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Preface

NOTICE TO CUSTOMERS

All documentation becomes dated, and this manual is no exception. Microchip tools and documentation are constantly evolving to meet customer needs, so some actual dialogs and/or tool descriptions may differ from those in this document. Please refer to our web site (www.microchip.com) to obtain the latest documentation available.

Documents are identified with a “DS” number. This number is located on the bottom of each page, in front of the page number. The numbering convention for the DS number is “DSXXXXXA”, where “XXXXX” is the document number and “A” is the revision level of the document.

For the most up-to-date information on development tools, see the MPLAB® IDE on-line help. Select the Help menu, and then Topics to open a list of available on-line help files.

INTRODUCTION

This chapter contains general information that will be useful to know before using the MCP1631 Multi-Chemistry Battery Charger Reference Design. Items discussed in this chapter include:

• Document Layout
• Conventions Used in this Guide
• Recommended Reading
• The Microchip Web Site
• Customer Support
• Document Revision History

DOCUMENT LAYOUT

This document describes how to use the MCP1631 Multi-Chemistry Battery Charger Reference Design. The manual layout is as follows:

• Chapter 1. “Product Overview” – Important information about the MCP1631 Multi-Chemistry Battery Charger Reference Design.
• Chapter 2. “Installation and Operation” – Includes instructions on how to get started with this user’s guide and a description of the user’s guide.
• Appendix A. “Schematic and Layouts” – Shows the schematic and layout diagrams for the MCP1631 Multi-Chemistry Battery Charger Reference Design.
• Appendix B. “Bill Of Materials (BOM)” – Lists the parts used to build the MCP1631 Multi-Chemistry Battery Charger Reference Design.
• Appendix C. “Demo Board Firmware” – Provides information about the application firmware and where the source code can be found.
**CONVENTIONS USED IN THIS GUIDE**

This manual uses the following documentation conventions:

<table>
<thead>
<tr>
<th>DOCUMENTATION CONVENTIONS</th>
<th>Description</th>
<th>Represents</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arial font:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Italic characters</td>
<td>Referenced books</td>
<td><em>MPLAB® IDE User’s Guide</em></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Emphasized text</td>
<td><em>...is the only compiler...</em></td>
<td></td>
</tr>
<tr>
<td>Initial caps</td>
<td>A window</td>
<td>the Output window</td>
<td></td>
</tr>
<tr>
<td></td>
<td>A dialog</td>
<td>the Settings dialog</td>
<td></td>
</tr>
<tr>
<td></td>
<td>A menu selection</td>
<td>select Enable Programmer</td>
<td></td>
</tr>
<tr>
<td>Quotes</td>
<td>A field name in a window or</td>
<td>&quot;Save project before build&quot;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>dialog</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Underlined, italic text</td>
<td>A menu path</td>
<td><em>File&gt;Save</em></td>
<td></td>
</tr>
<tr>
<td>with right angle bracket</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bold characters</td>
<td>A dialog button</td>
<td>Click OK</td>
<td></td>
</tr>
<tr>
<td></td>
<td>A tab</td>
<td>Click the <em>Power</em> tab</td>
<td></td>
</tr>
<tr>
<td>N’Rnnnn</td>
<td>A number in verilog format,</td>
<td>4'b0010, 2'hF1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>where N is the total number</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>of digits, R is the radix</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>and n is a digit.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Text in angle brackets &lt; &gt;</td>
<td>A key on the keyboard</td>
<td>Press &lt;Enter&gt;, &lt;F1&gt;</td>
<td></td>
</tr>
<tr>
<td>Courier New font:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plain Courier New</td>
<td>Sample source code</td>
<td><em>#define START</em></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Filenames</td>
<td><em>autoexec.bat</em></td>
<td></td>
</tr>
<tr>
<td></td>
<td>File paths</td>
<td><em>c:\mcc18\h</em></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Keywords</td>
<td><em>_asm, _endasm, static</em></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Command-line options</td>
<td><em>-Opa+, -Opa-</em></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bit values</td>
<td><em>0, 1</em></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Constants</td>
<td><em>0xFF, ‘A’</em></td>
<td></td>
</tr>
<tr>
<td>Italic Courier New</td>
<td>A variable argument</td>
<td><em>file.o</em>, where <em>file</em> can be any valid</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>filename</em></td>
<td></td>
</tr>
<tr>
<td>Square brackets [ ]</td>
<td>Optional arguments</td>
<td><em>mcc18 [options] file [options]</em></td>
<td></td>
</tr>
<tr>
<td>Curly brackets and pipe</td>
<td>Choice of mutually exclusive</td>
<td>*errorlevel {0</td>
<td>1}*</td>
</tr>
<tr>
<td>character: {{}}</td>
<td>arguments; an OR selection</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ellipses...</td>
<td>Replaces repeated text</td>
<td><em>var_name [, var_name...]</em></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Represents code supplied by</td>
<td><em>void main (void) { ... }</em></td>
<td></td>
</tr>
<tr>
<td></td>
<td>user</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
RECOMMENDED READING

This user's guide describes how to use MCP1631 Multi-Chemistry Battery Charger Reference Design. The following Microchip documents are available and recommended as supplemental reference resources.

