MCP1631 Multi-Chemistry Battery Charger Reference Design

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MCP1631 MULTI-CHEMISTRY BATTERY CHARGER REFERENCE DESIGN

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MCP1631 MULTI-CHEMISTRY BATTERY CHARGER REFERENCE DESIGN

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:

DOCUMENTATION CONVENTIONS

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

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

THE MICROCHIP WEB SITE

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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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- Distributor or Representative
- Local Sales Office
- Field Application Engineer (FAE)
- Technical Support

Customers should contact their distributor, representative or field application engineer (FAE) for support. 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

DOCUMENT REVISION HISTORY

Revision A (January 2008)

- Initial Release of this Document.

NOTES:

Chapter 1. Product Overview

1.1 INTRODUCTION

The MCP1631HV Multi-Chemistry referecne 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 algorithum 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.

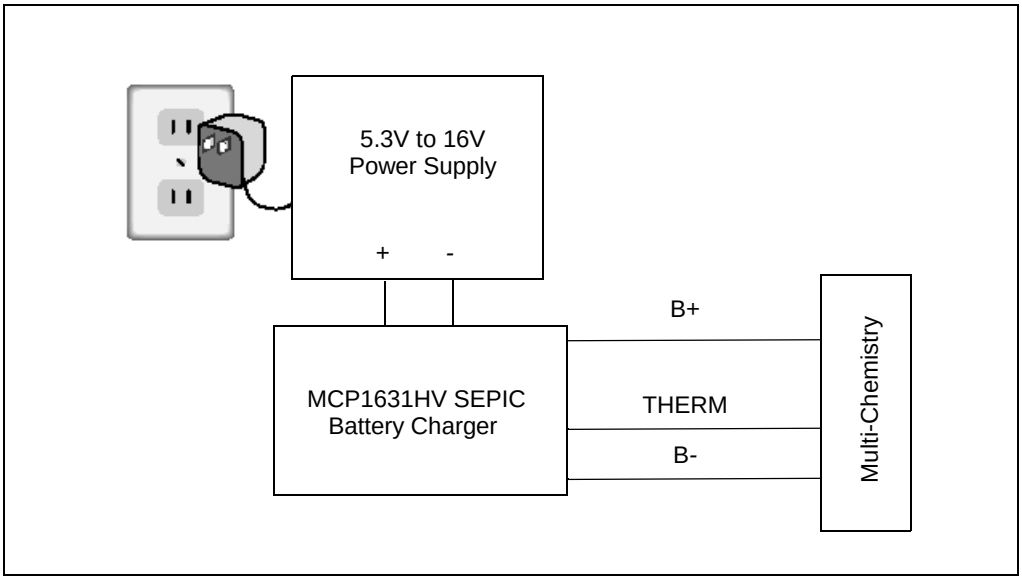


FIGURE 1-1: *MCP1631 Multi-Chemistry Battery Charger Reference Design Block Diagram.*

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 $V_{OUT} > V_{IN}$ becasue the SEPIC converter is capable of buck-boost operation.

TABLE 1-1: MULTI-CHEMISTRY CHARGER CAPABILITY

Battery Chemistry	1-Cell	2-Cell	3-Cell	4-Cell
Li-Ion	2A	1A	N/A	N/A
NiMH or NiCd	1.5A	1.5A	1.5A	1.5A

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 Multi-Chemistry Battery Charger Reference Design User's Guide, (DS51697).
  - 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 ($V_{IN} > V_{BATT}$)
- 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.

