Programmable Charge Current
• USB Compatible Charge Current Settings
• Programmable Safety Charge Timers
• Preconditioning of Deeply Depleted Cells
• Automatic End-of-Charge Control
• Optional Continuous Cell Temperature Monitoring

MCP73853
• Charge Status Output for Direct LED Drive
• Fault Output for Direct LED Drive

MCP73853
• Automatic Power-Down
• Thermal Regulation
• Temperature Range: -40°C to +85°C
• Packaging:
  - 16-Lead, 4x4 mm QFN (MCP73853)
  - 10-Lead, 3x3 mm DFN (MCP73855)

Applications
• Lithium-Ion/Lithium-Polymer Battery Chargers
• Personal Data Assistants (PDAs)
• Cellular Telephones
• Hand-Held Instruments
• Cradle Chargers
• Digital Cameras
• MP3 Players
• Bluetooth Headsets
• USB Chargers

Description
The MCP7385X devices are highly-advanced, linear charge management controllers, for use in space-limited, cost-sensitive applications. The MCP73853 combines high-accuracy constant-voltage, constant-current regulation, cell preconditioning, cell temperature monitoring, advanced safety timers, automatic charge termination, internal current sensing, reverse blocking protection and charge status and fault indication in a space-saving 16-lead, 4x4 QFN package.

The MCP7385 employs all the features of the MCP73853, with the exception of the cell temperature monitor and one status output. The MCP7385 is offered in a space-saving 10-lead, 3x3 DFN package.

The MCP73853 and MCP73855 are designed specifically for USB applications, adhering to all the specifications governing the USB power bus.

The MCP7385X devices provide two selectable voltage regulation options (4.1V or 4.2V) for use with either coke or graphite anodes.

These devices have complete and fully-functional, charge management solutions, operating with an input voltage range of 4.5V to 5.5V. These are fully specified over the ambient temperature range of -40°C to +85°C.

Package Types

<table>
<thead>
<tr>
<th>MCP73853</th>
<th>4x4 QFN*</th>
</tr>
</thead>
<tbody>
<tr>
<td>V_SET</td>
<td>1</td>
</tr>
<tr>
<td>V_DD1</td>
<td>2</td>
</tr>
<tr>
<td>V_DD2</td>
<td>3</td>
</tr>
<tr>
<td>V_SS1</td>
<td>4</td>
</tr>
<tr>
<td>V_BAT1</td>
<td>11</td>
</tr>
<tr>
<td>V_BAT2</td>
<td>17</td>
</tr>
<tr>
<td>V_BAT3</td>
<td>13</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>MCP73855</th>
<th>3x3 DFN*</th>
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<tbody>
<tr>
<td>V_SET</td>
<td>1</td>
</tr>
<tr>
<td>V_DD1</td>
<td>3</td>
</tr>
<tr>
<td>V_DD2</td>
<td>5</td>
</tr>
<tr>
<td>V_SS1</td>
<td>7</td>
</tr>
<tr>
<td>V_BAT1</td>
<td>11</td>
</tr>
<tr>
<td>V_BAT2</td>
<td>8</td>
</tr>
<tr>
<td>V_BAT3</td>
<td>9</td>
</tr>
</tbody>
</table>

*Exposed Pad (EP) is at V_SS potential.
Typical Application

400 mA Lithium-Ion Battery Charger

Functional Block Diagram

MCP73853/55

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1.0 ELECTRICAL CHARACTERISTICS

Absolute Maximum Ratings*

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>VDD1,2</td>
<td>4.5</td>
<td>5.5</td>
<td>5.5</td>
</tr>
<tr>
<td>Supply Voltage</td>
<td>VDD</td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>Supply Current</td>
<td>I\text{SS}</td>
<td>0.28</td>
<td>4</td>
</tr>
<tr>
<td>UVLO Start Threshold V\text{START}</td>
<td>4.25</td>
<td>4.45</td>
<td>4.65</td>
</tr>
<tr>
<td>UVLO Stop Threshold V\text{STOP}</td>
<td>4.20</td>
<td>4.40</td>
<td>4.55</td>
</tr>
</tbody>
</table>

DC CHARACTERISTICS

Electrical Specifications: Unless otherwise indicated, all limits apply for V\text{DD} = [V\text{REG}(\text{Typ}) + 0.3V] to 5.5V, T\text{A} = -40°C to 85°C. Typical values are at +25°C, V\text{DD} = [V\text{REG}(\text{Typ}) + 1V]

