MCP16501 Evaluation Board User's Guide

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ISBN: 978-1-5224-8158-4

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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 website (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 "DSXXXXXXXXA", where "XXXXXXXX" 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 online help. Select the Help menu, and then Topics to open a list of available online help files.

INTRODUCTION

This chapter contains general information that will be useful to know before using the MCP16501 Evaluation Board. Items discussed in this chapter include:

- Document Layout
- Conventions Used in this Guide
- Recommended Reading
- The Microchip Website
- Customer Support
- Document Revision History

DOCUMENT LAYOUT

This document describes how to use the MCP16501 Evaluation Board as a development tool. The manual layout is as follows:

- **Chapter 1. "Product Overview"** – Important information about the MCP16501 Evaluation Board.
- **Chapter 2. "Installation and Operation"** – Includes instructions on how to get started with the MCP16501 Evaluation Board and a description of each function.
- **Appendix A. "Schematic and Layouts"** – Shows the schematic and PCB layout for the MCP16501 Evaluation Board.
- **Appendix B. "Bill of Materials (BOM)"** – Lists the parts used to build the MCP16501 Evaluation Board.

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 the MCP16501 Evaluation Board. Another useful document is the following Microchip document listed below, which is available and recommended as a supplemental reference resource:

- **MCP16501 Data Sheet - *"Cost and Size Optimized PMIC for SAMA5DX/SAM9X6/SAMA7G Series MPUs" (DS20006388)***

THE MICROCHIP WEBSITE

Microchip provides online support via our website at www.microchip.com. This website is used as a means to make files and information easily available to customers. Accessible by using your favorite Internet browser, the website contains the following information:

- **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

CUSTOMER SUPPORT

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- Local Sales Office
- Field Application Engineer (FAE)
- Subject Matter Expert Engineers (SMEs)
- Technical Support

Customers should contact their distributor, representative, Field Application Engineer (FAE) or Subject Matter Expert Engineers (SME) 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 website at: http://www.microchip.com/support.

DOCUMENT REVISION HISTORY

Revision A (July 2020)

- Initial release of this document.

Revision B (August 2020)

- Minor editorial changes.

Revision C (April 2021)

- Added the Automotive AEC-Q100 Reliability test pass feature to **Section 1.2 "MCP16501 Short Overview"**.

NOTES:

Chapter 1. Product Overview

1.1 INTRODUCTION

This chapter provides an overview of the MCP16501 Evaluation Board and covers the following topics:

- MCP16501 Short Overview
- MCP16501 Evaluation Board Overview
- Contents of the MCP16501 Evaluation Board Kit

1.2 MCP16501 SHORT OVERVIEW

The MCP16501 is a cost and size-optimized integrated PMIC, compatible with Microchip's EMPUs (Embedded Microprocessor Units) and associated DRAM memories. It is compatible with SAMA5DX, SAM9X6 and SAMA7G MPUs, which are supported by dedicated device variants.

The MCP16501 integrates three DC-DC Buck regulators and one auxiliary LDO, and provides a comprehensive interface to the MPU.

All Buck channels can support loads up to 1A and are 100% duty cycle-capable.

The 300 mA LDO is provided such that sensitive analog loads can be supported.

The DDR memory voltage (Buck2 output) and MPU core voltage (Buck3 output) are selectable by means of two 3-state input pins. This method allows greater precision in the output voltage setting by eliminating inaccuracies due to external feedback resistors, while minimizing external component count. The voltage selection set allows easy migration across different generations of memory.

The default power channel sequencing is built-in according to the requirements of the MPU. A dedicated pin (LPM) facilitates the transition to Low-Power modes and the implementation of Backup mode with DDR in self-refresh (Hibernate mode).

The MCP16501 features a low no-load operational quiescent current and it draws less than 6 µA (V_{IN} = 4.5V, T_J = +105°C) in full shutdown.

Active discharge resistors are provided on each output.

All Buck channels support safe start-up into pre-biased outputs.

The MCP16501 is available in a 24-pin 4 mm × 4 mm VQFN package with an operating junction temperature range from -40°C to +125°C.

The key features of the MCP16501 include:

- Input Voltage: 2.7V to 5.5V
- Three 1A Output Current Buck Channels with 100% Maximum Duty Cycle Capability
- 2 MHz Buck Channels PWM Operation
- One Auxiliary 300 mA Low-Dropout (LDO) Linear Regulator
- ±1% Voltage Accuracy for DDR (Buck2 Output) and Core (Buck3 Output)
- Pin-Selectable Output Voltages for Buck2: 1.2V, 1.35V, 1.8V; and for Buck3: 1.0V, 1.15V,1.25V
- MPU-Specific Built-in Default Channel Sequencing and nRSTO Assertion Delay

- Support of MPU Hibernate and Low-Power Modes
- Low Noise, Forced PWM (FPWM) and Low I_Q, Light Load, High-Efficiency Mode Available
- Leakage-Free Interfacing to MPU in Any Operating Condition through Optimized ESD Protection
- 250 µA Low-Power Mode Typical Quiescent Current Bucks and LDO On, No Load
- 6 µA Maximum Shutdown Current (V_{IN} = 4.5V, T_J = +105°C)
- Separate LDO EN Input, Compatible to LV Logic
- Cost and Size-Optimized BOM
- Thermal Shutdown and Current Limit Protection
- 24-Pin 4 mm × 4 mm VQFN Package
- -40°C to +125°C Junction Temperature Range
- Passes Automotive AEC-Q100 Reliability Testing

