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MCP1631HV Multi-Chemistry Battery Charger Reference Design

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MCP1631HV MULTI-CHEMISTRY BATTERY CHARGER REFERENCE DESIGN

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MCP1631HV 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 MCP1631HV 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 MCP1631HV Multi-Chemistry Battery Charger Reference Design. The manual layout is as follows:

- **Chapter 1. "Product Overview"** – Important information about the MCP1631HV 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 Layout"** – Shows the schematic and layout diagrams for the MCP1631HV Multi-Chemistry Battery Charger Reference Design.
- **Appendix B. "Bill Of Materials (BOM)"** – Lists the parts used to build the MCP1631HV Multi-Chemistry Battery Charger Reference Design.
- **Appendix C. "Software"** – Provides information about the application firmware and where the source code can be found.
- **Appendix D. "Design Example"** – Shows a design example.

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
'b*nnnn*	A binary number where *n* is a digit	'b00100, 'b10
Text in angle brackets < >	A key on the keyboard	Press <Enter>, <F1>
Courier font:		
Plain Courier	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`
Italic Courier	A variable argument	*`file`*`.o`, where *`file`* can be any valid filename
`0x`*`nnnn`*	A hexadecimal number where *`n`* is a hexadecimal digit	`0xFFFF`, `0x007A`
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 MCP1631HV Multi-Chemistry Battery Charger Reference Design. The following Microchip documents are available on our web site (www.microchip.com) and recommended as supplemental reference resources.

MCP1631 Data Sheet, *"High-Speed, Microcontroller-Adaptable, Pulse Width Modulator"*, DS22063A

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"*, DS41291D

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

AN1137 Application Note, *"Using the MCP1631 Family to Develop Low-Cost Battery Chargers"*, DS01137A

THE MICROCHIP WEB SITE

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- **Product Support** – Data sheets and errata, application notes and sample programs, design resources, user's guides and hardware support documents, latest software releases and archived software
- **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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Users of Microchip products can receive assistance through several channels:

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- Local Sales Office
- Field Application Engineer (FAE)
- Technical Support
- Development Systems Information Line

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 2009)

- Initial Release of this Document.

NOTES:

Chapter 1. Product Overview

1.1 INTRODUCTION

The MCP1631HV Multi-Chemistry reference design board is used to charge one to five NiMH or NiCd batteries, charge one or two cell Li-Ion batteries, or drive one or two 1W LEDs. The board uses the MCP1631HV high speed analog PWM and PIC16F883 to generate the charge algorithm for NiMH, NiCd or Li-Ion batteries.

The MCP1631HV Multi-Chemistry Battery Charger is used to evaluate Microchip's

MCP1631HV in a SEPIC power converter application. As provided, the MCP1631HV Multi-Chemistry Battery Charger is user programmable using on board push buttons. The board can charge NiMH, NiCd or Li-Ion batteries. The MCP1631HV Multi-Chemistry Battery Charger 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 MCP1631HV Multi-Chemistry Battery Charger automatically detects the insertion or removal of a battery pack.

This chapter covers the following topics.

- What is the MCP1631HV Multi-Chemistry Battery Charger Reference Design?
- What the MCP1631HV Multi-Chemistry Battery Charger Reference Design Kit includes.

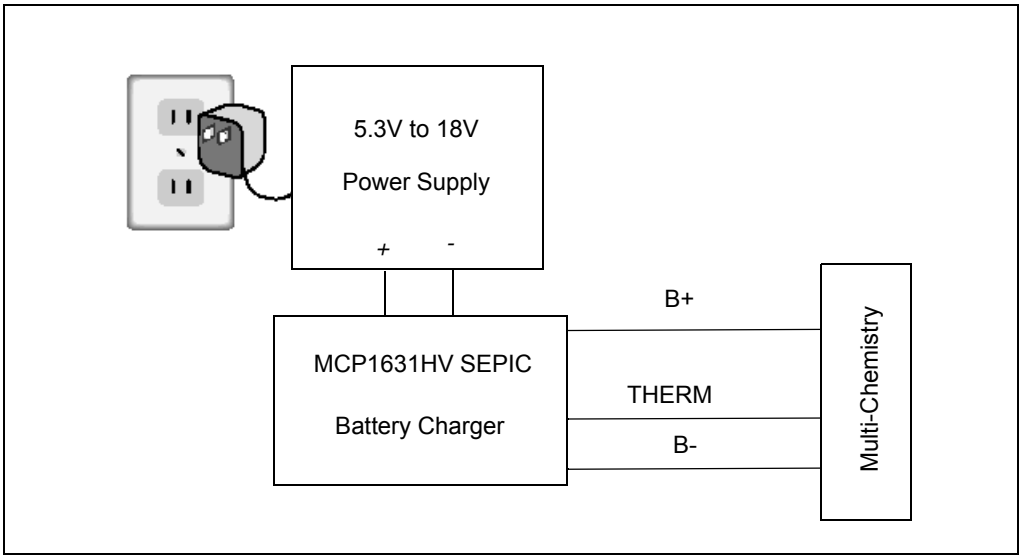


FIGURE 1-1: *MCP1631HV Multi-Chemistry Battery Charger Reference Design Block Diagram.*

1.2 WHAT IS THE MCP1631HV MULTI-CHEMISTRY BATTERY CHARGER REFERENCE DESIGN?

The MCP1631HV Multi-Chemistry Battery Charger is a complete stand-alone battery charger for NiMH, NiCd or Li-Ion battery packs. The board may also be used to drive LED devices using constant current mode. When charging NiMH or NiCd batteries the reference design is capable of charging one to five batteries connected in series. If Li-Ion chemistry is selected, the board is capable of charging one or two series batteries. When the LED driver is selected, the board is capable of driving one to two 1W LEDs. This board utilizes Microchip's MCP1631HV (high-speed PWM and PIC16F883 MCU). The input voltage range for the demo board is 5.3V to 16V.

The board is capable of both boosting and bucking the input voltage in order to obtain the desired output voltage because a SEPIC converter topology is used. The overvoltage limit for the board is set to 9V. The powertrain components may be changed to allow for higher output voltages and power.

TABLE 1-1: MULTI-CHEMISTRY CHARGER CAPABILITY

Battery Chemistry	1 Cell	2 Cell	3 Cell	4 Cell	5 Cell
Li-Ion	2A	1A	NA	NA	NA
NiMH or NiCd	1.5A	1.5A	1.5A	1.5A	1.5A
LED Driver	300 mA	300 mA	NA	NA	NA

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 10K thermistor. A programming header is available for updating the firmware contained in the PIC16F883.