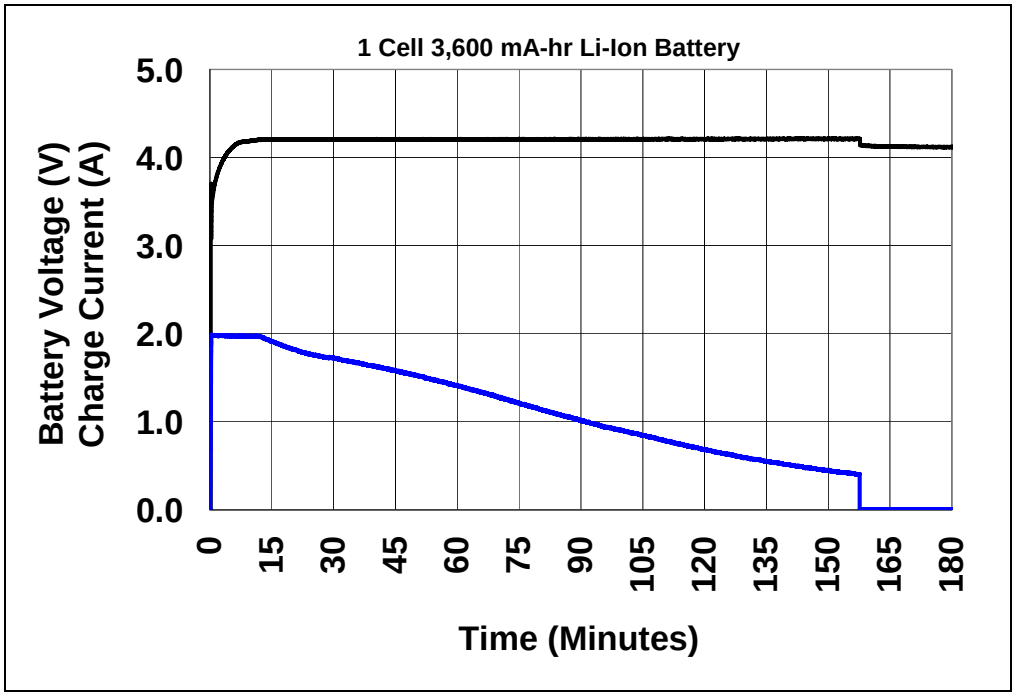


FIGURE 2-1: *MCP1631HV Multi-Chemistry Battery Charger Charge profile, Li-Ion.*

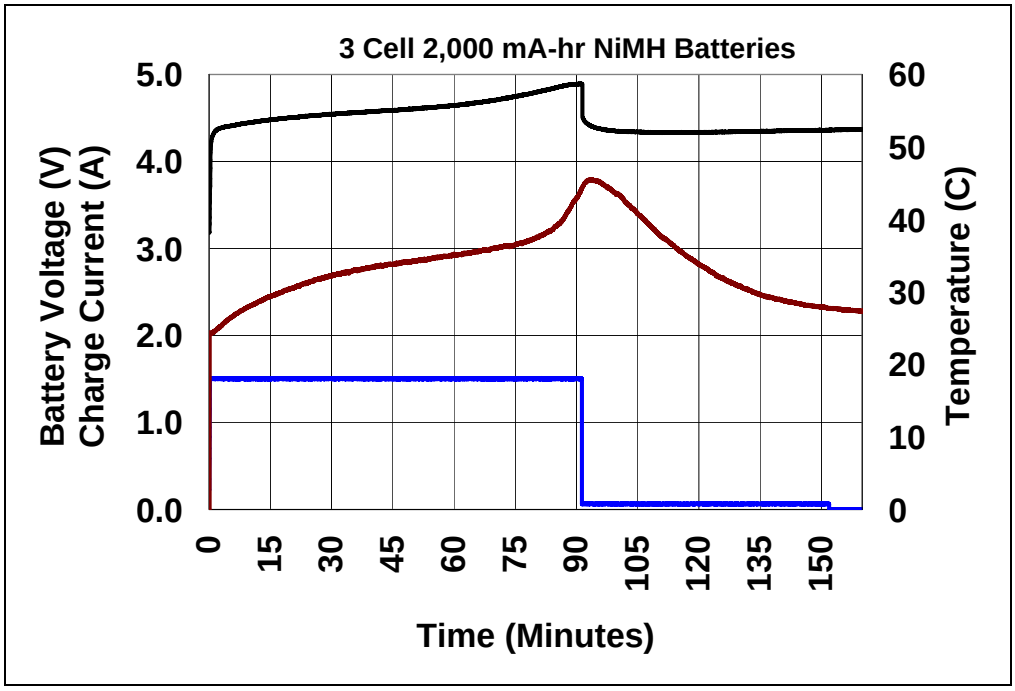


FIGURE 2-2: *MCP1631HV Multi-Chemistry Battery Charger Charge profile, NiMH/NiCd.*

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.

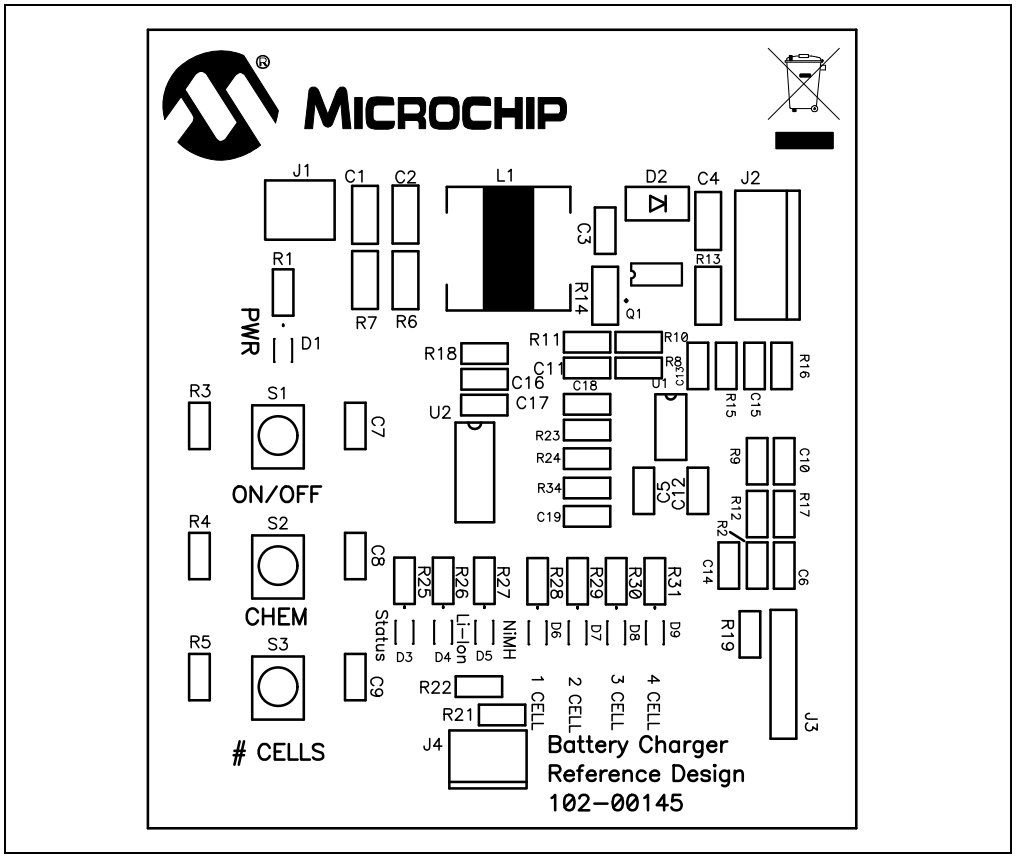


FIGURE 2-3: *Setup Configuration Diagram.*

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, reccomened 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.