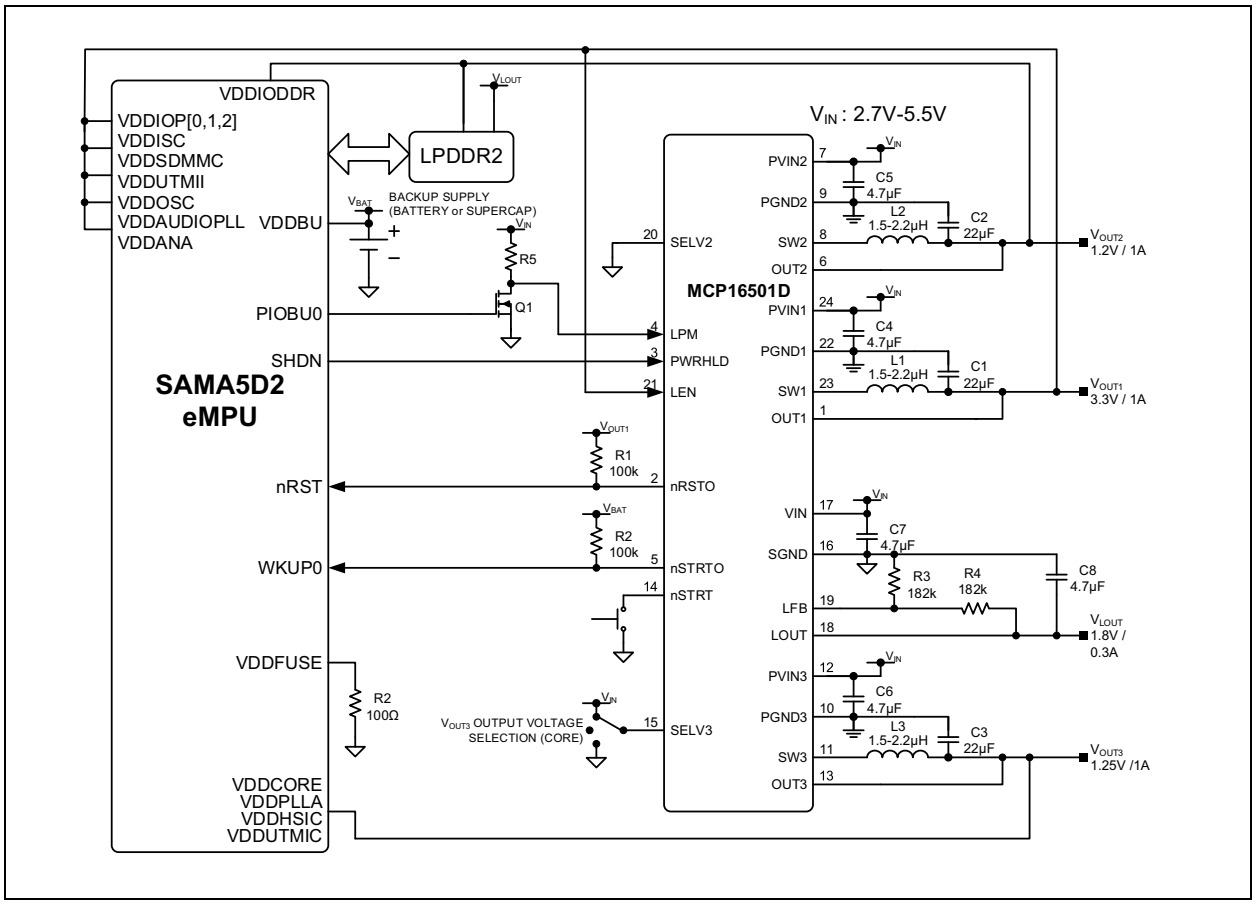


FIGURE 1-1: *Typical MCP16501D Application Schematic with SAMA5D2 and LPDDR2.*

1.3 MCP16501 EVALUATION BOARD OVERVIEW

The MCP16501 Evaluation Board is designed to simplify the evaluation and testing of all the MCP16501 capabilities. The V_{IN} supply has a 2.7V-5.5V range and V_{OUT} can be:

- 3.3V for Buck1 (set by the IC option)
- 1.2V-1.35V-1.8V for Buck2 (set by jumper)
- 1.0V-1.15V-1.25V for Buck3 (set by jumper)
- 1.8V for LDO (set by resistor divider)

The application allows for manual control of power state pins through 3-pin jumpers on the PWRHLD and LPM pins.

Additionally, an on-board load transient generator circuit is provided to evaluate the load step response of Buck2 and Buck3.

1.4 CONTENTS OF THE MCP16501 EVALUATION BOARD KIT

The MCP16501 Evaluation Board kit includes:

- MCP16501 Evaluation Board (ADM01123)
- Important Information Sheet

NOTES:

Chapter 2. Installation and Operation

2.1 INTRODUCTION

The MCP16501 Evaluation Board has been developed to test the MCP16501 device's capabilities. The board features test points for output voltage measurements and jumpers for selecting the output voltage, as well as an on-board load transient circuitry for fast transient behavior evaluation for Buck2 and Buck3.

2.2 BOARD FEATURES

The MCP16501 Evaluation Board has the following features:

- Input Voltage Range: 2.7V to 5.5V
- Three 1A Buck DC-DC Channels with 100% Maximum Duty Cycle Capability
- 2 MHz Buck Channels PWM Operation
- One Auxiliary 300 mA LDO with Independent Enable, Set to 1.8V by Resistor Voltage Divider
- Buck1 – I/O Output Voltage: 3.3V
- Buck2 – Pin-Selectable Output Voltages for DDR: 1.2V, 1.35V and 1.8V
- Buck3 – Pin-Selectable Output Voltages for Core: 1.0V, 1.15V and 1.25V
- ±1% Core Voltage Accuracy
- On-Board Load Generator for Buck2 and Buck3
- Built-in Channel Sequencing and nRSTO Assertion Delay
- Low-Noise Forced-PWM and Ultra-Low I_Q Low-Power Mode Available
- 250 µA Low-Power Mode Typical Quiescent Current (operational)
- 6 µA Maximum Shutdown Current
- Available jumpers for PWRHLD, LPM, SELV2, SELV3, LEN, VDDBU and nRST
- 12 mm x 12 mm Size-Optimized Layout Example

2.3 GETTING STARTED

The MCP16501 Evaluation Board is fully assembled and tested to evaluate and demonstrate the MCP16501 product.

This board requires a single power supply with at least 3A current capability if multiple channels are tested under load.