MCP1631 Data Sheet, “High-Speed, Microcontroller-Adaptable, Pulse Width Modulator”, DS22063

This data sheet provides detailed information regarding the MCP1631/MCP1631V, MCP1631HV and MCP1631VHV product family.

PIC16F883 Data Sheet, “8-Pin Flash-Based, 8-Bit CMOS Microcontrollers with Nano Watt Technology”, DS41291

This data sheet provides detailed information regarding the PIC16F883 product family.

AN1137 Application Note, “Using the MCP1631 Family to Develop Low-Cost Battery Chargers”, DS01137

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- **General Technical Support** – Frequently Asked Questions (FAQs), technical support requests, online discussion groups, Microchip consultant program member listing
- **Business of Microchip** – Product selector and ordering guides, latest Microchip press releases, listing of seminars and events, listings of Microchip sales offices, distributors and factory representatives

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- Technical Support

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Technical support is available through the web site at: http://support.microchip.com

DOCUMENT REVISION HISTORY

Revision A (January 2008)

- Initial Release of this Document.
Chapter 1. Product Overview

1.1 INTRODUCTION

The MCP1631HV Multi-Chemistry reference design board is used to charge one, two, three or four NiMH batteries or one or two cell Li-Ion batteries. The board uses the MCP1631HV high speed analog PWM and PIC16F883 to generate the charge algorithm for NiMH, NiCd or Li-Ion batteries.

The MCP1631 Multi-Chemistry Battery Charger Reference Design is used to evaluate Microchip’s MCP1631HV in a SEPIC power converter application. As provided, the MCP1631 Multi-Chemistry Battery Charger Reference Design is user programmable using on board push buttons. The board can charge NiMH, NiCd or Li-Ion batteries. The MCP1631 Multi-Chemistry Battery Charger Reference Design provides a constant current charge (Ni based chemistry) and constant current / constant voltage (Li-Ion) with preconditioning, cell temperature monitoring (Ni based) and battery pack fault monitoring. Also, the charger provides a status or fault indication. The MCP1631 Multi-Chemistry Battery Charger Reference Design automatically detects the insertion or removal of a battery pack.

This chapter covers the following topics.
- What is the MCP1631 Multi-Chemistry Battery Charger Reference Design?
- What the MCP1631 Multi-Chemistry Battery Charger Reference Design Kit includes.
1.2 WHAT IS THE MCP1631 MULTI-CHEMISTRY BATTERY CHARGER REFERENCE DESIGN?

The MCP1631 Multi-Chemistry Battery Charger Reference Design is a complete stand-alone constant current battery charger for NiMH, NiCd or Li-Ion battery packs. When charging NiMH or NiCd batteries the reference design is capable of charging one, two, three or four batteries connected in series. If Li-Ion chemistry is selected, the board is capable of charging one or two series batteries. This board utilizes Microchip’s MCP1631HV (high-speed PIC® MCU PWM TSSOP-20). The input voltage range for the demo board is 5.3V to 16V.

Note: For this board, $V_{IN}$ must be greater than $V_{OUT}$, duty cycle is limited to 50%. This can be modified so that $V_{OUT} = V_{IN}$ or $V_{OUT} > V_{IN}$ because the SEPIC converter is capable of buck-boost operation.

<table>
<thead>
<tr>
<th>Battery Chemistry</th>
<th>1-Cell</th>
<th>2-Cell</th>
<th>3-Cell</th>
<th>4-Cell</th>
</tr>
</thead>
<tbody>
<tr>
<td>Li-Ion</td>
<td>2A</td>
<td>1A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>NiMH or NiCd</td>
<td>1.5A</td>
<td>1.5A</td>
<td>1.5A</td>
<td>1.5A</td>
</tr>
</tbody>
</table>

An input terminal block is provided to apply the input voltage to the charger. An output header is also provided as a means to connect the external battery pack or simulated battery load and external 10 kΩ thermistor. A programming header is available for updating the firmware contained in the PIC16F883.