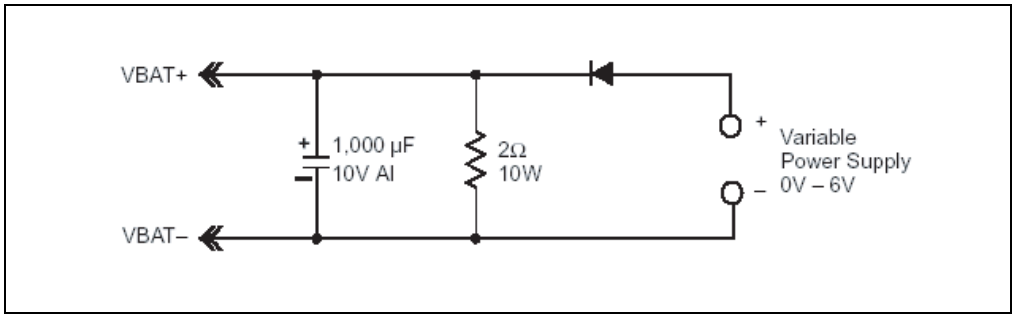


FIGURE 2-4: *Simulated Battery Load.*

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 idicating 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 Satus LED during various states of the charge cycle.

TABLE 2-1: STATUS OUTPUT

Charge Cycle State	LED
Programming	Flashing (Fast)
Qualification	OFF
Preconditioning	ON
Constant Current Fast Charge	ON
Top Off Charge	ON
Charge Complete	OFF
Safety Timer Fault	Flashing (2 Hertz)
Cell Temperature Invalid	Flashing (2 Hertz)
Battery Disconnected	Flashing (2 Hertz)
Input Power Removed	OFF

2.3.1.5 CHARGE PROFILE

- Li-Ion
  - Qualification: Precharge at 200 mA for V_{CELL} < 3.0V
  - 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 persistant, terminate attemtps and flash STATUS LED.
- NiMH/NiCd
  - Qualification: Precharge at 200 mA for V_{CELL} < 0.9V
  - 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 persistant, terminate attemtps and flash STATUS LED.

2.3.1.6 PROGRAMMING

Header J3 is provided for in-system circuit programming.