1.3 WHAT THE MCP1631HV MULTI-CHEMISTRY BATTERY CHARGER REFERENCE DESIGN KIT INCLUDES

This MCP1631HV Multi-Chemistry Battery Charger Reference Design kit includes:

- The MCP1631HV Multi-Chemistry Battery Charger Board,102-00232
- Analog and Interface Products Demonstration Boards CD-ROM includes (DS21912):
  - MCP1631HV Multi-Chemistry Battery Charger 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).
  - Application Note 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 the duty cycle and provides fast overcurrent protection based upon various external inputs. External signals include the switching frequency 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
- Maximum of 2A Charge Current for single cell Li-Ion
- Charge NiMH, NiCd or Li-Ion Chemistries
- Charge 1 cell or 2 cell Li-Ion Batteries in Series
- Charge 1 cell to 5 cell NiMH or NiCd Batteries in Series
- Drive one or two 1 Watt LEDs in series.
- Select Chemistry and Cells using push-buttons
- ON/OFF switch
- Charge Status Indication
- Programmable Charge Profile
- Programmable Overvoltage Shutdown (1.8V/Cell for NiMH/NiCd or 4.4V/Cell for Li-Ion)
- Complete "C" source code is provided

2.3 GETTING STARTED

The MCP1631HV Multi-Chemistry Battery Charger is fully assembled and tested for charging one or two series Li-Ion Batteries, one to five series cell NiMH or NiCd batteries, or driving one to two 1 Watt LEDs. The charge termination for Li-Ion is based upon 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.

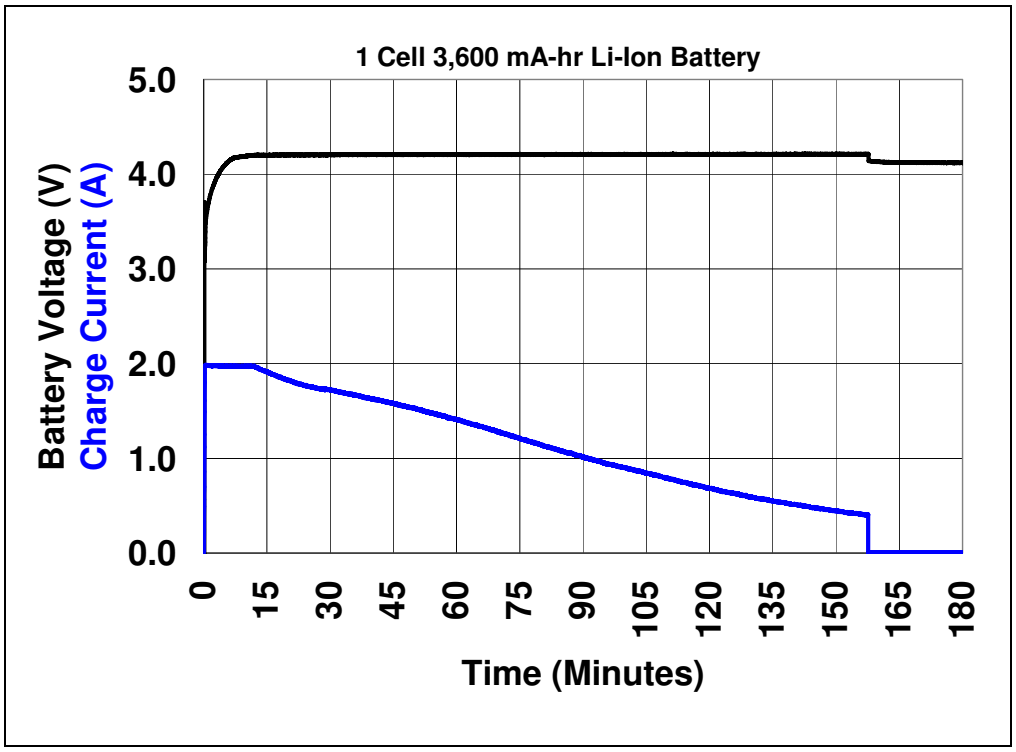


FIGURE 2-1: *MCP1631HV Multi-Chemistry Battery Charger Charge Profile, Li-Ion.*

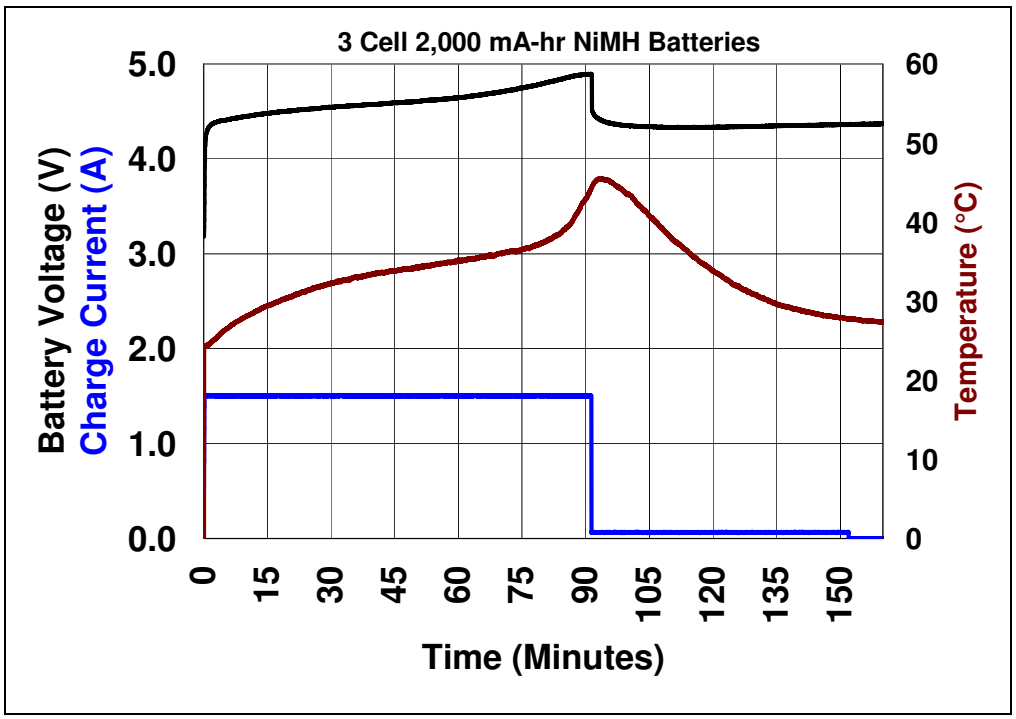


FIGURE 2-2: *MCP1631HV Multi-Chemistry Battery Charger Charge Profile, NiMH/NiCd.*

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 below.