The MCP16501 is available in five different product options, depending on the desired output voltages. The differences among the various product options are described in the *"MCP16501 Data Sheet"*. The Evaluation Board carries the D option, which is intended for an efficiency-optimized, high-performance (i.e., 500 MHz) SAMA5D2 application equipped with LPDDR2 memories.

2.3.1 Power Input and Output Connections

To power up the MCP16501 Evaluation Board, follow the steps below:

1. Connect a power supply to the VIN and PGND terminals. An ammeter may be placed between the input supply and the VIN terminal to the Evaluation Board. Ensure that the supply voltage is monitored at the VIN terminal. The ammeter and/or power lead resistance can reduce the voltage supplied to the input.

   Note: Keep the power supply disabled; do not apply power before Step 4.

2. Connect the loads to the VOUTx for Buck converters or LVOUT for LDO regulator and PGND terminals. The load can be either passive (resistive) or active (electronic load). An ammeter can be placed between the load and each output terminal. Ensure that the output voltage is monitored at the output terminals. Alternatively, for high-speed load transient testing at low output voltages, the on-board load transient generator can be used (see **Section 2.4 "On-Board Load Transient Generator"**).
3. Make sure the jumpers are connected as in Figure 2-1 (PWRHLD = HIGH, LPM = SELV2 = LOW, SELV3 = HIGH, VDDBU = VIN and LEN = VOUT1). By connecting the LDO Enable (LEN) input to VOUT1, the proper power-up sequence for LPDDR2 is achieved.

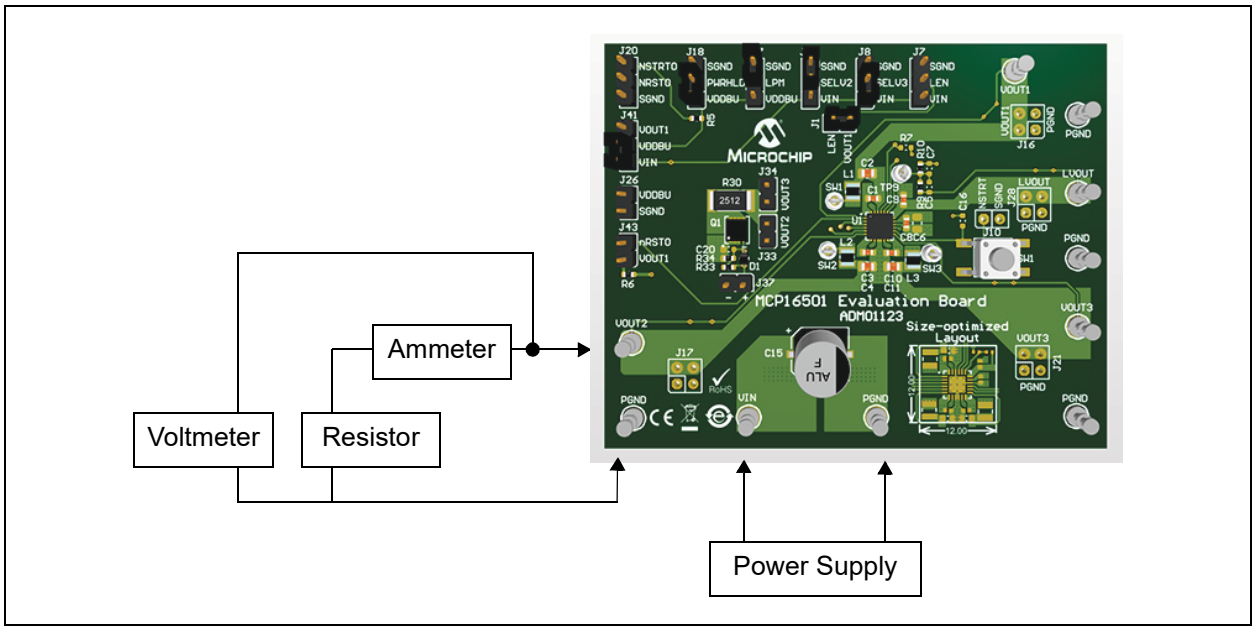


FIGURE 2-1: *MCP16501 Evaluation Board Connection and Jumper Placement.*

4. Set the power supply to 5V and turn it on.
5. Press the **SW1** button.
6. Verify that the output voltages are regulated to the desired VOUT setting for each channel.
7. The PMIC settings can be modified using the provided jumpers. In order for the voltage changes to be executed, a power cycle is needed. The output voltage is chosen only when the PMIC is powered up and will not change if the VIN voltage is present.

2.4 ON-BOARD LOAD TRANSIENT GENERATOR

The MCP16501 Evaluation Board provides circuitry to enable load transient testing with fast current rise time and fast, yet controlled, fall time. This is done by a fast turn-on and controlled turn-off MOSFET switch (Q1). MOSFET Q1 must be driven by an external signal generator, connected at J37, using a square wave (the suggested low level is 0V, the high level is 5V-6V). Drive levels can be adjusted to modify the switching speed of Q1, but should always ensure complete turn-on and turn-off of Q1, after settling, while not exceeding its V_{GS} ratings. By default, the R30 resistor is 4.7Ω with a power dissipation rating of 1.5W. It is very important not to exceed the power dissipation limit of R30. When using the 2512 resistor (1.5W rating), the constraint is:

EQUATION 2-1:

$$D \times \frac{V_{OUT}^{2}}{R30} < 1.5W$$

Where:

D = The on-time duty cycle of Q1

V_{OUT} = The selected output voltage

The on-board load transients generator can be used to test either Buck2, by connecting a jumper to J33, or Buck3, by connecting a jumper to J34.

The on-board load transient generator is especially useful when testing at very low output voltages, since not many active loads can perform well under those conditions, while current rise times achievable with external load boards are limited by stray inductance.