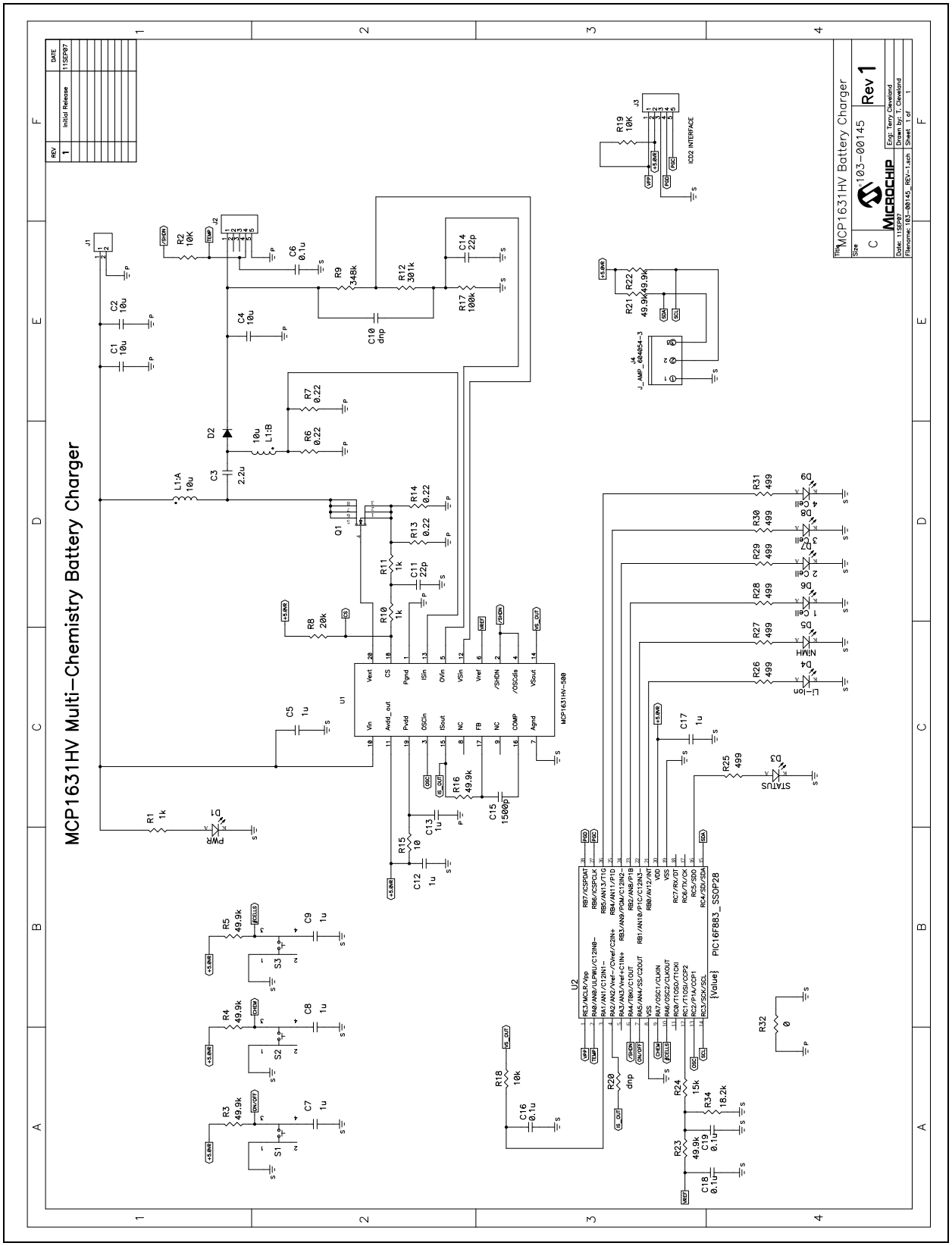
Appendix A. Schematic and Layouts

A.1 INTRODUCTION

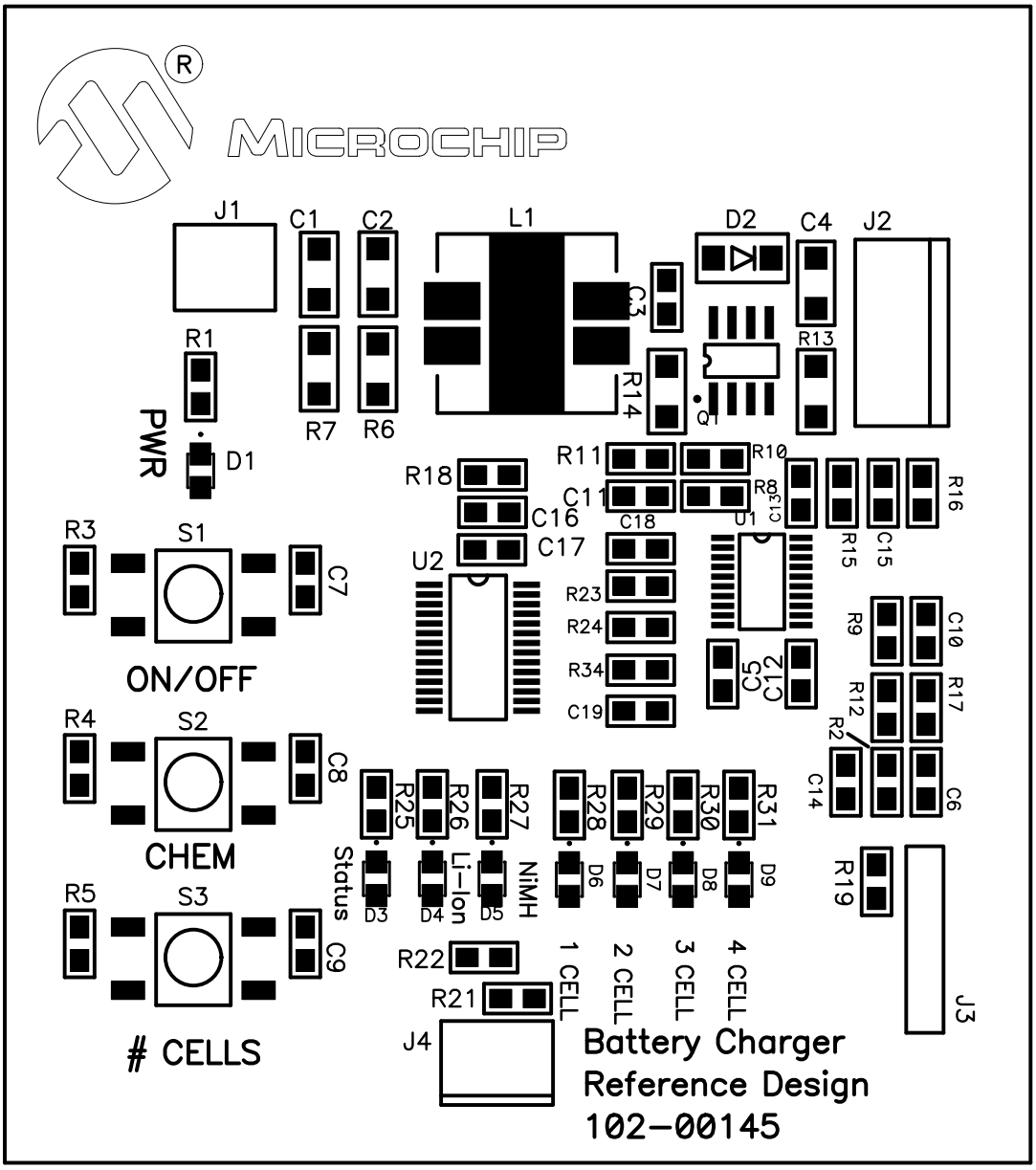
This appendix contains the following schematics and layouts for the MCP1631 Multi-Chemistry Battery Charger Reference Design:

- Board Schematic
- Board – Top Silk Layer
- Board – Top Metal Layer
- Board – Mid1 Metal Layer
- Board – Mid2 Metal Layer
- Board – Bottom Metal Layer