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply Voltage</td>
<td>V\text{DD}</td>
<td>4.079</td>
<td>4.121</td>
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<tr>
<td>Supply Current</td>
<td>I\text{SS}</td>
<td>0.28</td>
<td>4</td>
</tr>
<tr>
<td>UVLO Start Threshold V\text{START}</td>
<td>4.25</td>
<td>4.45</td>
<td>4.65</td>
</tr>
<tr>
<td>UVLO Stop Threshold V\text{STOP}</td>
<td>4.20</td>
<td>4.40</td>
<td>4.55</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.
### Charge Termination

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Units</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Charge Termination Current I_TERM</td>
<td>3.7</td>
<td>6.5</td>
<td>9.3</td>
<td>mA</td>
<td>PROG = OPEN,</td>
</tr>
<tr>
<td></td>
<td>18</td>
<td>32</td>
<td>46</td>
<td>mA</td>
<td>PROG = V_SS, T_A = -5°C to +55°C</td>
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</tbody>
</table>

### Automatic Recharge

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Units</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recharge Threshold Voltage V_RTH</td>
<td>V_REG - 300mV</td>
<td>V_REG - 200mV</td>
<td>V_REG - 100mV</td>
<td>V</td>
<td>V_BAT High-to-Low</td>
</tr>
</tbody>
</table>

### Thermistor Reference - MCP73853

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Units</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermistor Reference Output Voltage</td>
<td>2.475</td>
<td>2.55</td>
<td>2.625</td>
<td>V</td>
<td>T_A = 25°C, V_DD = V_REG(Typ) + 1V, I_TERM = 0 mA</td>
</tr>
<tr>
<td>Thermistor Reference Source Current</td>
<td>200</td>
<td>—</td>
<td>—</td>
<td>μA</td>
<td></td>
</tr>
<tr>
<td>Thermistor Reference Line Regulation</td>
<td>0.05</td>
<td>0.25</td>
<td>%/V</td>
<td>V_DD = [V_REG (Typ) + 1V] to 5.5V</td>
<td></td>
</tr>
<tr>
<td>Thermistor Reference Load Regulation</td>
<td>0.02</td>
<td>0.10</td>
<td>%</td>
<td>I_TERM = 0 mA to 0.20 mA</td>
<td></td>
</tr>
</tbody>
</table>

### Thermistor Comparator - MCP73853

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Units</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper Trip Threshold V_T1</td>
<td>1.18</td>
<td>1.25</td>
<td>1.32</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>Upper Trip Point Hysteresis V_T1HYS</td>
<td>—</td>
<td>-50</td>
<td>—</td>
<td>mV</td>
<td></td>
</tr>
<tr>
<td>Lower Trip Threshold V_T2</td>
<td>0.59</td>
<td>0.62</td>
<td>0.66</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>Lower Trip Point Hysteresis V_T2HYS</td>
<td>—</td>
<td>80</td>
<td>—</td>
<td>mV</td>
<td></td>
</tr>
<tr>
<td>Input Bias Current I_BIAS</td>
<td>—</td>
<td>—</td>
<td>2</td>
<td>μA</td>
<td></td>
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</table>

### Status Indicator – STAT1, STAT2

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Units</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sink Current</td>
<td>4</td>
<td>8</td>
<td>12</td>
<td>mA</td>
<td>I_SINK = 1 mA, V_STAT1,2 = 5.5V</td>
</tr>
<tr>
<td>Low Output Voltage V_OL</td>
<td>—</td>
<td>200</td>
<td>400</td>
<td>mV</td>
<td>I_SINK = 0 mA, V_STAT1,2 = 5.5V</td>
</tr>
<tr>
<td>Input Leakage Current I_LK</td>
<td>—</td>
<td>0.01</td>
<td>1</td>
<td>μA</td>
<td>V_ENABLE = 5.5V</td>
</tr>
</tbody>
</table>

### Enable Input

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Units</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input High Voltage Level V_IH</td>
<td>1.4</td>
<td>—</td>
<td>—</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>Input Low Voltage Level V_IL</td>
<td>—</td>
<td>—</td>
<td>0.8</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>Input Leakage Current I_LK</td>
<td>—</td>
<td>0.01</td>
<td>1</td>
<td>μA</td>
<td>V_ENABLE = 5.5V</td>
</tr>
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</table>

### Thermal Shutdown

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Units</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Die Temperature T_SD</td>
<td>—</td>
<td>155</td>
<td>—</td>
<td>°C</td>
<td></td>
</tr>
<tr>
<td>Die Temperature Hysteresis T_SDHYS</td>
<td>—</td>
<td>10</td>
<td>—</td>
<td>°C</td>
<td></td>
</tr>
</tbody>
</table>
### AC CHARACTERISTICS