2.5 LAYOUT CONSIDERATIONS

The MCP16501 PMIC requires at least nine vias from the IC's Exposed Pad to the Ground (GND) plane, to dissipate the generated heat. The GND plane can be increased or decreased based on the ambient temperature, air flow or other devices that generate heat. The rule of thumb is that the GND plane must be as big as possible.

The MCP16501 also features Power Ground (PGND) pins that must be connected to the power components (power input and output capacitors) and to a low-impedance return path, such as a dedicated plane or copper pour. It is also recommended to connect the input and output capacitor GND connections, as well as the PGND pins on the same layer (thus avoiding vias inductance) and the same continuous copper plane for optimal performance.

The PGND pins and GND planes should be connected together at the Exposed Pad. See **Appendix A. "Schematic and Layouts"** for a PCB layout example.

For low EMI (Electromagnetic Interference) emissions, the switching node of the Buck regulators should be routed on an internal plane, surrounded/enclosed by input supply voltage distribution or GND planes.

NOTES:

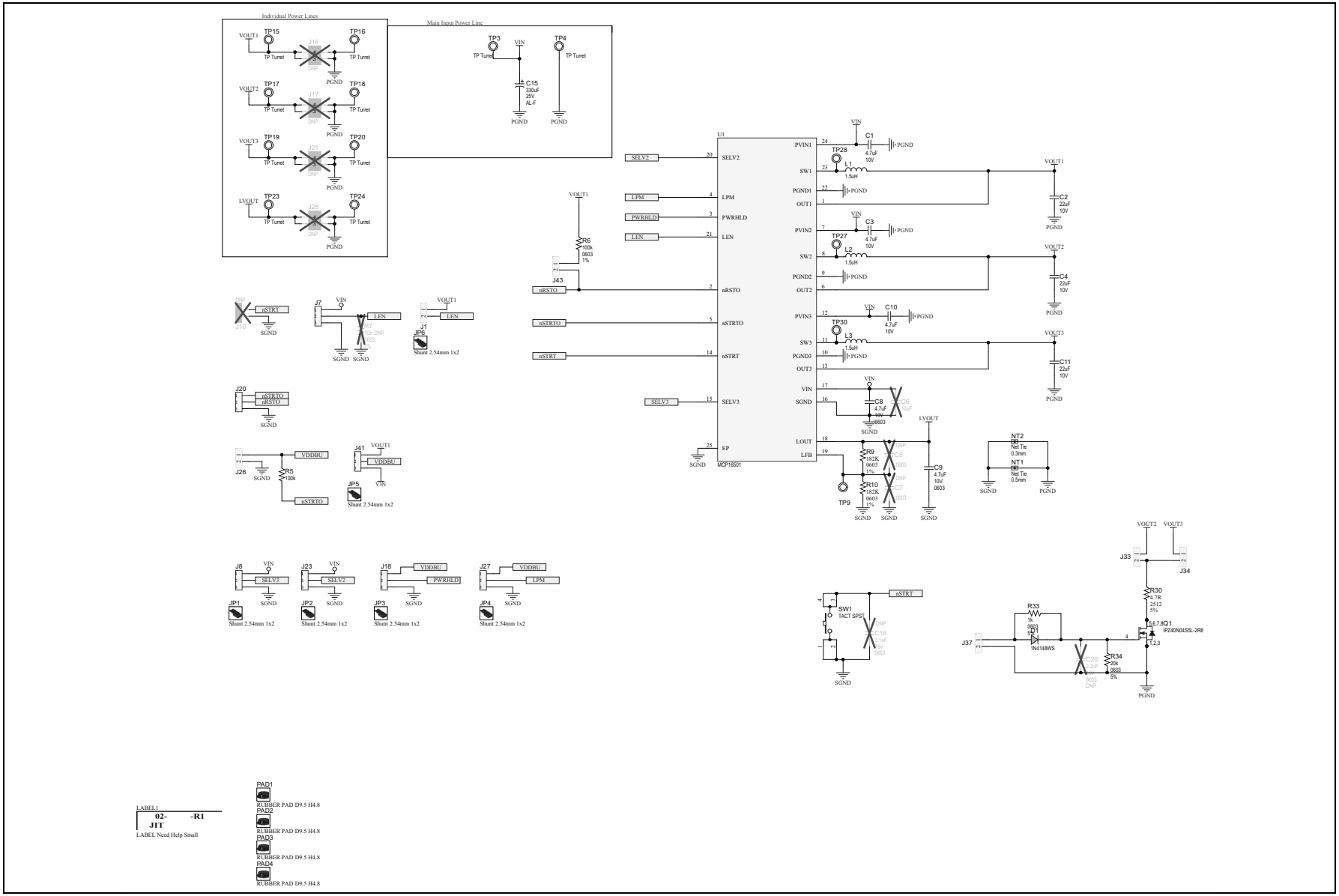
Appendix A. Schematic and Layouts

A.1 INTRODUCTION

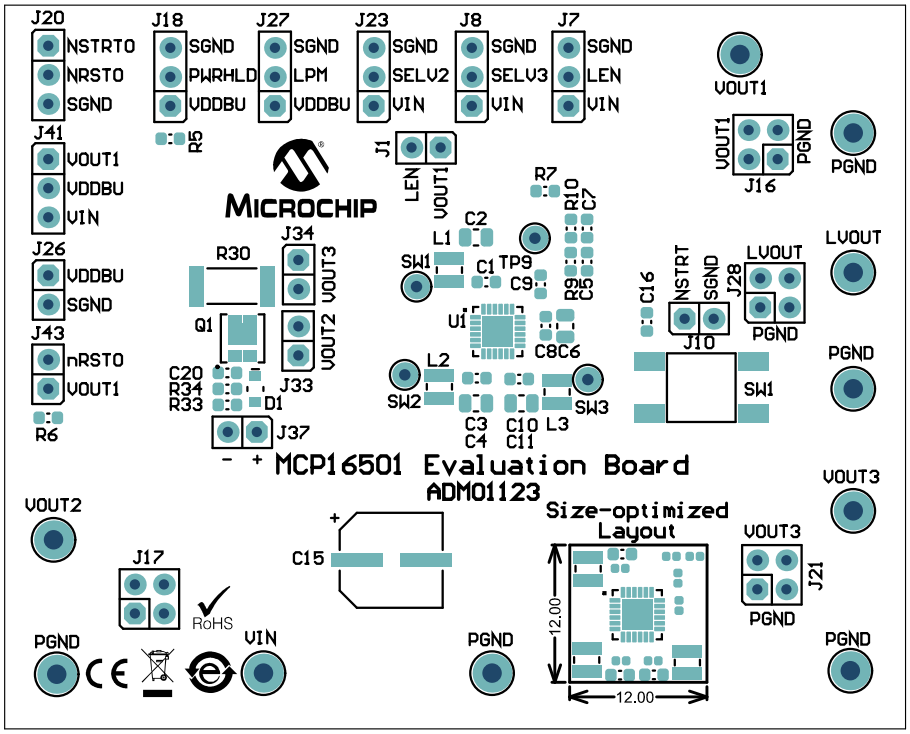
This appendix contains the following schematic and layouts for the MCP16501 Evaluation Board:

- Board – Schematic
- Board – Top Silk
- Board – Top Copper and Silk
- Board – Top Copper
- Board – Mid-Layer 1
- Board – Mid-Layer 2
- Board – Bottom Copper
- Board – Bottom Copper and Silk
- Board – Bottom Silk

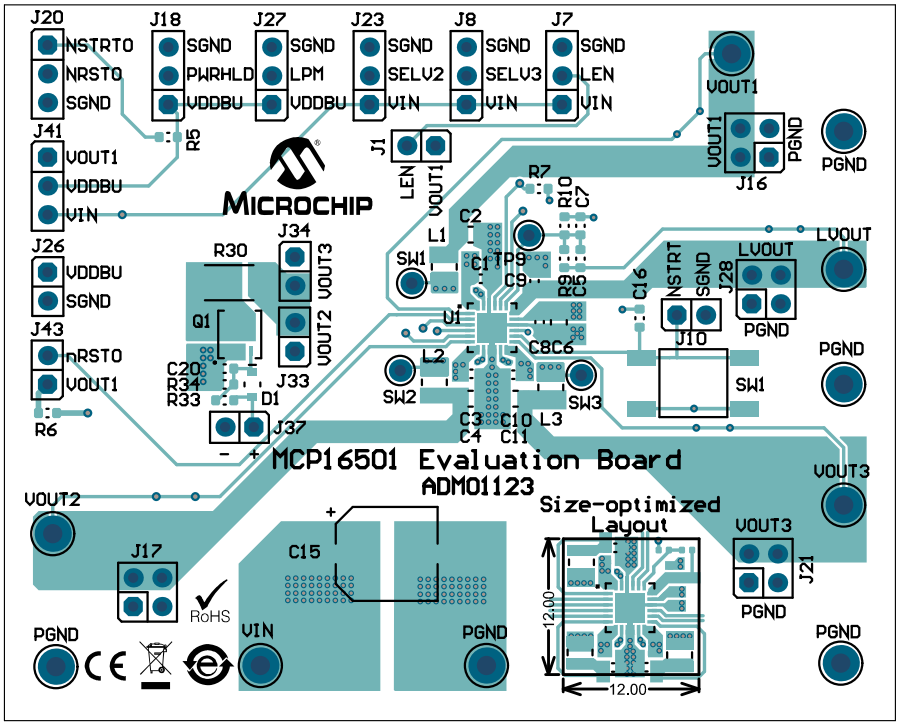
A.2 BOARD – SCHEMATIC