1.3 WHAT THE MCP1631 MULTI-CHEMISTRY BATTERY CHARGER REFERENCE DESIGN KIT INCLUDES

This MCP1631 Multi-Chemistry Battery Charger Reference Design kit includes:

- The MCP1631 Multi-Chemistry Battery Charger Reference Design Board, 102-00145
- Analog and Interface Products Demonstration Boards CD-ROM (DS21912)
  - MCP1631 Data Sheet, "High-Speed, Microcontroller-Adaptable, Pulse Width Modulator", (DS22063).
  - PIC16F883 Data Sheet, “8-Pin Flash-Based, 8-Bit CMOS Microcontrollers with nanoWatt Technology", (DS41291).
  - AN1137, Using the MCP1631 Family to Develop Low-Cost Battery Chargers, (DS01137)
Chapter 2. Installation and Operation

2.1 INTRODUCTION

The MCP1631HV Multi-Chemistry Battery Charger demonstrates Microchip’s high-speed Pulse Width Modulator (PWM), MCP1631HV, used in a multi-chemistry battery charger application. When used in conjunction with a microcontroller, the MCP1631HV will control the power system duty cycle to provide output voltage or current regulation. The PIC16F883 microcontroller can be used to regulate output voltage or set current, switching frequency and maximum duty cycle. The MCP1631HV generates duty cycle and provides fast overcurrent protection based off various external inputs. External signals include the input oscillator, the reference voltage, the feedback voltage and the current sense. The output signal is a square-wave pulse. The power train used for the MCP1631HV Multi-Chemistry Battery Charger is a Single-Ended Primary Inductive Converter (SEPIC). The MCP1631HV microcontroller is programmable, allowing the user to modify or develop their own firmware routines to further evaluate the MCP1631HV Multi-Chemistry Battery Charger in this application.

2.2 FEATURES

The MCP1631HV Multi-Chemistry Battery Charger has the following features:

- Input Operating Voltage Range
  - +5.3V to +16V ($V_{\text{IN}} > V_{\text{BATT}}$)
- Maximum of 2A Charge Current for single cell Li-Ion
- Charge NiMH, NiCd or Li-Ion Chemisties
- Charge 1 or 2 Cell Li-Ion Batteries in Series
- Charge 1 to 4 Cells of NiMH or NiCd Batteries in Series
- Select Chemistry and Cells using push-buttons
- ON/OFF switch
- Charge Status Indication
- Programmable Charge Profile
- OV Shutdown (2.0V / Cell for NiMH/NiCd or 4.4V/Cell for Li-Ion)
2.3 GETTING STARTED

The MCP1631HV Multi-Chemistry Battery Charger is fully assembled and tested for charging one or two series Li-Ion Batteries or one to four series cell NiMH or NiCd batteries. The charge termination for Li-Ion is based a percentage of fast charge current, the charge termination for NiMH is based on a negative voltage change versus time or positive temperature change versus time. This board requires the use of an external voltage source to charge the series connected batteries with a range of +5.3V to +16V input. An external load and thermistor is also required to evaluate the charger reference design.

**FIGURE 2-1:** MCP1631HV Multi-Chemistry Battery Charger Charge profile, Li-Ion.
2.3.1 Power Input and Output Connection

2.3.1.1 POWERING THE MCP1631HV MULTI-CHEMISTRY BATTERY CHARGER

1. Apply the input voltage to the input terminal block, J1. The input voltage source should be limited to the 0V to +16V range. For nominal operation the input voltage should be between +5.3V and +16V.

2. Connect the positive side of the input source (+) to pin 1 of J1. Connect the negative or return side (-) of the input source to pin 2 of J1. Refer to Figure 2-3.

FIGURE 2-2: MCP1631HV Multi-Chemistry Battery Charger Charge profile, NiMH/NiCd.
2.3.1.2 APPLYING A LOAD TO THE MCP1631HV MULTI-CHEMISTRY BATTERY CHARGER

1. To apply a load (battery pack), to the MCP1631HV Multi-Chemistry Battery Charger, the positive side of the battery pack (B+) should be connected to pin 1 of J2. The negative side of the load (B-) should be connected to pin 5 of J2.

2. For NiMH or NiCd battery packs, a thermistor referenced to (B-) in the battery pack should be utilized, recommended EPCOS Inc. PN B57500M0103A005. If a thermistor is not available or not desired, a 10 kΩ resistor should be placed between pins 4 and 5 of the battery header (J2) or the charger will detect a missing thermistor and no charge cycle will begin.
2.3.1.3 SELECTING BATTERY CHEMISTRY AND NUMBER OF CELLS

2.3.1.3.1 Three push buttons are used to start a charge cycle, select chemistry and select number of series cells. There are two LED’s, (green - NiMH, red - Li-Ion) used to indicate chemistry type and four yellow LED’s to indicate the number of series cells selected (D6, D7, D8, D9).