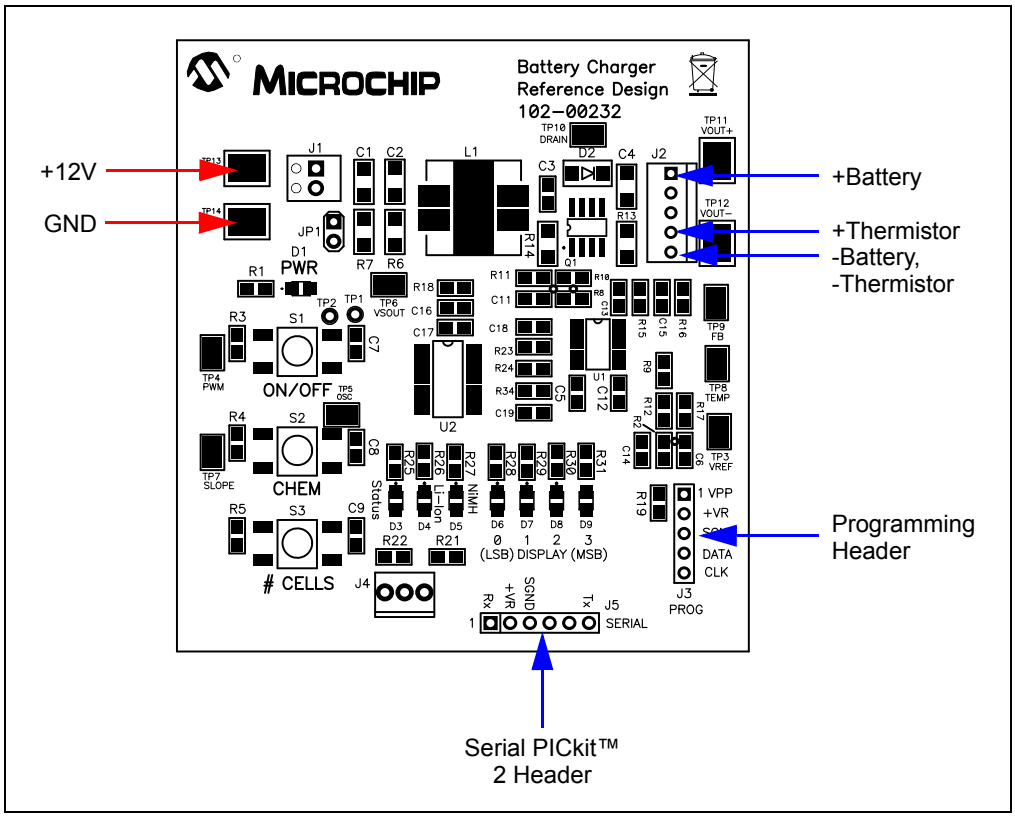


FIGURE 2-3: *Setup Configuration Diagram.*

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. EPCOS Inc. PN B57500M0103A005 is the recommended thermistor. 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 charger will detect a missing thermistor and no charge cycle will begin.

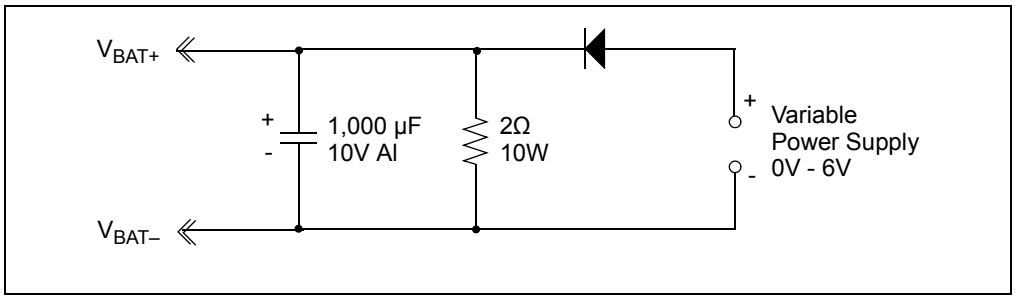


FIGURE 2-4: *Simulated Battery Load.*

2.3.1.3 SELECTING BATTERY CHEMISTRY AND NUMBER OF CELLS

- Three push buttons are used to start a charge cycle, select chemistry and select number of series cells. There are two LEDs, (red - NiMH, green - Li-Ion, red + green - LED Driver) used to indicate chemistry type and four yellow LEDs to indicate the number of series cells selected (D6, D7, D8, D9).
- 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 be illuminated. Release S1 and STATUS LED (D3) will be flashing, indicating that the board is in programming mode.
- Press S2 (CHEM) to select the desired chemistry, indication is provided by red LED D4 (Li-Ion) or green LED D5 (NiMH/NiCd) or both (LED Driver).
- Press S3 (CELLS) to select the number of series cells, indication is provided by yellow LEDs D6 thru D9 where D6 = bit 0 and D9 = bit 3 of a 4-bit hexadecimal value.
- Once the desired chemistry and number of cells is selected, press S1 (ON/OFF) to store the settings. The selected chemistry LED and number of series cells LED both should be illuminated.
- 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.
- 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.
- Remove input voltage and check connections and verify the proper battery pack chemistry and number of series cells.
- Once the problem is corrected, apply the input voltage, verify chemistry and # of cells LEDs and press S1 to start a charge cycle.

Note: For single cell Li-Ion, a 3600 mA-Hr battery with internal protection circuitry is recommended for evaluation. For NiMH charge cycle, Panasonic HHR-210AA/B2B were used to develop the -dV/dt and +dT/dt termination methods.

2.3.1.4 STATUS LED

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, Chemistry, and Display LEDs during various states of the charge cycle.