**Electrical Specifications:** Unless otherwise indicated, all limits apply for \( V_{DD} = [V_{REG} \text{ (Typ)} + 0.3V] \) to 5.5V, \( T_A = -40^\circ \text{C} \) to 85°C. Typical values are at +25°C, \( V_{DD} = [V_{REG} \text{ (Typ)} + 1.0V] \)

<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>UVLO Start Delay</td>
<td>( t_{START} )</td>
<td>—</td>
<td>—</td>
<td>5</td>
<td>ms</td>
<td>( V_{DD} ) Low-to-High</td>
</tr>
<tr>
<td>Current Regulation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transition Time Out of Preconditioning</td>
<td>( t_{DELAY} )</td>
<td>—</td>
<td>—</td>
<td>1</td>
<td>ms</td>
<td>( V_{BAT} &lt; V_{PTH} ) to ( V_{BAT} &gt; V_{PTH} )</td>
</tr>
<tr>
<td>Current Rise Time Out of Preconditioning</td>
<td>( t_{RISE} )</td>
<td>—</td>
<td>—</td>
<td>1</td>
<td>ms</td>
<td>( I_{OUT} ) Rising to 90% of ( I_{REG} )</td>
</tr>
<tr>
<td>Fast Charge Safety Timer Period</td>
<td>( t_{FAST} )</td>
<td>1.1</td>
<td>1.5</td>
<td>1.9</td>
<td>Hours</td>
<td>( C_{TIMER} = 0.1 \mu \text{F} )</td>
</tr>
<tr>
<td>Preconditioning Current Regulation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preconditioning Charge Safety Timer Period</td>
<td>( t_{PRECON} )</td>
<td>45</td>
<td>60</td>
<td>75</td>
<td>Minutes</td>
<td>( C_{TIMER} = 0.1 \mu \text{F} )</td>
</tr>
<tr>
<td>Charge Termination</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elapsed Time Termination Period</td>
<td>( t_{TERM} )</td>
<td>2.2</td>
<td>3</td>
<td>3.8</td>
<td>Hours</td>
<td>( C_{TIMER} = 0.1 \mu \text{F} )</td>
</tr>
<tr>
<td>Status Indicators</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Status Output Turn-off</td>
<td>( t_{OFF} )</td>
<td>—</td>
<td>—</td>
<td>200</td>
<td>μs</td>
<td>( I_{SINK} = 1 \text{ mA to } 0 \text{ mA} )</td>
</tr>
<tr>
<td>Status Output Turn-on</td>
<td>( t_{ON} )</td>
<td>—</td>
<td>—</td>
<td>200</td>
<td>μs</td>
<td>( I_{SINK} = 0 \text{ mA to } 1 \text{ mA} )</td>
</tr>
</tbody>
</table>

### TEMPERATURE SPECIFICATIONS

**Electrical Specifications:** Unless otherwise indicated, all limits apply for \( V_{DD} = [V_{REG} \text{ (Typ)} + 0.3V] \) to 5.5. Typical values are at +25°C, \( V_{DD} = [V_{REG} \text{ (Typ)} + 1.0V] \)

<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>Temperature Ranges</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>-40</td>
<td>—</td>
<td>+85</td>
<td>°C</td>
<td></td>
</tr>
<tr>
<td>Operating Temperature Range</td>
<td>( T_J )</td>
<td>-40</td>
<td>—</td>
<td>+125</td>
<td>°C</td>
<td></td>
</tr>
<tr>
<td>Storage Temperature Range</td>
<td>( T_A )</td>
<td>-65</td>
<td>—</td>
<td>+150</td>
<td>°C</td>
<td></td>
</tr>
<tr>
<td>Thermal Package Resistances</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thermal Resistance, 16-L, 4mm x 4mm QFN</td>
<td>( \theta_{JA} )</td>
<td>—</td>
<td>37</td>
<td>—</td>
<td>°C/W</td>
<td>4-Layer JC51-7 Standard Board, Natural Convection</td>
</tr>
<tr>
<td>Thermal Resistance, 10-L, 3mm x 3mm DFN</td>
<td>( \theta_{JA} )</td>
<td>—</td>
<td>51</td>
<td>—</td>
<td>°C/W</td>
<td>4-Layer JC51-7 Standard Board, Natural Convection</td>
</tr>
</tbody>
</table>
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, \( V_{DD} = [V_{REG(Typ)} + 1V], I_{OUT} = 10 \text{ mA} \) and \( T_A = +25^\circ C \).

**FIGURE 2-1:** Battery Regulation Voltage \( (V_{BAT}) \) vs. Charge Current \( (I_{OUT}) \).

**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:** Supply Current \( (I_{SS}) \) vs. Charge Current \( (I_{OUT}) \).