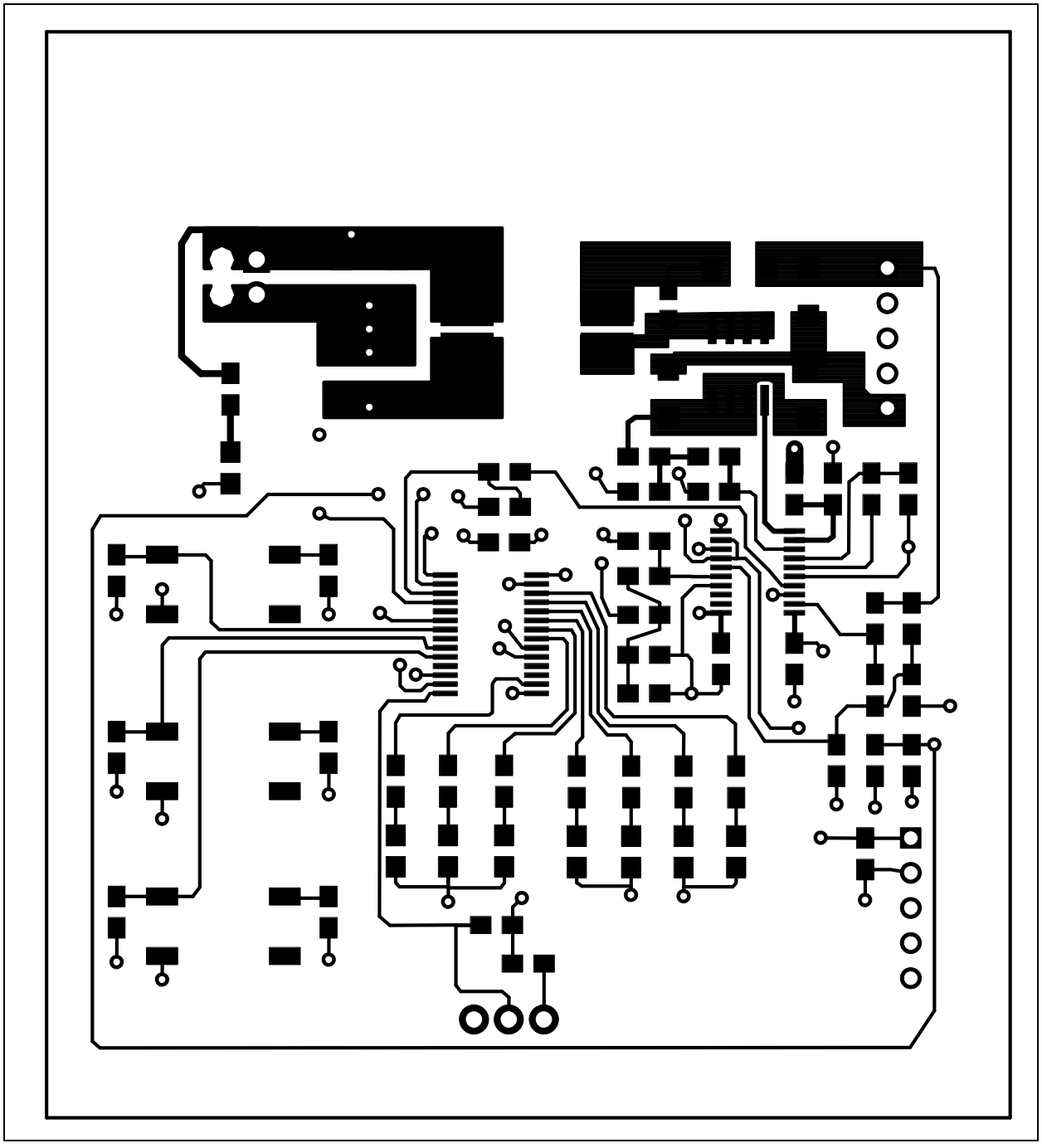
A.2 BOARD – SCHEMATIC



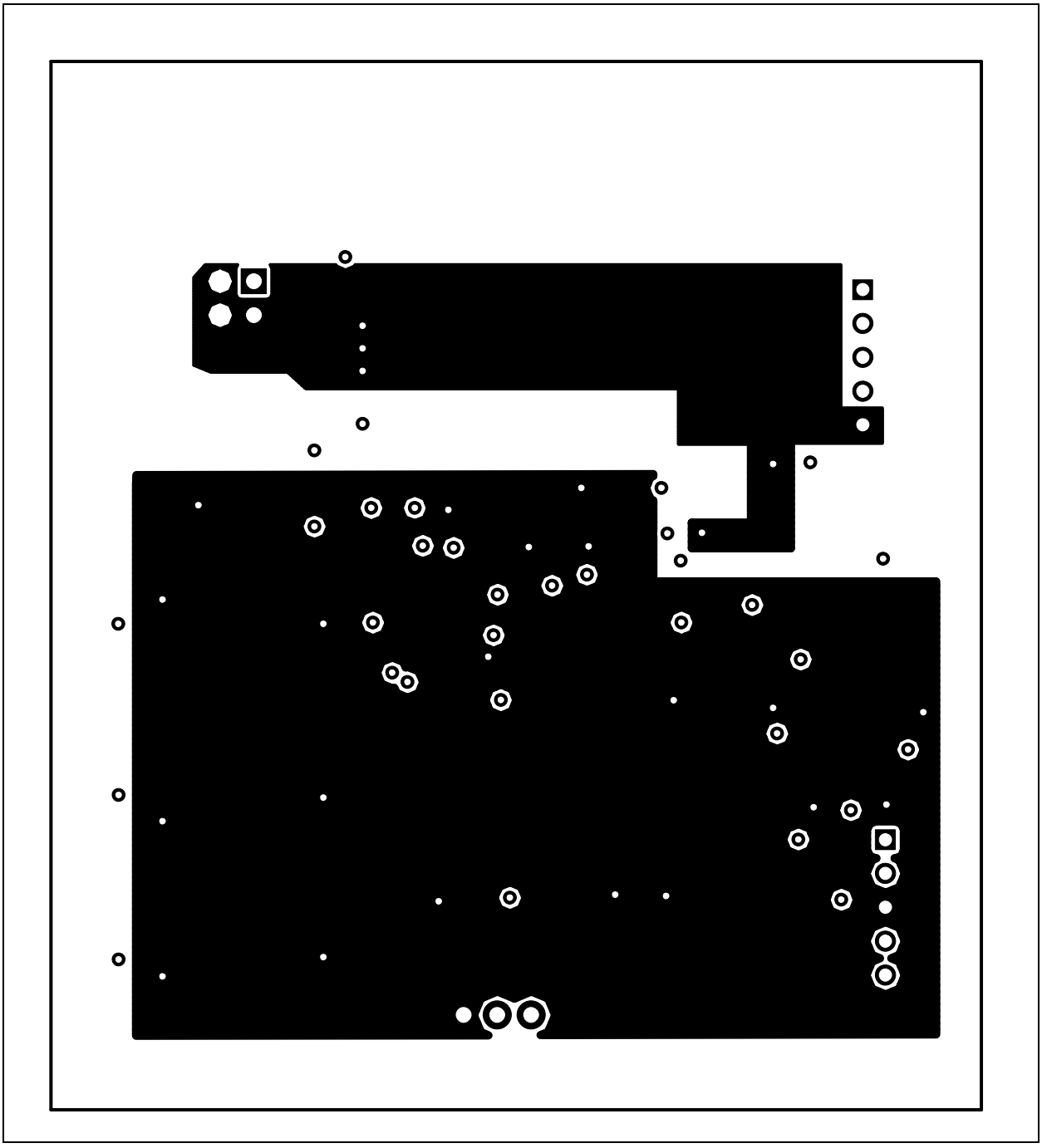
A.3 BOARD – TOP SILK LAYER



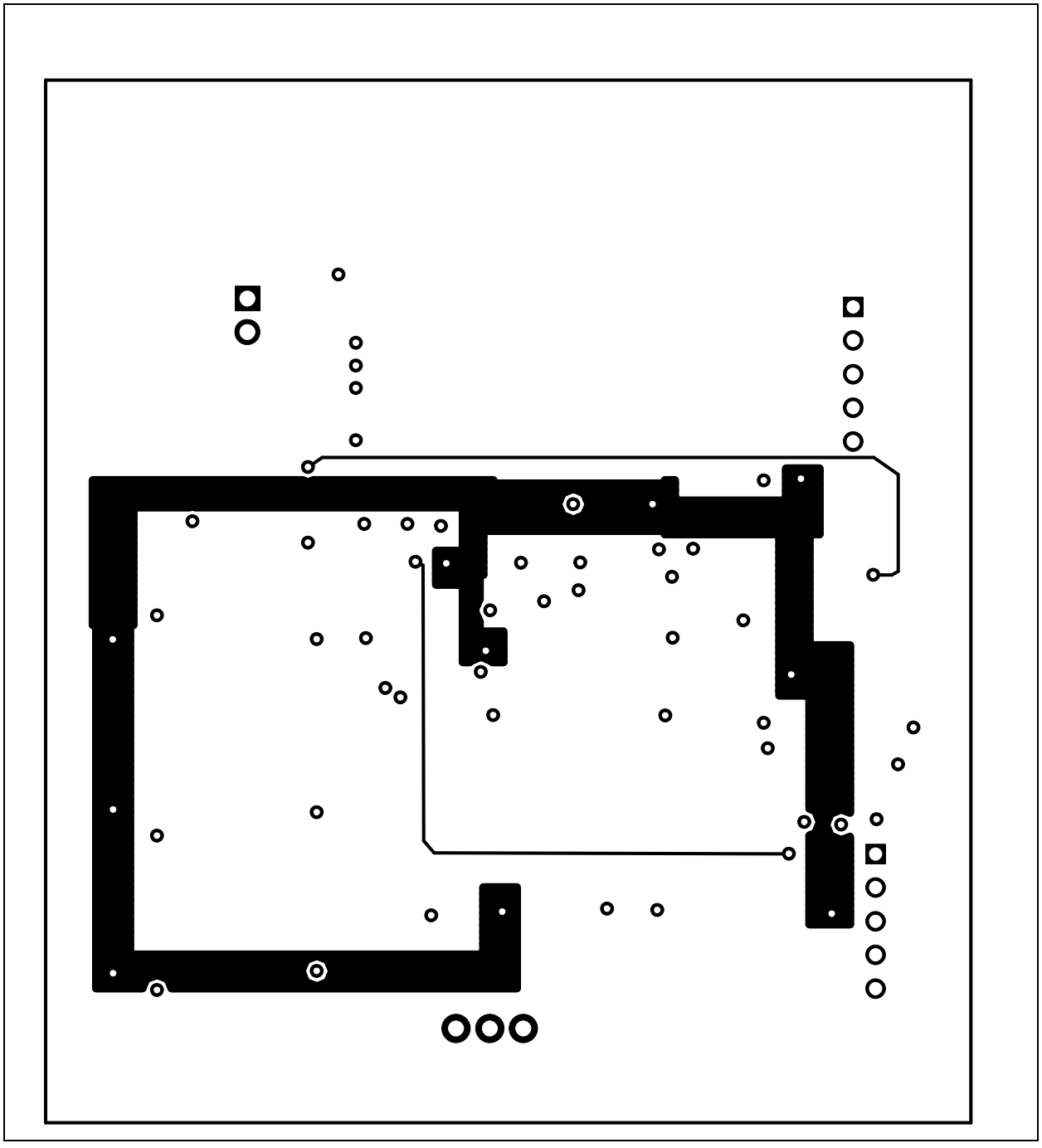
A.4 BOARD – TOP METAL LAYER



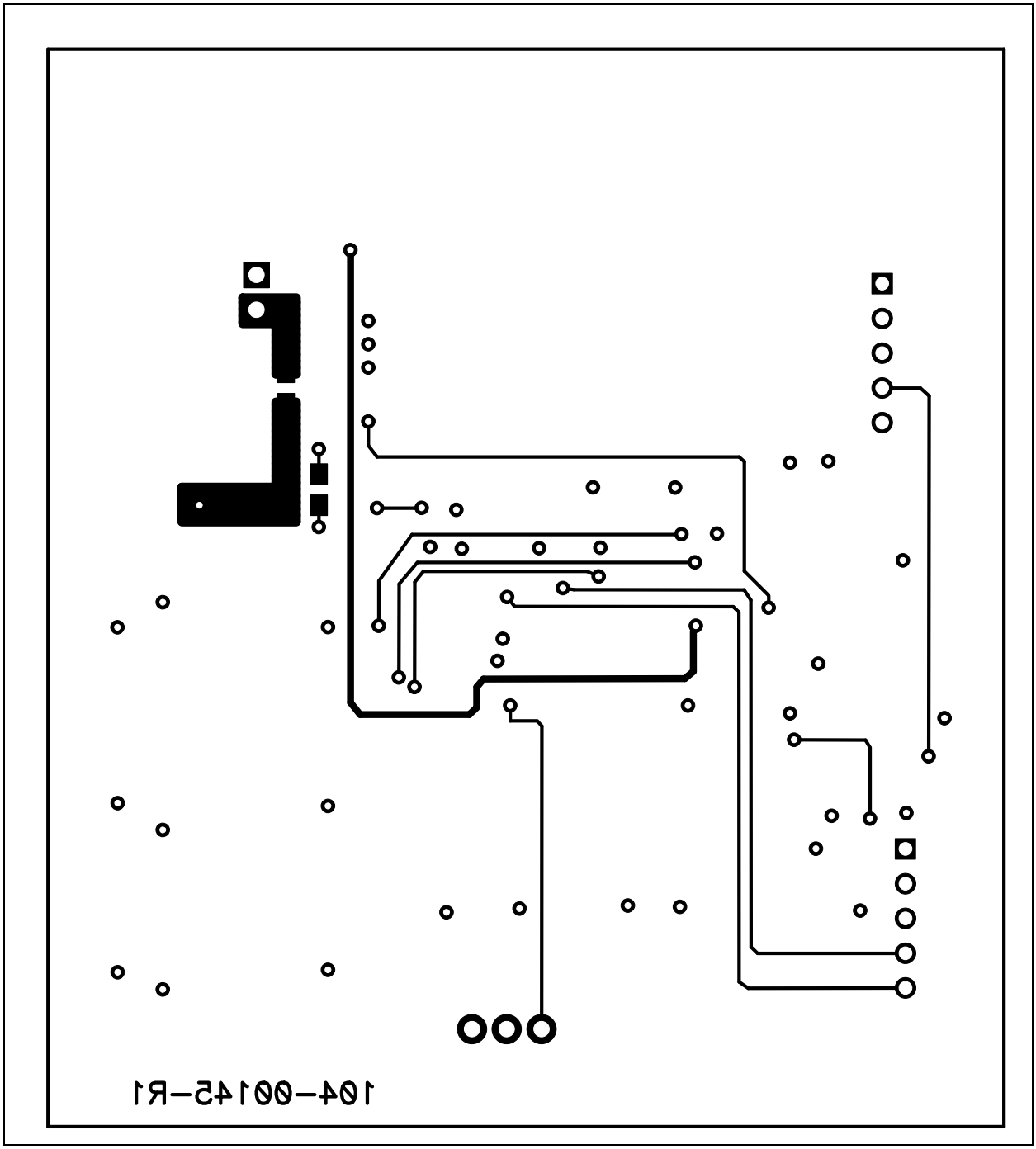
A.5 BOARD – MID1 METAL LAYER



A.6 BOARD – MID2 METAL LAYER



A.7 BOARD – BOTTOM METAL LAYER



NOTES:

Appendix B. Bill Of Materials (BOM)

TABLE B-1: BILL OF MATERIALS (BOM)

Qty	Reference	Description	Manufacturer	Part Number
3	C1, C2, C4	CAP CERAMIC 10UF 25V X5R 1206	Panasonic® - ECG	ECJ-3YB1E106M
1	C3	CAP CER 2.2UF 25V X7R 0805	Murata Electronics® North America	GRM21BR71E225KA73L
7	C5, C7, C8, C9, C12, C13, C17	CAP CER 1.0UF 25V X7R 0805	Taiyo Yuden®	TMK212BJ105KG-TR
4	C6, C16, C18, C19	CAP .1UF 16V CERAMIC X7R 0805	Panasonic - ECG	ECJ-2VB1C104K
1	C10	DO NOT POPULATE SMT0805 CAPACITOR	—	—