TABLE 2-1: LED INDICATOR TABLE

Mode	Status	Li-Ion	NiMH	LSBit 0	Bit 1	Bit 2	MSBit 3
Power-Up	OFF	CHEM	CHEM	#CELLS	#CELLS	#CELLS	#CELLS
Enter Config	OFF	ON	ON	ON	ON	ON	ON
Config	4Hz	CHEM	CHEM	#CELLS	#CELLS	#CELLS	#CELLS
Calibrated	4Hz	OFF	OFF	ON	ON	ON	ON
Off	OFF	CHEM	CHEM	#CELLS	#CELLS	#CELLS	#CELLS
Charging	ON	1/2 Hz CHEM	1/2 Hz CHEM	#CELLS	#CELLS	#CELLS	#CELLS
Fault	FLASH	CHEM	CHEM	#CELLS	#CELLS	#CELLS	#CELLS
Fault-OV	2Hz	CHEM	CHEM	#CELLS	#CELLS	#CELLS	#CELLS
Fault-OT	1Hz	CHEM	CHEM	#CELLS	#CELLS	#CELLS	#CELLS
Term. Code (#CELLS pressed)	No Change	No Change	No Change	ΔV/Δt	ΔT/Δt	OVP	OTP
State Code (CHEM pressed)	No Change	No Change	No Change	STATE LS Bit 0	STATE Bit 1	STATE Bit 2	STATE MS Bit 3

TABLE 2-2: WHEN 'CHEM' SWITCH IS PRESSED, SHOWS CURRENT STATE

State Code	LSBit 0	Bit 1	Bit 2	MSBit 3
Startup	1	0	0	0
ON	0	1	0	0
Qualification	1	1	0	0
NiMH CC	0	0	1	0
NiMH Topoff	1	0	1	0
Li-Ion CC	0	1	1	0
Li-Ion CV	1	1	1	0
LED CC	0	0	0	1
Overvoltage	1	0	0	1
Off	0	1	0	1

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, User Calibrated
  - 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} < 0.9V.
  - Constant Current = 1.5A for 1 to 5 Cells.
  - Terminate Fast Charge for -dV/dT or +dT/dt.
  - Timed 50 mA top off charge for 1 hour.
  - Overvoltage Detection, once detected, will attempt to restart charge cycle five times. If overvoltage is still present, charging will terminate and STATUS LED will flash.
- LED Driver
  - Constant Current = 0 to 300 mA for 1 to 2 LEDs.
  - Pressing CHEM switch increments output current. Limited to 300 mA.
  - Pressing CELLS switch decrements output current. Limited to 0 mA.
  - Overvoltage Detection, once detected, will attempt to restart charge cycle five times. If overvoltage is still present, charging will terminate and STATUS LED will flash.

2.3.1.6 PROGRAMMING

Header J3 is provided for in-system circuit programming using either ICD 2 or PICkit™ 2.

2.3.1.7 DATA LOGGING

Header J5 is provided for serial data logging using the PICkit™ Serial Analyzer. The source code for the evaluation board contains the code necessary to transmit data via a PICkit™ Serial interface to a PC running the PICkit Serial Analyzer GUI interface. The data currently logged consists of charging current setpoint, output voltage, temperature thermistor voltage, current system state, and termination code.

The data logging feature allows the user to create and save a complete charging profile for a specific battery pack. The interface software provided with the PICkit Serial Analyzer allows the user to save the logged data to a file.