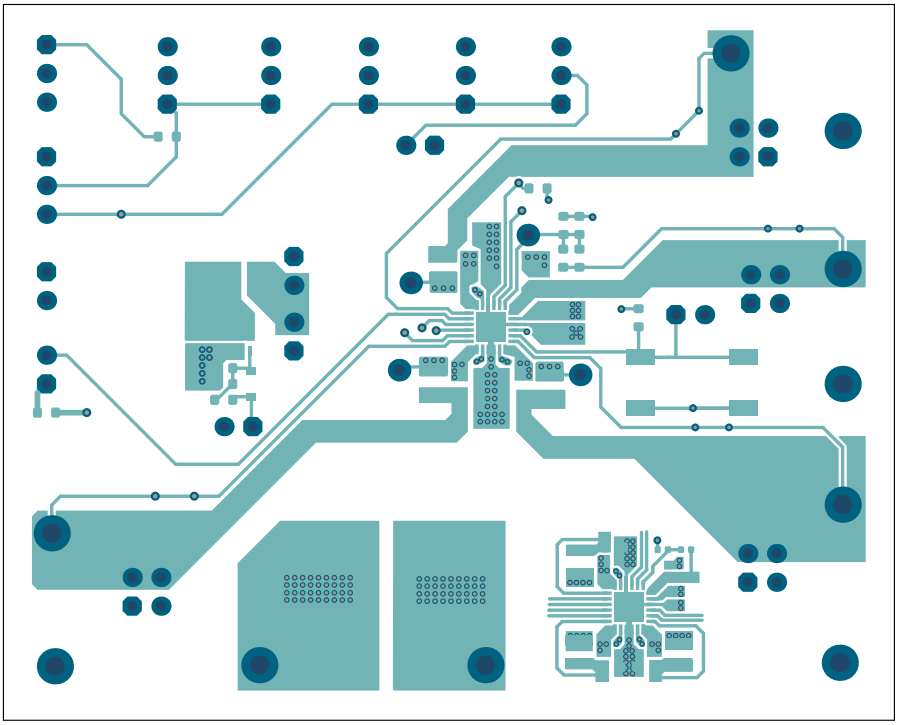
A.3 BOARD – TOP SILK



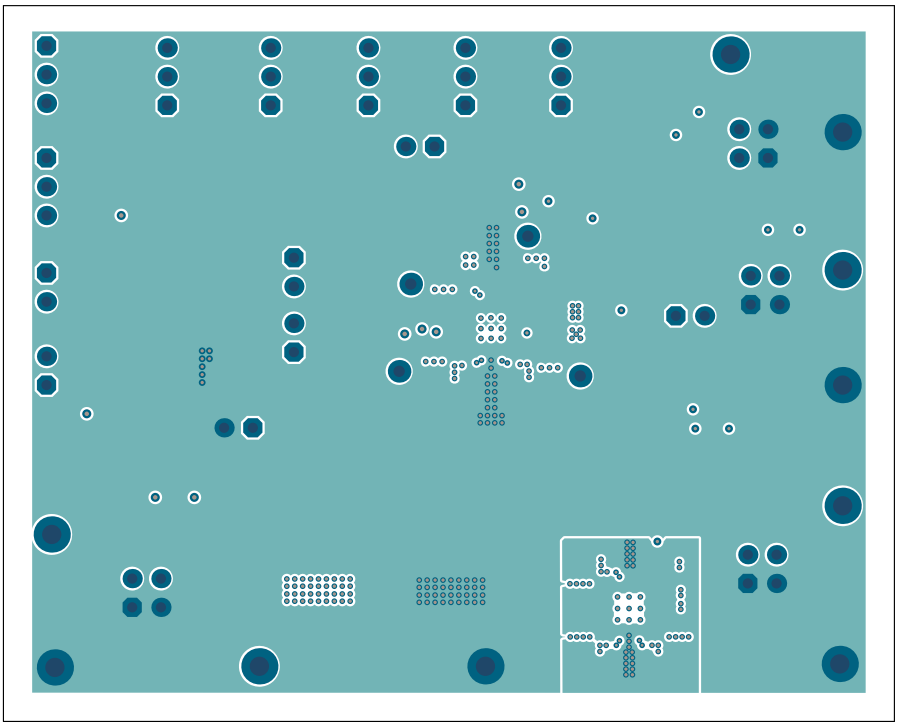
A.4 BOARD – TOP COPPER AND SILK



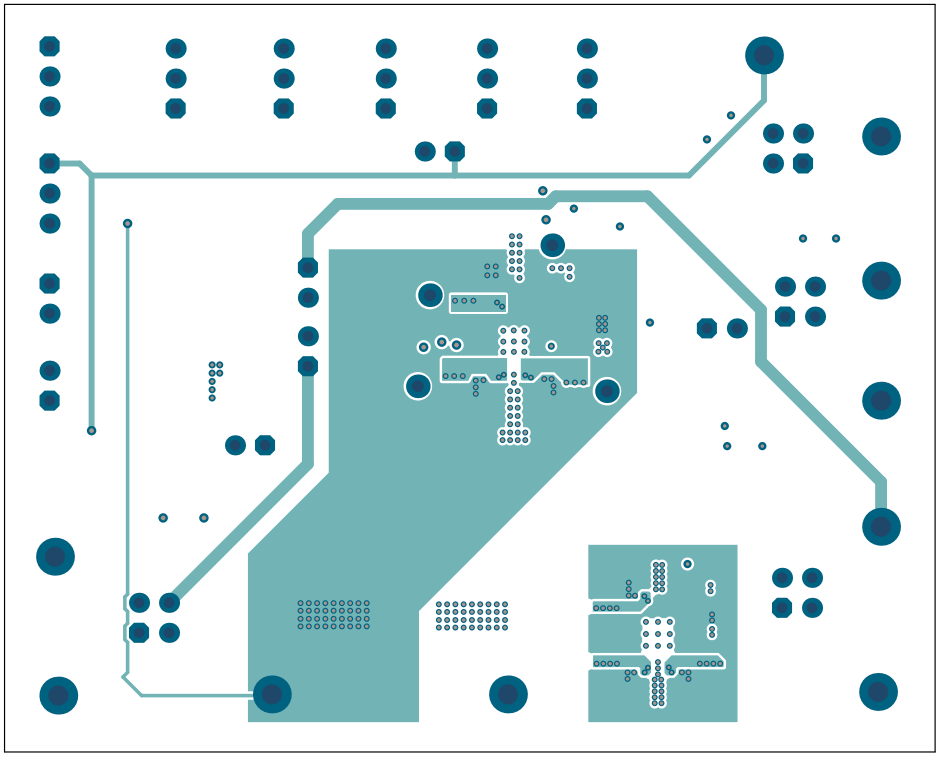
A.5 BOARD – TOP COPPER



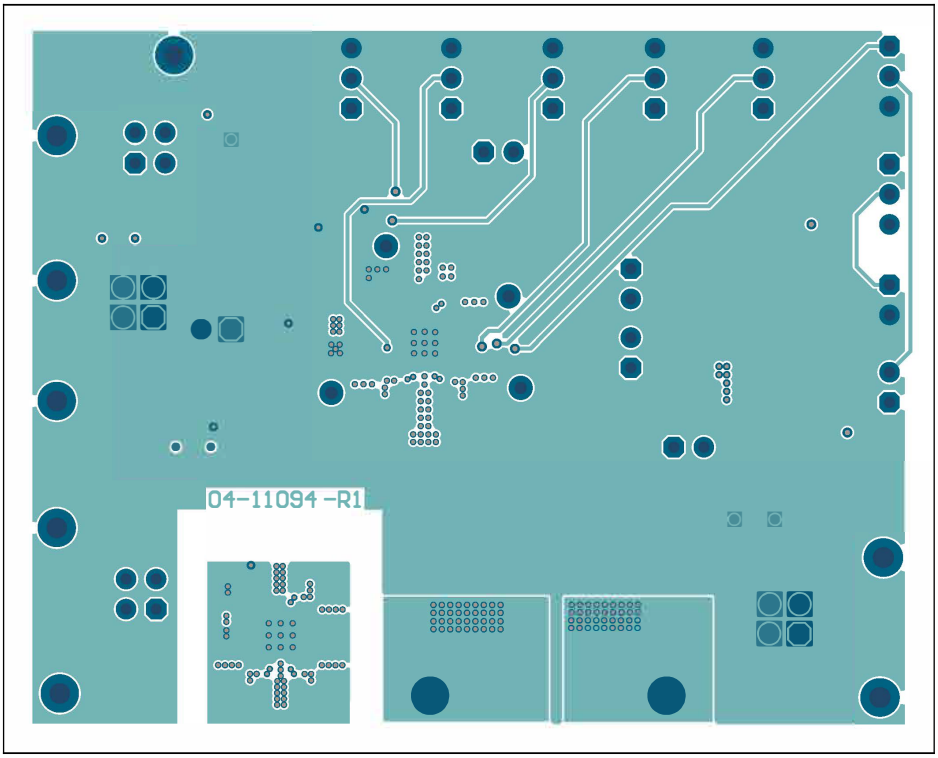
A.6 BOARD – MID-LAYER 1