**FIGURE 2-5:** Supply Current \( (I_{SS}) \) vs. Supply Voltage \( (V_{DD}) \).

**FIGURE 2-6:** Supply Current \( (I_{SS}) \) vs. Supply Voltage \( (V_{DD}) \).

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

FIGURE 2-7: Output Leakage Current ($I_{\text{DISCHARGE}}$) vs. Battery Voltage ($V_{BAT}$).

FIGURE 2-8: Thermistor Reference Voltage ($V_{\text{THREF}}$) vs. Supply Voltage ($V_{DD}$).

FIGURE 2-9: Thermistor Reference Voltage ($V_{\text{THREF}}$) vs. Thermistor Bias Current ($I_{\text{THREF}}$).

FIGURE 2-10: Supply Current ($I_{SS}$) vs. Ambient Temperature ($T_A$).

FIGURE 2-11: Battery Regulation Voltage ($V_{BAT}$) vs. Ambient Temperature ($T_A$).

FIGURE 2-12: Thermistor Reference Voltage ($V_{\text{THREF}}$) vs. Ambient Temperature ($T_A$).

FIGURE 2-14: Load Transient Response.

FIGURE 2-15: Power Supply Ripple Rejection.

FIGURE 2-16: Line Transient Response.

FIGURE 2-17: Load Transient Response.

FIGURE 2-18: Power Supply Ripple Rejection.

NOTE: Unless otherwise indicated, VDD = [VREG(Typ) + 1V], IOUT = 10 mA, and TA = +25°C.
**FIGURE 2-19:** Charge Current ($I_{OUT}$) vs. Programming Resistor ($R_{PROG}$).

**FIGURE 2-20:** Charge Current ($I_{OUT}$) vs. Ambient Temperature ($T_A$).
3.0 PIN DESCRIPTION

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

<table>
<thead>
<tr>
<th>TABLE 3-1: PIN FUNCTION TABLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>MCP73853</td>
</tr>
<tr>
<td>------------</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
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<tr>
<td>3</td>
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<tr>
<td>15</td>
</tr>
<tr>
<td>16</td>
</tr>
<tr>
<td>17</td>
</tr>
</tbody>
</table>

3.1 Voltage Regulation Selection (VSET)
Connect to VSS for 4.1V regulation voltage. Connect to VDD for 4.2V regulation voltage.

3.2 Battery Management Input Supply (VDD1, VDD2)
A supply voltage of \([V_{REG}(Typ) + 0.3V]\) to 5.5V is recommended. Bypass to VSS with a minimum of 4.7 µF.

3.3 Battery Management 0V Reference (VSS1, VSS2, VSS3)
Connect to negative terminal of battery.

3.4 Current Regulation Set (PROG)
Preconditioning, fast and termination currents are scaled by placing a resistor from PROG to VSS.

3.5 Cell Temperature Sensor Bias (THREF)
THREF is a voltage reference to bias external thermistor for continuous cell temperature monitoring and pre-qualification.

3.6 Cell Temperature Sensor Input (THERM)
Input for an external thermistor for continuous cell-temperature monitoring and prequalification. Connect to THREF/3 to disable temperature sensing.

3.7 Timer Set (TIMER)
All safety timers are scaled by \(C_{TIMER}/0.1\) µF.

3.8 Battery Charge Control Output (VBAT1, VBAT2)
Connect to positive terminal of battery. Drain terminal of internal P-channel MOSFET pass transistor. Bypass to VSS with a minimum of 4.7 µF to ensure loop stability when the battery is disconnected.

3.9 Battery Voltage Sense (VBAT3)
Voltage sense input. Connect to positive terminal of battery. A precision internal resistor divider regulates the final voltage on this pin to \(V_{REG}\).

3.10 Logic Enable (EN)
Input to force charge termination, initiate charge, clear faults or disable automatic recharge.

3.11 Fault Status Output (STAT2)
Current-limited, open-drain drive for direct connection to an LED for charge status indication. Alternatively, a pull-up resistor can be applied for interfacing to a host microcontroller.

3.12 Charge Status Output (STAT1)
Current-limited, open-drain drive for direct connection to a LED for charge status indication. Alternatively, a pull-up resistor can be applied for interfacing to a host microcontroller.
4.0 DEVICE OVERVIEW

The MCP7385X devices are highly-advanced, linear charge management controllers. For more information, refer to the “Functional Block Diagram” on page 2. Figure 4-2 depicts the operational flow algorithm from charge initiation to completion and automatic recharge.