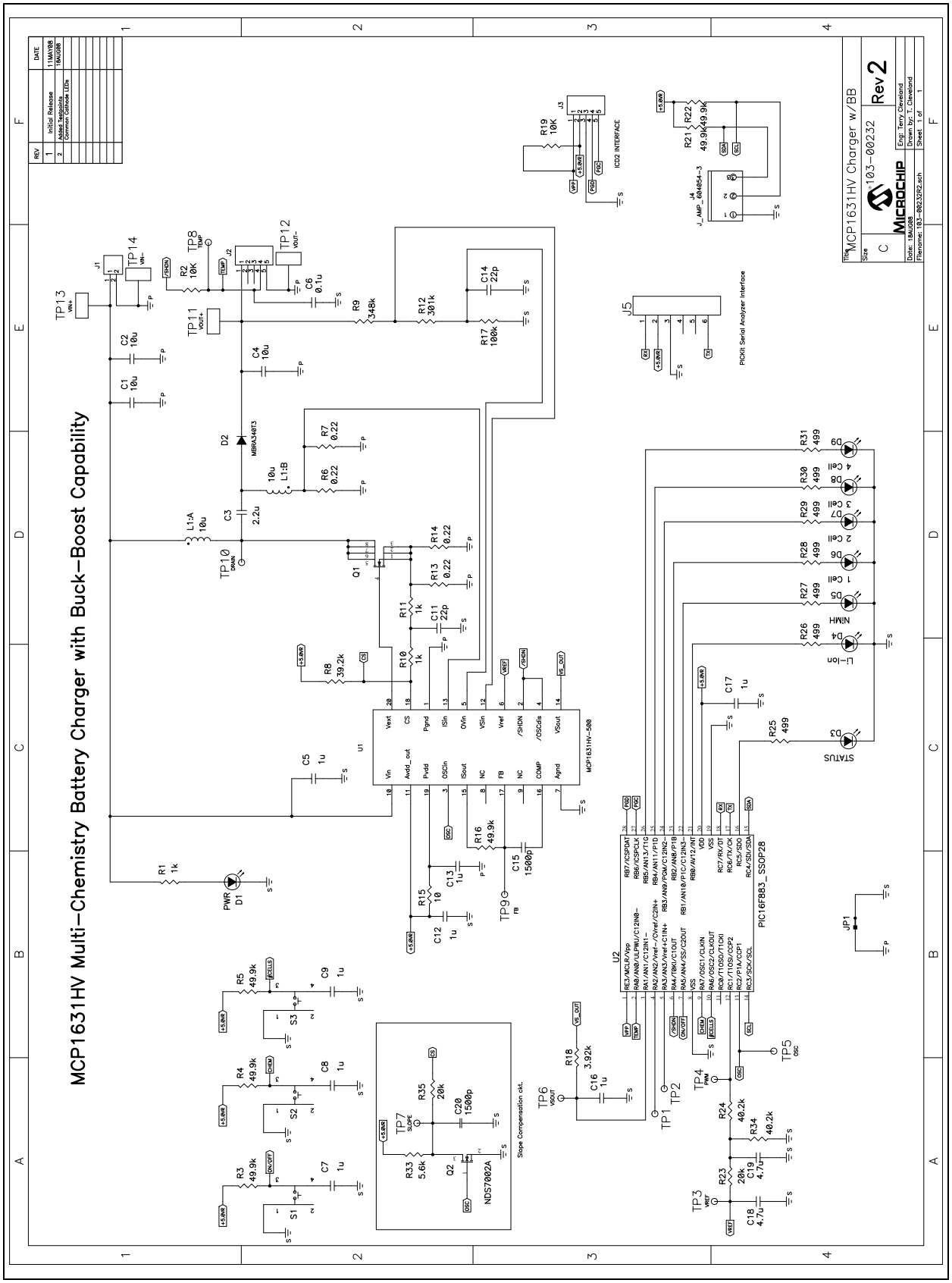
Appendix A. Schematic and Layout

A.1 INTRODUCTION

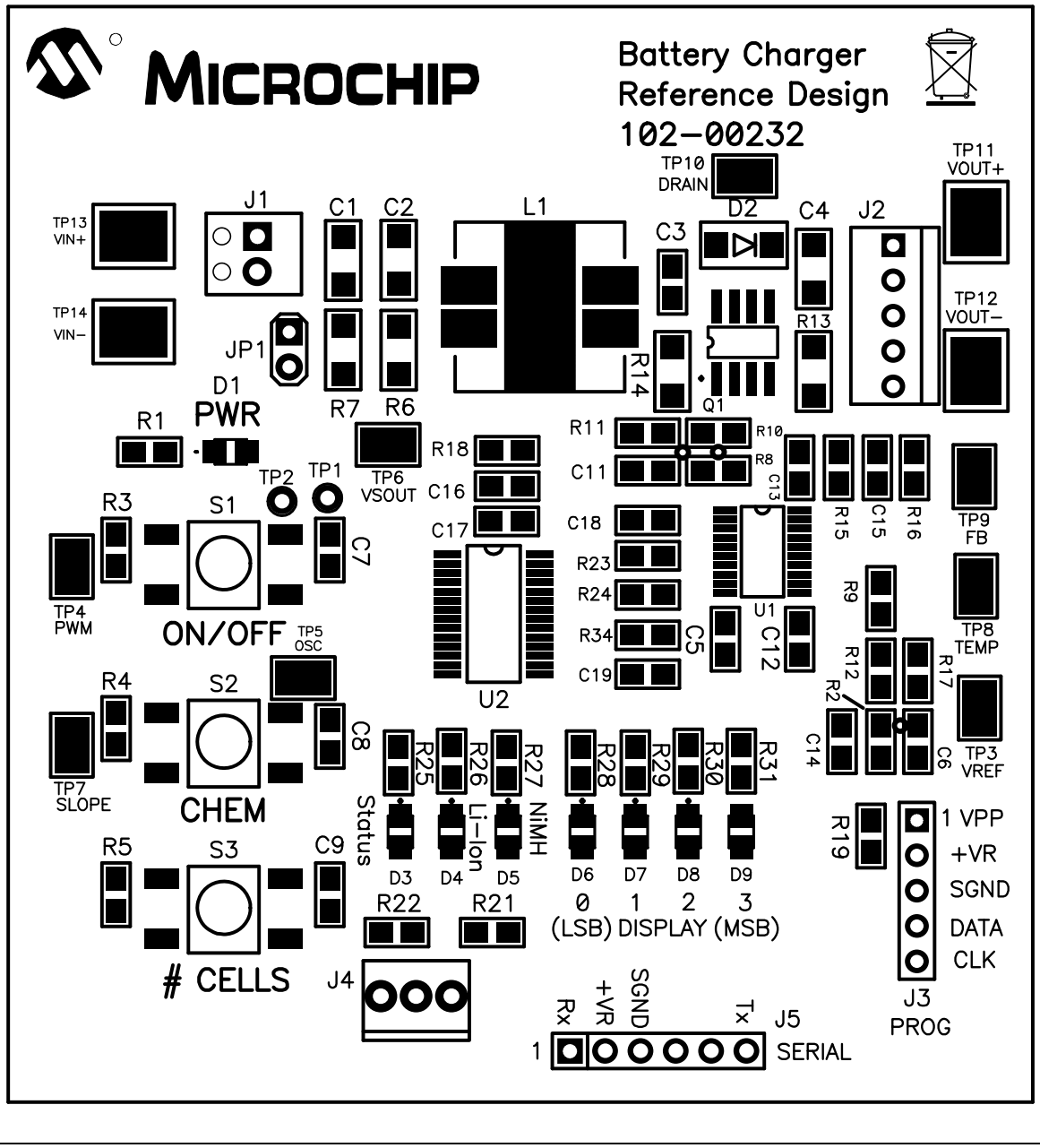
This appendix contains the following schematics and layouts for the MCP1631 Multi-Chemistry Battery Charger Reference Design:

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

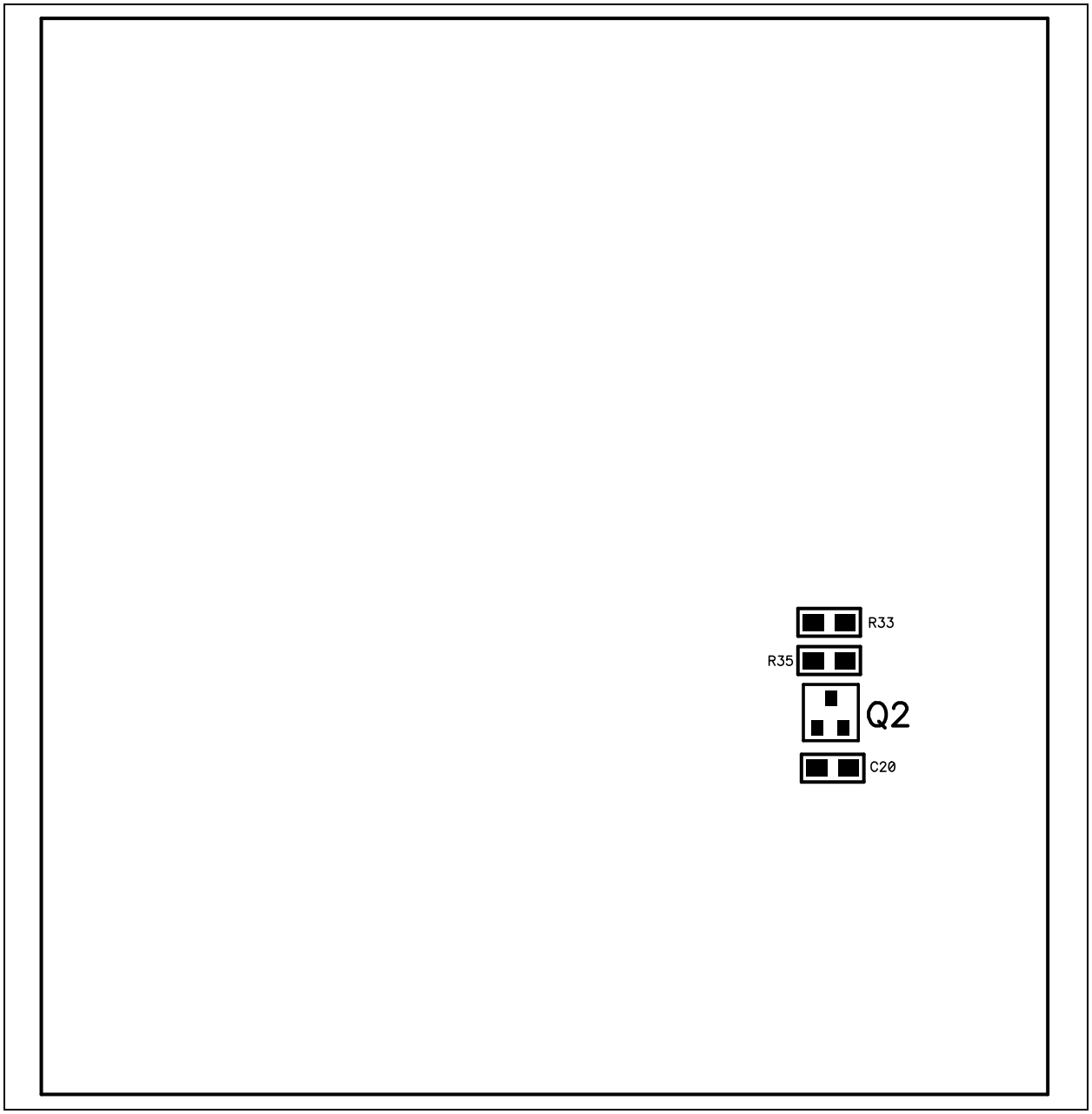
A.2 BOARD – SCHEMATIC



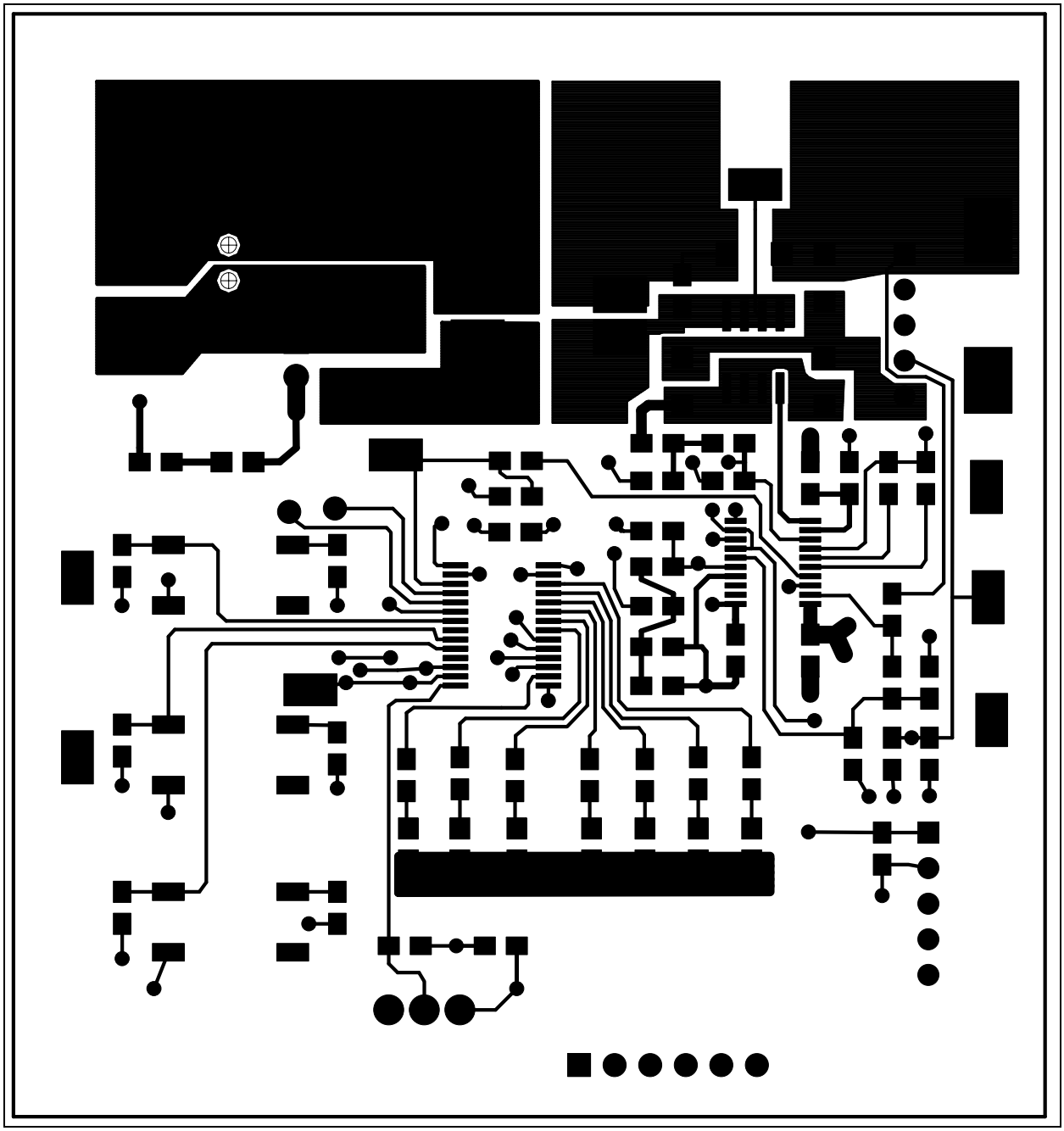
A.3 BOARD – TOP SILK LAYER



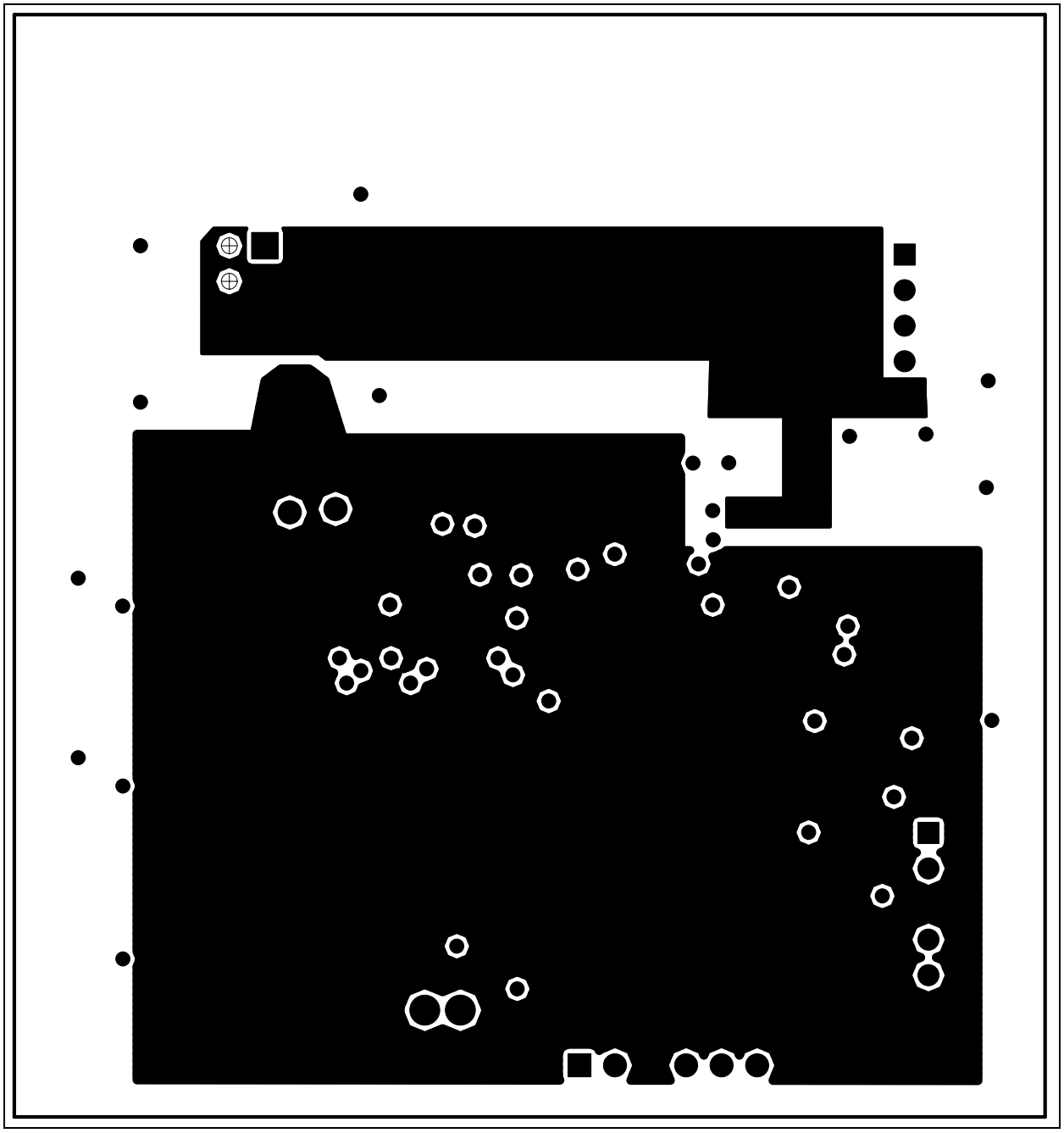
A.4 BOARD – BOTTOM SILK LAYER



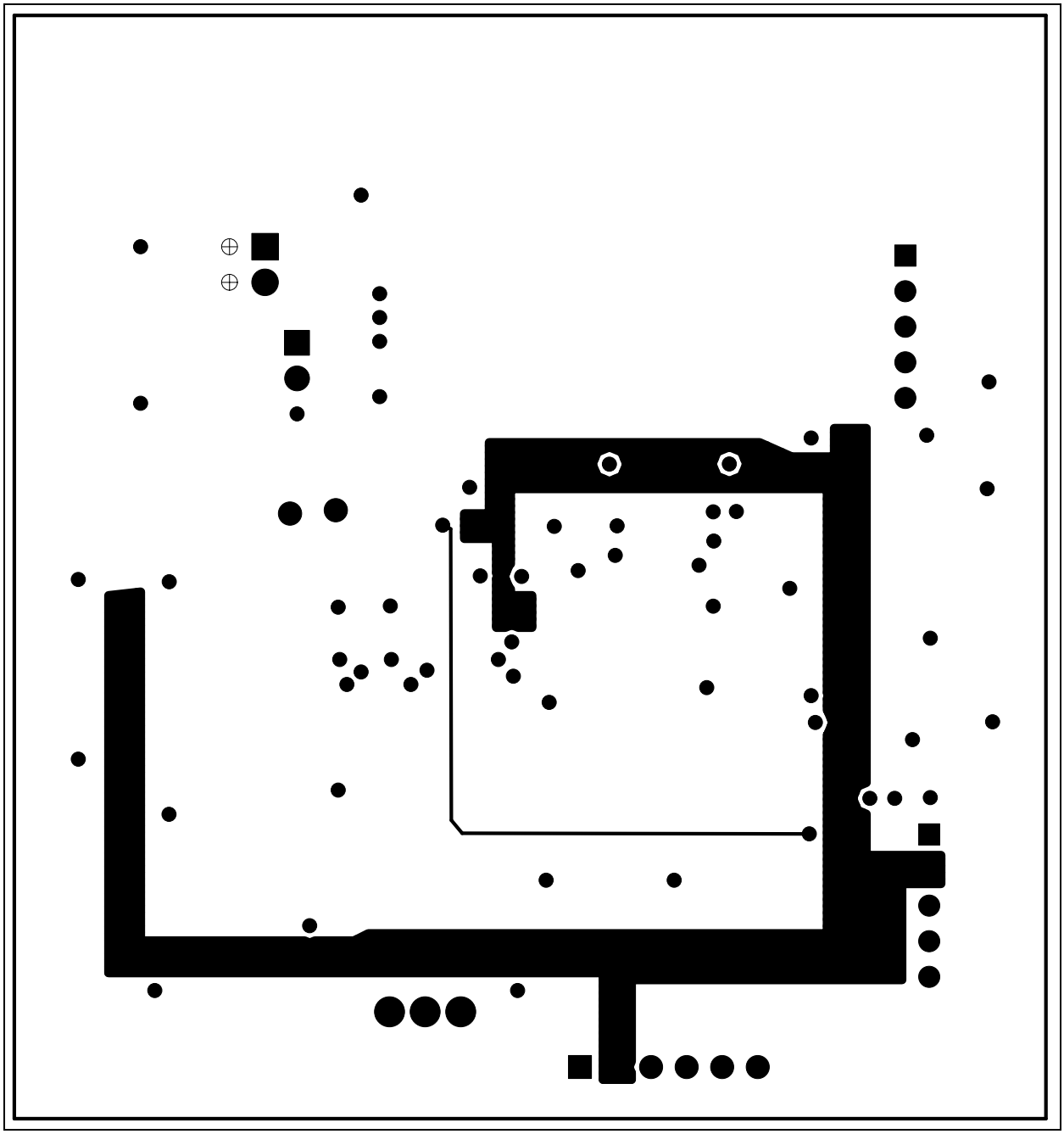
A.5 BOARD – TOP METAL LAYER



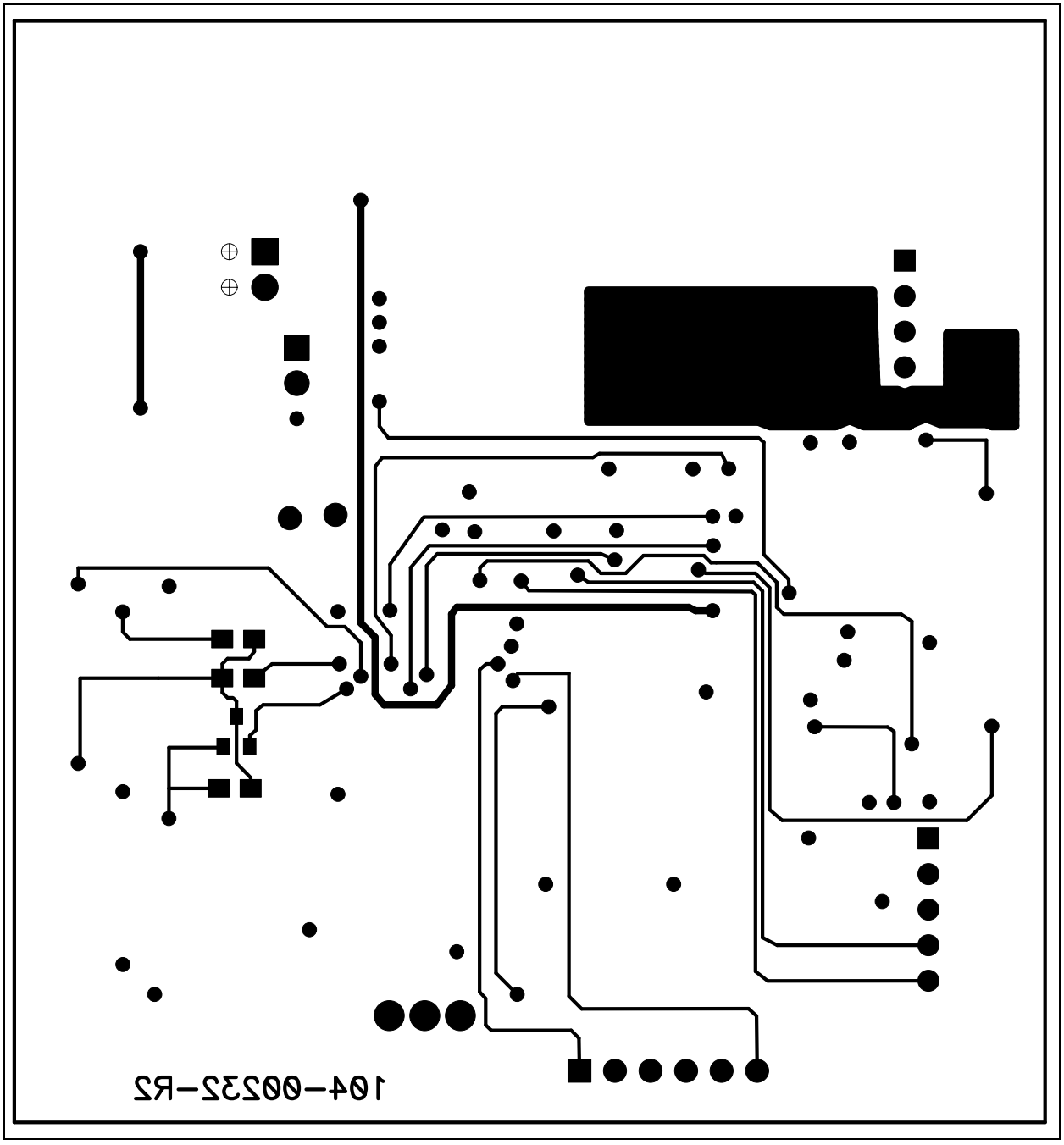
A.6 BOARD – MID1 METAL LAYER



A.7 BOARD – MID2 METAL LAYER



A.8 BOARD – BOTTOM METAL LAYER



Appendix B. Bill Of Materials (BOM)