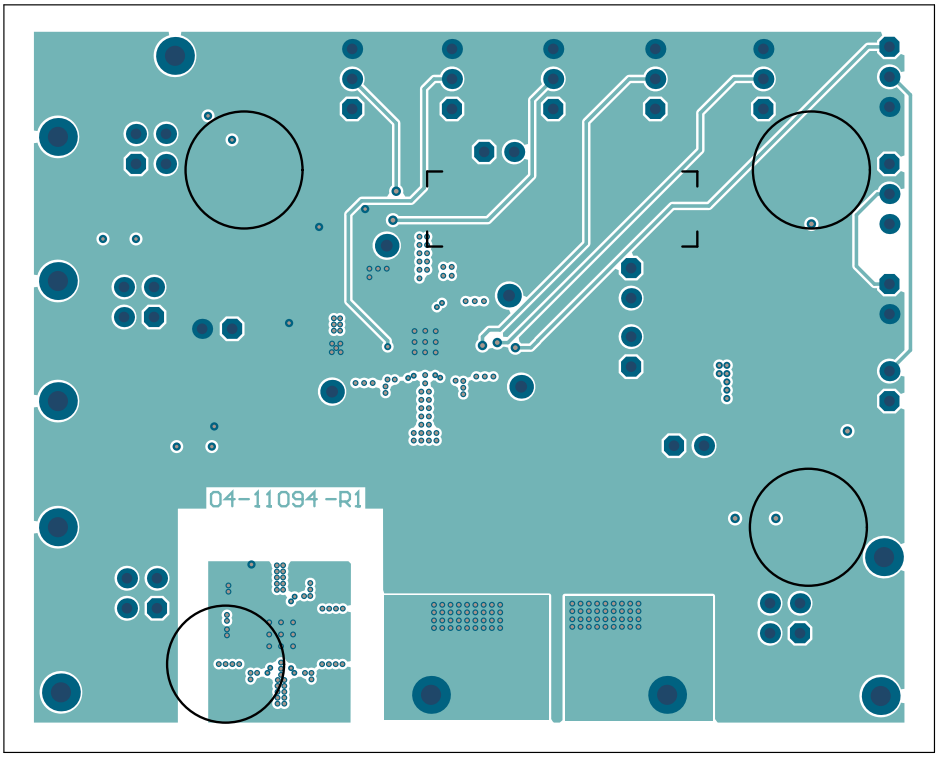
A.7 BOARD – MID-LAYER 2



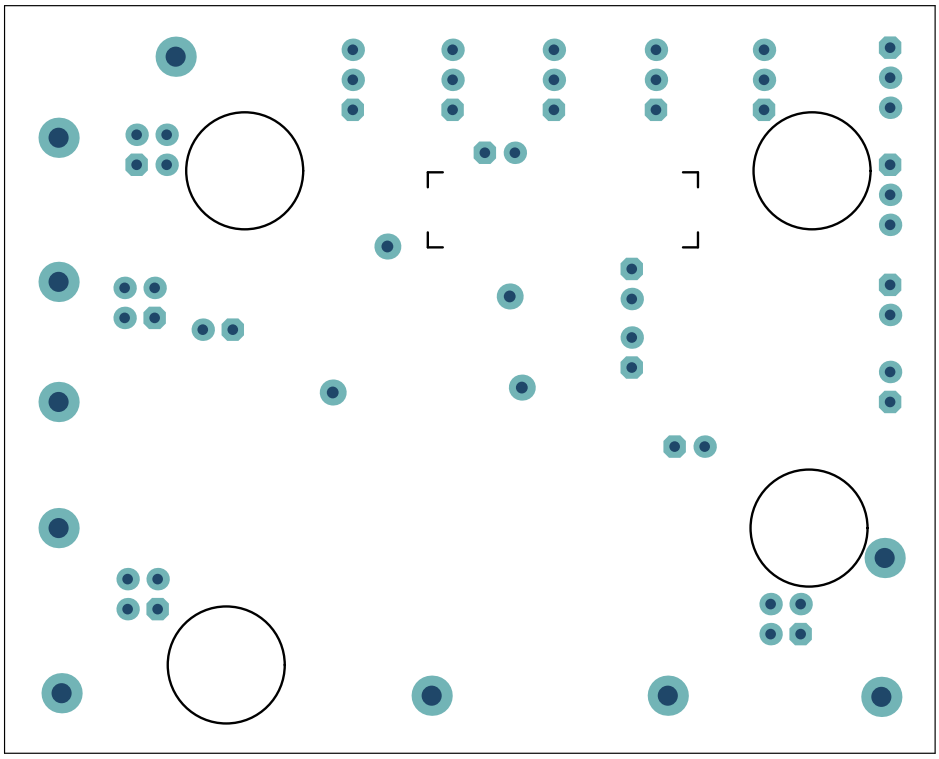
A.8 BOARD – BOTTOM COPPER



A.9 BOARD – BOTTOM COPPER AND SILK



A.10 BOARD – BOTTOM SILK



Appendix B. Bill of Materials (BOM)

TABLE B-1: BILL OF MATERIALS (BOM)[1]