4.1 Charge Qualification and Preconditioning

Upon insertion of a battery or application of an external supply, the MCP7385X devices automatically perform a series of safety checks to qualify the charge. The input source voltage must be above the Undervoltage Lockout (UVLO) threshold, the enable pin must be above the logic high level, and the cell temperature monitor must be within the upper and lower thresholds (MCP73853 only). The qualification parameters are continuously monitored, with any deviation beyond the limits automatically suspending or terminating the charge cycle. The input voltage must deviate below the UVLO stop threshold for at least one clock period to be considered valid.

Once the qualification parameters have been met, the MCP7385X devices initiate a charge cycle. The charge status output is pulled low throughout the charge cycle (see Table 5-1 and Table 5-2 for charge status outputs). If the battery voltage is below the preconditioning threshold (VPTH), the MCP7385X devices precondition the battery with a trickle charge. The preconditioning current is set to approximately 10% of the fast charge regulation current. The preconditioning trickle charge safely replenishes deeply depleted cells and minimizes heat dissipation during the initial charge cycle. If the battery voltage has not exceeded the preconditioning threshold before the preconditioning timer has expired, a fault is indicated and the charge cycle is terminated.

4.2 Constant Current Regulation – Fast Charge

Preconditioning ends and fast charging begins when the battery voltage exceeds the preconditioning threshold. Fast charge regulates to a constant current (I_REG), which is set via an external resistor connected to the PROG pin. Fast charge continues until either the battery voltage reaches the regulation voltage (V_REG) or the fast charge timer expires; in which case, a fault is indicated and the charge cycle is terminated.

4.3 Constant Voltage Regulation

When the battery voltage reaches the regulation voltage (V_REG), constant voltage regulation begins. The MCP7385X devices monitor the battery voltage at the VBat pin. This input is tied directly to the positive terminal of the battery. The MCP7385X devices select the voltage regulation value based on the state of V_SET.

With V_SET tied to VSS, the MCP7385X devices regulate to 4.1V or with V_SET tied to VDD, the MCP7385X devices regulate to 4.2V.

4.4 Charge Cycle Completion and Automatic Recharge

The MCP7385X devices monitor the charging current during the Constant-voltage Regulation mode. The charge cycle is considered complete when either the charge current has diminished below approximately 7% of the regulation current (I_REG) or the elapsed timer has expired.

Assuming all the qualification parameters are met, the MCP7385X devices automatically begin a new charge cycle when the battery voltage falls below the recharge threshold (V_RTH).

4.5 Thermal Regulation

The MCP7385X devices limit the charge current based on the die temperature. Thermal regulation optimizes the charge cycle time while maintaining device reliability. If thermal regulation is entered, the timer is automatically slowed down to ensure that a charge cycle does not terminate prematurely. Figure 4-1 depicts the thermal regulation.

4.6 Thermal Shutdown

The MCP7385X devices suspend charge if the die temperature exceeds 155°C. Charging resumes when the die temperature has cooled by approximately 10°C. The thermal shutdown is a secondary safety feature in the event that there is a failure within the thermal regulation circuitry.
FIGURE 4-2: Operational Flow Algorithm.

Note 1: The qualification parameters are continuously monitored throughout the charge cycle. For more details, refer to \textit{Section 4.1 "Charge Qualification and Preconditioning".}

Note 2: The charge current will be scaled based on the die temperature during thermal regulation. For more details, refer to \textit{Section 4.5 "Thermal Regulation".}
5.0 DETAILED DESCRIPTION

5.1 Analog Circuitry

5.1.1 BATTERY MANAGEMENT INPUT SUPPLY (VDD1, VDD2)

The VDD pin is the input supply pin for the MCP7385X devices. The MCP7385X devices automatically enter a power-down mode if the voltage on the VDD input falls below the UVLO voltage (VSTOP). This feature prevents draining the battery pack when the VDD supply is not present.

5.1.2 PROG INPUT

Fast charge current regulation can be scaled by placing a programming resistor (RPROG) from the PROG input to VSS. Connecting the PROG input to VSS allows a maximum fast charge current of 400 mA, typically. The minimum fast charge current is 85 mA (Typ) and is set by letting the PROG input float. Equation 5-1 calculates the value for RPROG:

\[
R_{PROG} = \frac{13.32 - 33.3 \times I_{REG}}{14.1 \times I_{REG} - 1.2}
\]

Where:

- \( I_{REG} \) is the desired fast charge current in amps
- \( R_{PROG} \) is in kilohms.

The preconditioning trickle charge current and the charge termination current are scaled to approximately 10% and 7% of \( I_{REG} \) respectively.

5.1.3 CELL TEMPERATURE SENSOR BIAS (THREF)

A 2.55V voltage reference is provided to bias an external thermistor for continuous cell temperature monitoring and prequalification. A ratiometric window comparison is performed at threshold levels of \( V_{THREF}/2 \) and \( V_{THREF}/4 \).