2	C11, C14	CAP 22PF 50V CERM CHIP 0805 SMD	Panasonic - ECG	ECJ-2VC1H220J
1	C15	CAP 1500PF 50V CERM CHIP 0805	Panasonic - ECG	ECJ-2VB1H152K
2	D1, D4	LED 0805 Super RED Clear	Para Light Corp.	L-C170KRCT-U1
1	D2	DIODE SCHOTTKY 30V 3A SMA	Diodes Inc.	B330A-13-F
2	D3, D5	LED 0805 Super Green Clear	Para Light Corp.	L-C170KGCT-U1
4	D6, D7, D8, D9	LED 0805 Super Yellow Clear	Para Light Corp.	L-C170KYCT-U1
1	J1	CONN TERM BLOCK 2.54MM 2POS	Phoenix Contact	1725656
1	J2	CONN HEADER 5POS .100 VERT TIN FRICTION LOCK	Molex® Electronics	22-23-2051
1	J3	CONN HEADER 5POS .100 VERT TIN	Molex Electronics	22-03-2051
1	J4	CONN HEADER 3POS .100 VERT TIN	Molex Electronics	22-23-2031
1	L1	INDUCT/XFRMR SHIELD DL 10UH SMD	Coiltronics/Div of Cooper/Bussmann	DRQ127-100-R
1	PCB	RoHS Compliant Bare PCB, MCP1631 Multi-Chemistry Charger	—	104-00145