TABLE B-1: BILL OF MATERIALS (BOM)

Qty	Reference	Description	Manufacturer	Part Number
4	B1, B2, B3, B4	BUMPON HEMISPHERE .44X.20 CLEAR	3M	SJ-5303 (CLEAR)
3	C1, C2, C4	CAP CERAMIC 10UF 25V X5R 1206	Panasonic® - ECG	ECJ-3YB1E106M
2	C11, C14	CAP 22PF 50V CERM CHIP 0805 SMD	Panasonic - ECG	ECJ-2VC1H220J
2	C15, C20	CAP 1500PF 50V CERM CHIP 0805	Panasonic - ECG	ECJ-2VB1H152K
2	C18, C19	CAP CER 4.7UF 10V X7R 20% 0805	TDK Corporation	C2012X7R1A475M
1	C3	CAP CER 2.2UF 25V X7R 0805	Murata Electronics® North America	GRM21BR71E225KA73L
8	C5, C7, C8, C9, C12, C13, C16, C17	CAP CER 1.0UF 25V X7R 0805	Taiyo Yuden	TMK212BJ105KG-TR
1	C6	CAP .1UF 16V CERAMIC X7R 0805	Panasonic - ECG	ECJ-2VB1C104K
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
1/6	J5	CONN HEADER .100 SNGL R/A 36POS	3M	929835-01-36-RK
1	JP1	BARE WIRE, 22 AWG to 26 AWG, 0.330	—	—
1	L1	INDUCT/XFRMR SHIELD DL 10UH SMD	Wurth Elektronik	744870100
1	PCB	RoHS Compliant Bare PCB, MCP1631 Multi-Chemistry Charger with Buck-Boost	—	104-00232

Note 1: 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.