5.1.4 CELL TEMPERATURE SENSOR INPUT (THERM)

The MCP73853 continuously monitors temperature by comparing the voltage between the THERM input and VSS with the upper and lower temperature thresholds. A negative or positive temperature coefficient, NTC or PTC thermistor, and an external voltage divider typically develop this voltage. The temperature-sensing circuit has its own reference, to which it performs a ratiometric comparison. Therefore, it is immune to fluctuations in the supply input (VDD). The temperature-sensing circuit is removed from the system when VDD is not applied, eliminating additional discharge of the battery pack.

Figure 6-1 depicts a typical application circuit with connection of the THERM input. The resistor values of \( R_{T1} \) and \( R_{T2} \) are calculated with the following equations:

For NTC thermists:

\[
R_{T1} = \frac{2 \times R_{COLD} \times R_{HOT}}{R_{COLD} - R_{HOT}}
\]
\[
R_{T2} = \frac{2 \times R_{COLD} \times R_{HOT}}{R_{COLD} - 3 \times R_{HOT}}
\]

For PTC thermists:

\[
R_{T1} = \frac{2 \times R_{COLD} \times R_{HOT}}{R_{HOT} - R_{COLD}}
\]
\[
R_{T2} = \frac{2 \times R_{COLD} \times R_{HOT}}{R_{HOT} - 3 \times R_{COLD}}
\]

Where:

- \( R_{COLD} \) and \( R_{HOT} \) are the thermistor resistance values at the temperature window of interest.

Applying a voltage equal to \( V_{THREF}/3 \) to the THERM input disables temperature monitoring.

5.1.5 TIMER SET INPUT (TIMER)

The TIMER input programs the period of the safety timers by placing a timing capacitor (CTIMER) between the TIMER input pin and VSS. Three safety timers are programmed via the timing capacitor:

The preconditioning safety timer period:

\[
\frac{t_{PRECON}}{C_{TIMER} \times 1.0Hours} = \frac{0.1\mu F}{1.0Hours}
\]

The fast charge safety timer period:

\[
\frac{t_{FAST}}{C_{TIMER} \times 1.5Hours} = \frac{0.1\mu F}{1.5Hours}
\]

And, the elapsed time termination period:

\[
\frac{t_{TERM}}{C_{TIMER} \times 3.0Hours} = \frac{0.1\mu F}{3.0Hours}
\]

The preconditioning timer starts after qualification and resets when the charge cycle transitions to the constant-current, fast charge phase. The fast charge timer and the elapsed timer start after the MCP7385X devices transition from preconditioning. The fast charge timer resets when the charge cycle transitions to the Constant-voltage mode. The elapsed timer expires and terminates the charge if the sensed current does not diminish below the termination threshold.

During thermal regulation, the timer is slowed down proportional to the charge current.
5.1.6 BATTERY VOLTAGE SENSE (VBAT3)
The MCP73853 monitors the battery voltage at the VBAT3 pin. This input is tied directly to the positive terminal of the battery pack.

5.1.7 BATTERY CHARGE CONTROL OUTPUT (VBAT1, VBAT2)
The battery charge control output is the drain terminal of an internal P-channel MOSFET. The MCP7385X devices provide constant-current and constant-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.

5.2 Digital Circuitry

5.2.1 CHARGE STATUS OUTPUTS (STAT1, STAT2)
Two status outputs provide information on the state of charge for the MCP73853. One status output provides information on the state of charge for the MCP73855. The current-limited, open-drain outputs can be used to illuminate external LEDs. Optionally, a pull-up resistor can be used on the output for communication with a host microcontroller. Table 5-1 and Table 5-2 summarize the state of the status outputs during a charge cycle for the MCP73853 and MCP73855, respectively.

### Table 5-1: STATUS OUTPUTS – MCP73853

<table>
<thead>
<tr>
<th>CHARGE CYCLE STATE</th>
<th>STAT1</th>
<th>STAT2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Qualification</td>
<td>OFF</td>
<td>OFF</td>
</tr>
<tr>
<td>Preconditioning</td>
<td>ON</td>
<td>OFF</td>
</tr>
<tr>
<td>Constant-Current Fast Charge</td>
<td>ON</td>
<td>OFF</td>
</tr>
<tr>
<td>Constant-voltage</td>
<td>ON</td>
<td>OFF</td>
</tr>
<tr>
<td>Charge Complete</td>
<td>OFF</td>
<td>OFF</td>
</tr>
<tr>
<td>Fault</td>
<td>OFF</td>
<td>ON</td>
</tr>
<tr>
<td>THERM Invalid</td>
<td>OFF</td>
<td>Flashing (1 Hz, 50% duty cycle)</td>
</tr>
<tr>
<td>Disabled - Sleep mode</td>
<td>OFF</td>
<td>OFF</td>
</tr>
<tr>
<td>Input Voltage Disconnected</td>
<td>OFF</td>
<td>OFF</td>
</tr>
</tbody>
</table>

**Note:** OFF state: open-drain is high-impedance; ON state: open-drain can sink current, typically 7 mA; FLASHING: toggles between OFF and ON states.