1	Q1	HEX/MOS N-CHAN 30V 8.3A 8SOIC	International Rectifier®	IRF7807VTRPBF
3	R1, R10, R11	RES 1.00K OHM 1/8W 1% 0805 SMD	Panasonic - ECG	ERJ-6ENF1001V
3	R2, R18, R19	RES 10.0K OHM 1/8W 1% 0805 SMD	Panasonic - ECG	ERJ-6ENF1002V
7	R3, R4, R5, R16, R21, R22, R23	RES 49.9K OHM 1/8W 1% 0805 SMD	Panasonic - ECG	ERJ-6ENF4992V
4	R6, R7, R13, R14	RES .22 OHM 1/4W 1% 1206 SMD	Panasonic - ECG	ERJ-8RQFR22V
1	R8	RES 20.0K OHM 1/8W 1% 0805 SMD	Panasonic - ECG	ERJ-6ENF2002V
1	R9	RES 348K OHM 1/8W 1% 0805 SMD	Panasonic - ECG	ERJ-6ENF3483V
1	R12	RES 301K OHM 1/8W 1% 0805 SMD	Panasonic - ECG	ERJ-6ENF3013V
1	R15	RES 10.0 OHM 1/8W 1% 0805 SMD	Panasonic - ECG	ERJ-6ENF10R0V

Note: The components listed in this Bill Of Materials are respresentative of the PCB assembly. The released BOM used in manufacturing uses all RoHS-compliant components.