2.3.1.3.2 S1 (ON/OFF) is used to start and stop the charge cycle or to enter the programming mode. When the input voltage is within the specified operating range (+5.3V to +16V), press and hold the ON/OFF button for 5 seconds, all LEDs with the exception of D3 should flash. Release S1 and STATUS LED (D3) will be flash, indicating that the board is in programming mode.

1. Press S2 (CHEM) to select the desired chemistry. Indication is provided by a red LED (D4) (Li-Ion) or a green LED (D5) (NiMH/NiCd).
2. Press S3 (CELLS) to select the number of series cells. Indication is provided by yellow (D6 thru D9) (1 Cell to 4 Cell LED’s) where D6 = 1 cell, D7 = 2 cell, D8 = 3 cell and D9 = 4 cell.
3. Once the desired chemistry and number of cells is selected, press and release S1 ON/OFF to store the settings. The selected chemistry LED and number of series cells LED both should be illuminated.
4. To start a charge cycle, press and release S1. D3 (green) will be illuminated indicating a charge cycle has begun, the selected chemistry LED should flash slowly indicating normal charge cycle conditions.
5. If the chemistry LED is not flashing and the Status LED is flashing, a fault condition has persisted for 5 attempts indicating that the charge cycle has terminated.
6. Remove the input voltage and check the connections and verify the proper battery pack chemistry and number of series cells.
7. Once the problem is corrected, apply the input voltage, check the chemistry and number of series cells LEDs and press S1 to start a charge cycle.

**Note:** For single cell Li-Ion, a 3,600 mA-Hr. battery with internal protection circuitry is recommended for evaluation. For NiMH charge cycle, Panasonic HHR-210AA/B2B batteries were used to develop the -dV/dt and +dT/dt termination methods.
2.3.1.4  STATUS LED

1. The MCP1631HV Multi-Chemistry Battery Charger has an LED to indicate charge status or fault status. Table 2-1 represents the state of the Status LED during various states of the charge cycle.

**TABLE 2-1:  STATUS OUTPUT**

<table>
<thead>
<tr>
<th>Charge Cycle State</th>
<th>LED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Programming</td>
<td>Flashing (Fast)</td>
</tr>
<tr>
<td>Qualification</td>
<td>OFF</td>
</tr>
<tr>
<td>Preconditioning</td>
<td>ON</td>
</tr>
<tr>
<td>Constant Current Fast Charge</td>
<td>ON</td>
</tr>
<tr>
<td>Top Off Charge</td>
<td>ON</td>
</tr>
<tr>
<td>Charge Complete</td>
<td>OFF</td>
</tr>
<tr>
<td>Safety Timer Fault</td>
<td>Flashing (2 Hertz)</td>
</tr>
<tr>
<td>Cell Temperature Invalid</td>
<td>Flashing (2 Hertz)</td>
</tr>
<tr>
<td>Battery Disconnected</td>
<td>Flashing (2 Hertz)</td>
</tr>
<tr>
<td>Input Power Removed</td>
<td>OFF</td>
</tr>
</tbody>
</table>

2.3.1.5  CHARGE PROFILE

- **Li-Ion**
  - Qualification: Precharge at 200 mA for \( V_{CELL} < 3.0 \)V
  - Constant Current = 2A for 1 Cell, 1A for 2 Cell
  - Constant Voltage = 4.20V, Calibrated at board final test
  - Charge Termination = 140 mA for 1 Cell and 2 Cell
  - Overvoltage Detection, once detected, attempt to restart charge cycle 5 times, if overvoltage is persistent, terminate attempts and flash STATUS LED.

- **NiMH/NiCd**
  - Qualification: Precharge at 200 mA for \( V_{CELL} < 0.9 \)V
  - Constant Current = 1.5A for 1 Cell to 4 Cell
  - Terminate Fast Charge for \(-dV/dT\) or \(+dT/dt\)
  - Timed 50 mA top off charge for 1 hour
  - Overvoltage Detection, once detected, attempt to restart charge cycle 5 times, if overvoltage is persistent, terminate attempts and flash STATUS LED.