### Table 5-2: STATUS OUTPUT – MCP73855

<table>
<thead>
<tr>
<th>CHARGE CYCLE STATE</th>
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<tbody>
<tr>
<td>Qualification</td>
<td>OFF</td>
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<tr>
<td>Preconditioning</td>
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</tr>
<tr>
<td>Constant Current Fast Charge</td>
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<tr>
<td>Constant Voltage</td>
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<tr>
<td>Charge Complete</td>
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<tr>
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<tr>
<td>THERM Invalid</td>
<td>Flashing (1 Hz, 50% duty cycle)</td>
</tr>
<tr>
<td>Disabled - Sleep mode</td>
<td>OFF</td>
</tr>
<tr>
<td>Input Voltage Disconnected</td>
<td>OFF</td>
</tr>
</tbody>
</table>

**Note:** OFF state: open-drain is high-impedance; ON state: open-drain can sink current, typically 7 mA; FLASHING: toggles between OFF state and ON state.

The flashing rate (1 Hz) is based on a timer capacitor (CTIMER) of 0.1 µF. The rate varies based on the value of the timer capacitor.

5.2.1.1 MCP73853 Only
STAT1 is on whenever the input voltage is above the under voltage lockout, the device is enabled, and all conditions are normal.

During a fault condition, the STAT1 status output is off and the STAT2 status output flashes. To recover from a fault condition, the input voltage must be removed and then reapplied, or the enable input, EN, must be deasserted to a logic low, then asserted to a logic high.

When the voltage on the THERM input is outside the preset window, the charge cycle will either not start or be suspended. However, the charge cycle is not terminated, with recovery being automatic. The charge cycle resumes (or starts) once the THERM input is valid and all other qualification parameters are met.

5.2.2 VSET INPUT
The VSET input selects the regulated output voltage of the MCP7385X devices. With VSET tied to VSS, the MCP7385X devices regulate to 4.1 V. With VSET tied to VDD, the MCP7385X devices regulate to 4.2 V.

5.2.3 LOGIC ENABLE (EN)
The logic enable input pin (EN) can be used to terminate a charge anytime during the charge cycle, initiate a charge cycle or initiate a recharge cycle.

Applying a logic high input signal to the EN pin, or tying it to the input source, enables the device. Applying a logic low input signal disables the device and terminates a charge cycle. When disabled, the device’s supply current is reduced to 0.28 µA, typically.
6.0 APPLICATIONS

The MCP7385X devices are designed to operate in conjunction with a host microcontroller or in stand-alone applications. The MCP7385X devices provide the preferred charge algorithm for Li-Ion/Li-Polymer cells. The algorithm uses a constant current followed by a constant voltage charging method. Figure 6-1 depicts a typical stand-alone application circuit, while Figure 6-2 and Figure 6-3 depict the accompanying charge profile.

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

**FIGURE 6-2:** Typical Charge Profile.
FIGURE 6-3: Typical Charge Profile in Thermal Regulation.
6.1 Application Circuit Design

Due to the low efficiency of linear charging, the most important factors are thermal design and cost. These 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 exists 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 to be a guide for the component selection process.

6.1.1.1 CURRENT PROGRAMMING RESISTOR (RPROG)

The preferred fast charge current for Lithium-Ion cells is at the 1C rate, with an absolute maximum current at the 2C rate. For example, a 500 mAh battery pack has a preferred fast charge current of 500 mA. Charging at this rate provides the shortest charge cycle times without degradation to the battery pack performance or life.

400 mA is the typical maximum charge current obtainable from the MCP7385X devices. For this situation, the PROG input should be connected directly to VSS.

6.1.1.2 THERMAL CONSIDERATIONS

The worst-case power dissipation in the battery charger occurs when the input voltage is at its maximum and the device has transitioned from the Preconditioning mode to the Constant-current mode. In this case, the power dissipation is:

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

Where \(V_{\text{DDMAX}}\) is the maximum input voltage, \(I_{\text{REGMAX}}\) is the maximum fast charge current, and \(V_{\text{PTHMIN}}\) is the minimum transition threshold voltage. Power dissipation with a 5V, +/-10% input voltage source is:

\[
\text{PowerDissipation} = (5.5V - 2.7V) \times 475mA = 1.33W
\]

With the battery charger mounted on a 1 in² pad of 1 oz. copper, the junction temperature rise is approximately 50°C. This allows for a maximum operating ambient temperature of 35°C before thermal regulation is entered.