TABLE B-1: BILL OF MATERIALS (BOM) (CONTINUED)

Qty	Reference	Description	Manufacturer	Part Number
1	R17	RES 100K OHM 1/8W 1% 0805 SMD	Panasonic - ECG	ERJ-6ENF1003V
1	R20	DO NOT POPULATE SMT0805 RESISTOR	—	—
1	R24	RES 15.0K OHM 1/8W 1% 0805 SMD	Panasonic - ECG	ERJ-6ENF1502V
7	R25, R26, R27, R28, R29, R30, R31	RES 499 OHM 1/8W 1% 0805 SMD	Panasonic - ECG	ERJ-6ENF4990V
1	R32	RES 0.0 OHM 1/8W 5% 0805 SMD	Panasonic - ECG	ERJ-6GEY0R00V
1	R34	RES 18.2K OHM 1/8W 1% 0805 SMD	Panasonic - ECG	ERJ-6ENF1822V
3	S1, S2, S3	SWITCH TACT 6MM 260GF SMT	E-Switch	TL3301NF260QG
1	U1	MCP1631HV 5.0V 20 Pin TSSOP High Speed PWM	Microchip Technology Inc.	MCP1631HV-500E/ST
1	U2	IC PIC MCU FLASH 4KX14 28SSOP	Microchip Technology Inc.	PIC16F883-I/SS

Note: The components listed in this Bill Of Materials are respresentative 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.

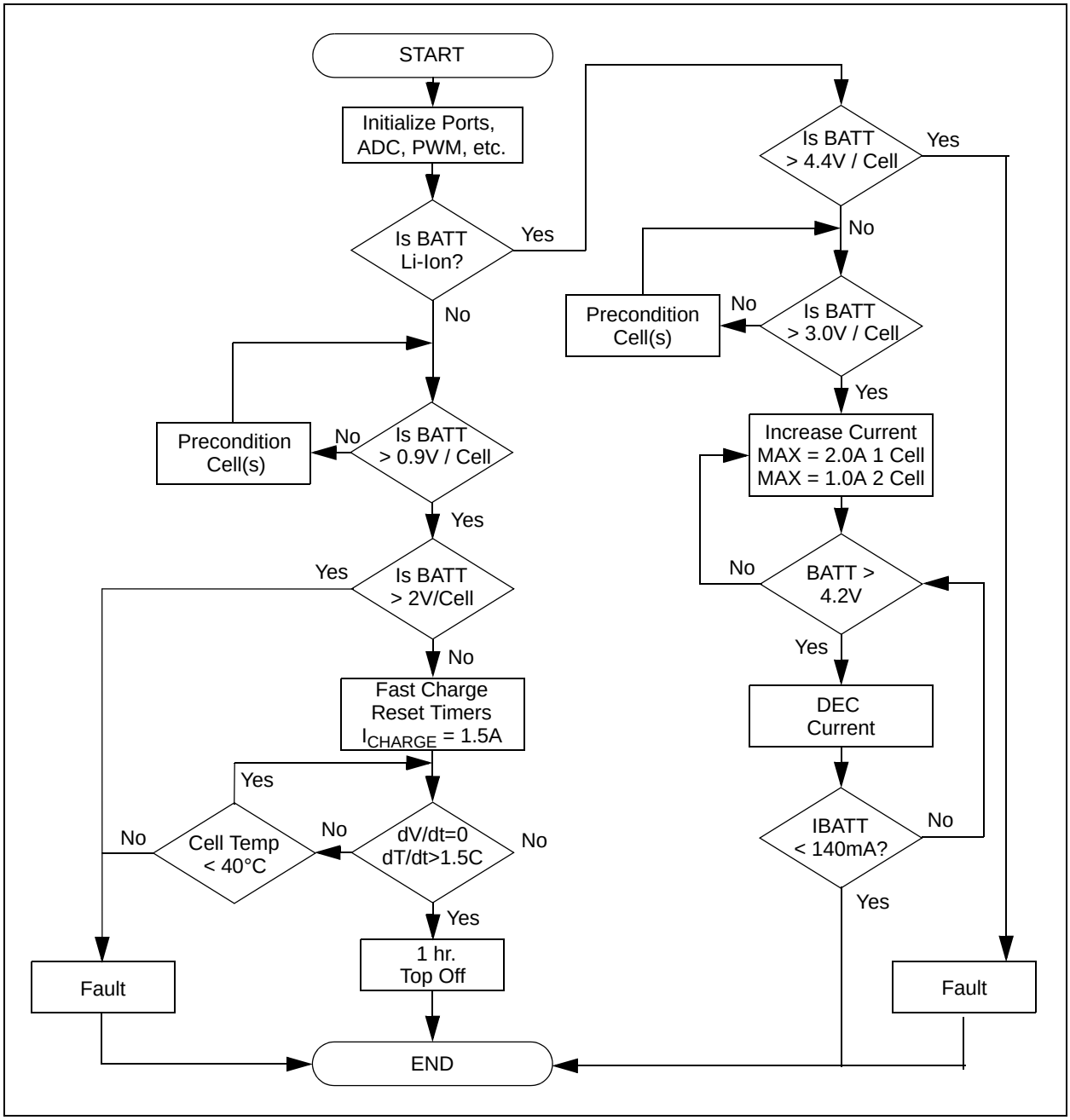


FIGURE C-1: *Firmware Flowchart.*

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