Qty.	Reference	Description	Manufacturer	Part Number
5	C1, C3, C8, C9, C10	Ceramic Capacitor, 4.7 µF, 10V, 10%, X7S, SMD, 0603	TDK Corporation	C1608X7S1A475K080AC
3	C2, C4, C11	Ceramic Capacitor, 22 µF, 10V, 20%, X7S, SMD, 0805	TDK Corporation	C2012X7S1A226M125AC
1	C15	Aluminum Capacitor, 330 µF, 25V, 20%, SMD, F	Nichicon Corporation	UWT1E331MNL1GS
1	D1	Diode Rectifier, 1.25V, 150 mA 75V, SOD-323	Diodes Incorporated®	1N4148WS-7-F
6	J1, J26, J33, J34, J37, J43	Connector Header, 2.54 mm Insulated Height, Male, 1x2 Gold, 5.84 mm Contact Length, TH, Vertical, Black	Amphenol ICC (FCI)	77311-118-02LF
7	J7, J8, J18, J20, J23, J27, J41	Connector Header, 2.54 mm Insulated Height, Male, 1x3 Tin, 5.84 mm Contact Length, TH, Vertical, Black	Samtec, Inc.	TSW-103-07-T-S
1	L1, L2, L3	Inductor, 1.5 µH, 3.5A, 20%, SMD, 1008	Murata Manufacturing Co., Ltd.	DFE252012P-1R5M=P2
1	PCB1	MCP16501 Evaluation Board Printed Circuit Board	Microchip Technology Inc.	**04-11094-R1**
10	Q1	Transistor MOSFET N-Channel, 40V, 40A, 0.0028R, 71W, TDSON-8, AEC-Q101	Infineon Technologies AG	IPZ40N04S5L2R8ATMA1
2	R5, R6	Resistor, TF, 100 kΩ, 1%, 1/8W, SMD, 0603	Vishay Beyschlag	MCT06030C1003FP500
2	R9, R10	Resistor, TKF, 182 kΩ, 1%, 1/10W, SMD, 0603	Yageo Corporation	RC0603FR-07182KL
1	R30	Resistor, TKF, 4.7R, 5%, 1.5W, SMD, 2512	Stackpole Electronics, Inc.	RPC2512JT4R70
1	R33	Resistor, TKF, 1 kΩ, 5%, 1/10W, SMD, 0603	Panasonic® - ECG	ERJ3GEYJ102V
1	R34	Resistor, TKF, 20 kΩ, 5%, 1/10W, SMD, 0603	Panasonic - ECG	ERJ-3GEYJ203V
1	SW1	Tactile Switch, SPST, 12V, 50 mA, SMD	E-Switch®, Inc.	TL3301NF260QG
10	TP3, TP4, TP15, TP16, TP17, TP18, TP19, TP20, TP23, TP24	Connector Test Point Pin, Tin, TH	Harwin Plc.	H2121-01
4	TP9, TP27, TP28, TP30	Multipurpose Test Point, Miniature, White	Keystone® Electronics Corp.	5002
1	U1	Microchip Analog PMIC Switcher Buck ADJ, VQFN-24	Microchip Technology Inc.	**MCP16501TD-E/RMB**

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.

TABLE B-2: BILL OF MATERIALS (BOM) – MECHANICAL PARTS(1)

Qty.	Reference	Description	Manufacturer	Part Number
6	JP1, JP2, JP3, JP4, JP5, JP6	Mechanical Headers and Wire Jumper, 2.54 mm, 1x2	3M	969102-0000-DA
4	PAD1, PAD2, PAD3, PAD4	Mechanical HW Rubber Pad, 0.374 mm x 0.189 mm, Clear	Essentra Components	RBS-35

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.

TABLE B-3: BILL OF MATERIALS (BOM) – DO NOT POPULATE PARTS(1)

Qty.	Reference	Description	Manufacturer	Part Number
2	C5, C7	Ceramic Capacitor, 0.012 µF, 50V, 10%, X7R, SMD, 0603	KEMET	C0603C123K5RACTU
1	C6	Ceramic Capacitor, 10 µF, 10V, 10%, X7R, SMD, 0805	Samsung Electro-Mechanics America, Inc.	CL21B106KPQNFNE
5	C12, C14, C18, C21, C23	Ceramic Capacitor, 4.7 µF, 6.3V, 20%, X5R, SMD, 0402	Murata Electronics®	GRM155R60J475ME47D
3	C13, C17, C19	Ceramic Capacitor, 22 µF, 10V, 20%, X5R, SMD, 0603	TDK Corporation	C1608X5R1A226M080AC
1	C16	Ceramic Capacitor, 0.1 µF, 16V, 10%, X7R, SMD, 0603	Wurth Elektronik	885012206046
1	C20	Ceramic Capacitor, 2.2 µF, 10V, 10%, X7R, SMD, 0603	Murata Electronics®	GRM188R71A225KE15D
1	J10	Connector Header, 2.54, Male, 1x2, Gold, 5.84 MH, TH, Vertical	Amphenol ICC (FCI)	77311-118-02LF
4	J16, J17, J21, J28	Connector Header, 2.54, Male, 2x2, Gold, 5.84 MH, TH, Vertical	Wurth Elektronik	61300421121
3	L4, L5, L6	Inductor, 1.5 µH, 3.5A, 20%, SMD, 1008	Murata Electronics®	DFE252012P-1R5M=P2
1	R2	Resistor, TKF, 300 kΩ, 1%, 1/10W, SMD, 0402	Panasonic® - ECG	ERJ-2RKF3003X
1	R3	Resistor, 162 kΩ, 0.1%, 1/10W, SMD, 0402	TE Connectivity, Ltd.	RP73PF1E162KBTD
1	R7	Resistor, TF, 10 kΩ, 1%, 1/10W, SMD, 0603	TE Connectivity, Ltd.	5-1879337-9
1	U2	Microchip Analog PMIC Switcher Buck ADJ, VQFN-24	Microchip Technology Inc.	**MCP16501TD-E/RMB**

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.

NOTES:

Worldwide Sales and Service

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