6.1.3 EXTERNAL CAPACITORS

The MCP7385X devices are stable with or without a battery load. To maintain good AC stability in the Constant-voltage mode, a minimum capacitance of 4.7 µF is recommended to bypass the VBAT pin to VSS. 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.

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 4.7 µF ceramic, tantalum or aluminum electrolytic capacitor at the output is usually sufficient to ensure stability for up to the maximum output current.

6.1.4 REVERSE BLOCKING PROTECTION

The MCP7385X devices provide protection from a faulted or shorted input or from a reversed-polarity input source. Without the protection, a faulted or shorted input would discharge the battery pack through the body diode of the internal pass transistor.

6.1.5 ENABLE INTERFACE

In the stand-alone configuration, the enable pin is generally tied to the input voltage. The MCP7385X devices automatically enter a low power mode when voltage on the VDD input falls below the UVLO voltage (VSTOP), reducing the battery drain current to 0.28 µA, typically.

6.1.6 CHARGE STATUS INTERFACE

Two status outputs provide information on the state of charge. The current-limited, open-drain outputs can be used to illuminate external LEDs. Refer to Table 5-1 and Table 5-2 for a summary of the state of the status output during a charge cycle.

6.2 PCB Layout Issues

For optimum voltage regulation, place the battery pack as close as possible to the device’s VBAT and VSS pins. It is recommended that the designer minimizes voltage drops along the high-current-carrying PCB traces.

If the PCB layout is used as a heat sink, adding many vias in the heat sink pad helps to conduct more heat to the PCB backplane, thus reducing the maximum junction temperature.
7.0 PACKAGING INFORMATION

7.1 Package Marking Information

Legend:

- XX...X  Customer specific information*
- YY  Year code (last 2 digits of calendar year)
- WW  Week code (week of January 1 is week ‘01’)
- NNN  Alphanumeric traceability code

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.

* Standard OTP marking consists of Microchip part number, year code, week code, and traceability code.
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
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

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

**RECOMMENDED LAND PATTERN**

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**Notes:**
1. Dimensioning and tolerancing per ASME Y14.5M
   BSC: Basic Dimension. Theoretically exact value shown without tolerances.
16-Lead Plastic Quad Flat, No Lead Package (ML) – 4x4x0.9 mm Body [QFN]

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

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<td>0.50</td>
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Notes:
1. Pin 1 visual index feature may vary, but must be located within the hatched area.
2. Package is saw singulated.
3. 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 C04-127B
16-Lead Plastic Quad Flat, No Lead Package (ML) - 4x4x0.9mm Body [QFN]

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

![Recommended Land Pattern Diagram]

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

Microchip Technology Drawing No. C04-2127A
APPENDIX A:  REVISION HISTORY

Revision C (April 2013)
Following is the list of modifications:
1. Updated Table 3-1 with the Exposed Pad information.

Revision B (February 2012)
Following is the list of modifications:
3. Updated Section 7.1 "Package Marking Information".

Revision A (November 2004)
• Original Release of this Document.
PRODUCT IDENTIFICATION SYSTEM

To order or obtain information, e.g., on pricing or delivery, refer to the factory or the listed sales office.

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<tr>
<th>Device</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>MCP73853</td>
<td>USB compatible charge controller with temperature monitor</td>
</tr>
<tr>
<td>MCP73853T</td>
<td>USB compatible charge controller with temperature monitor, Tape and Reel</td>
</tr>
<tr>
<td>MCP73855</td>
<td>USB compatible charge controller</td>
</tr>
<tr>
<td>MCP73855T</td>
<td>USB compatible charge controller, Tape and Reel</td>
</tr>
</tbody>
</table>

Temperature Range I = -40°C to +85°C (Industrial)

<table>
<thead>
<tr>
<th>Package</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ML</td>
<td>Plastic Quad Flat No Lead, 4x4 mm Body (QFN), 16-Lead</td>
</tr>
<tr>
<td>MF</td>
<td>Plastic Dual Flat No Lead, 3x3 mm Body (DFN), 10-Lead</td>
</tr>
</tbody>
</table>

Examples:

a) MCP73853T-I/ML: Tape and Reel, USB compatible charge controller with temperature monitor
b) MCP73853-I/ML: USB compatible charge controller with temperature monitor
a) MCP73855T-I/MF: Tape and Reel, USB compatible charge controller
b) MCP73855-I/MF: USB compatible charge controller
Note the following details of the code protection feature on Microchip devices:

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