2.3.1.6  PROGRAMMING

Header J3 is provided for in-system circuit programming.
Appendix A. Schematic and Layouts

A.1 INTRODUCTION

This appendix contains the following schematics and layouts for the MCP1631 Multi-Chemistry Battery Charger Reference Design:

• Board Schematic
• Board – Top Silk Layer
• Board – Top Metal Layer
• Board – Mid1 Metal Layer
• Board – Mid2 Metal Layer
• Board – Bottom Metal Layer
A.2 BOARD – SCHEMATIC
A.5 BOARD – MID1 METAL LAYER

[Image of a schematic diagram of the board's MID1 metal layer]
A.6 BOARD – MID2 METAL LAYER
### TABLE B-1: BILL OF MATERIALS (BOM)

<table>
<thead>
<tr>
<th>Qty</th>
<th>Reference</th>
<th>Description</th>
<th>Manufacturer</th>
<th>Part Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>C1, C2, C4</td>
<td>CAP CERAMIC 10UF 25V X5R 1206</td>
<td>Panasonic® - ECG</td>
<td>ECJ-3YB1E106M</td>
</tr>
<tr>
<td>1</td>
<td>C3</td>
<td>CAP CER 2.2UF 25V X7R 0805</td>
<td>Murata Electronics® North America</td>
<td>GRM21BR71E225KA73L</td>
</tr>
<tr>
<td>7</td>
<td>C5, C7, C8, C9, C12, C13, C17</td>
<td>CAP CER 1.0UF 25V X7R 0805</td>
<td>Taiyo Yuden®</td>
<td>TMK212BJ105KG-TR</td>
</tr>
<tr>
<td>4</td>
<td>C6, C16, C18, C19</td>
<td>CAP .1UF 16V CERAMIC X7R 0805</td>
<td>Panasonic - ECG</td>
<td>ECJ-2VB1C104K</td>
</tr>
<tr>
<td>1</td>
<td>C10</td>
<td>DO NOT POPULATE SMT0805 CAPACITOR</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>2</td>
<td>C11, C14</td>
<td>CAP 22PF 50V CERM CHIP 0805 SMD</td>
<td>Panasonic - ECG</td>
<td>ECJ-2VC1H220J</td>
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<td>Para Light Corp.</td>
<td>L-C170KRC-T-U1</td>
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<td>Diodes Inc.</td>
<td>B330A-13-F</td>
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<td>Coiltronics/Div of Cooper/Bussmann</td>
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<td>1</td>
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<td>International Rectifier®</td>
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<td>R1, R10, R11</td>
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<td>Panasonic - ECG</td>
<td>ERJ-6ENF1001V</td>
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<td>R3, R4, R5, R16, R21, R22, R23</td>
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<td>Panasonic - ECG</td>
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</table>

**Note:** The components listed in this Bill Of Materials are representative of the PCB assembly. The released BOM used in manufacturing uses all RoHS-compliant components.
### TABLE B-1: BILL OF MATERIALS (BOM) (CONTINUED)

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<th>Qty</th>
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<td>DO NOT POPULATE SMT0805 RESISTOR</td>
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<td>Panasonic - ECG</td>
<td>ERJ-6ENF4990V</td>
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<td>Panasonic - ECG</td>
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<td>Panasonic - ECG</td>
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<td>SWITCH TACT 6MM 260GF SMT</td>
<td>E-Switch</td>
<td>TL3301NF260QG</td>
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<td>Microchip Technology Inc.</td>
<td>MCP1631HV-500E/ST</td>
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<td>IC PIC MCU FLASH 4KX14 28SSOP</td>
<td>Microchip Technology Inc.</td>
<td>PIC16F883-I/SS</td>
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</table>

**Note:** The components listed in this Bill Of Materials are representative of the PCB assembly. The released BOM used in manufacturing uses all RoHS-compliant components.
Appendix C. Demo Board Firmware

C.1 DEVICE Firmware Flowchart Page 1

For the latest copy of the MCP1631 Multi-Chemistry Battery Charger Reference Design firmware, visit our web site at www.microchip.com.

FIGURE C-1: Firmware Flowchart.

START

Initialize Ports, ADC, PWM, etc.

Is BATT Li-Ion?

Yes

Is BATT > 2V/Cell

Yes

Fast Charge
Reset Timers
ICHARGE = 1.5A

Yes

Cell Temp < 40°C

No

dV/dt=0

dT/dt>1.5C

No

1 hr.
Top Off

No

Fault

Yes

Fault

No

BATT > 4.2V

Yes

DEC Current

No

IBATT < 140mA?

Yes

increase Current
MAX = 2.0A 1 Cell
MAX = 1.0A 2 Cell

No

Precondition Cell(s)

No

Is BATT > 0.9V / Cell

Yes

Is BATT > 4.4V / Cell

Yes

No

BATT > 3.0V / Cell

Yes

Precondition Cell(s)

No

Is BATT > 2V/Cell

Yes

Fault