MIC23158/9
Synchronous Buck Regulator Evaluation Board
User's Guide

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Object of Declaration: MIC23158/9 Synchronous Buck Regulator Evaluation Board

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Signed for and on behalf of Microchip Technology Inc. at Chandler, Arizona, USA.

Derek Carlson
VP Development Tools

11-NOV-16
Date

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MIC23158/9 EVALUATION BOARD USER'S GUIDE

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Preface

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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 "DSXXXXXXXA", where "XXXXXXX" 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 MIC23158/9 Synchronous Buck Regulator 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 MIC23158/9 Synchronous Buck Regulator Evaluation Board as a demonstration board to evaluate the MIC23158/9 device. The manual layout is as follows:

- **Chapter 1. "Product Overview"** – Provides important information about the MIC23158/9 Synchronous Buck Regulator Evaluation Board.
- **Chapter 2. "Installation and Operation"** – Includes a detailed description of the demo board and instructions on how to use it.
- **Appendix A. "Schematics and Layout"** – Schematics and layout diagrams of the MIC23158/9 Synchronous Buck Regulator Evaluation Board.
- **Appendix B. "Bill of Materials (BOM)"** – Lists the parts used to build the MIC23158/9 Synchronous Buck Regulator Evaluation Board.

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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) { ... }`

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RECOMMENDED READING

This user's guide describes how to use MIC23158/9 Synchronous Buck Regulator Evaluation Board. The following Microchip documents are available and recommended as supplemental reference resources:

- **MIC23158/9 Data Sheet - *"3MHz, PWM, Dual 2A Buck Regulator with Hyper-Light Load® and Power Good"***

This data sheet provides detailed information regarding the MIC23158/9 device.

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

DOCUMENT REVISION HISTORY

Revision A (March 2017)

- Initial conversion of Micrel evaluation board document to Microchip User's Guide DS50002588A. Minor grammatical corrections throughout.
- Updated multiple connector references, schematics, drawings, and BOM to reflect the use of ADM00829 board.

NOTES:

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Chapter 1. Product Overview

1.1 INTRODUCTION

This chapter provides an overview of the MIC23158/9 Evaluation Board and covers the following topics:

- MIC23158/9 Short Overview
- What is the MIC23158/9 Evaluation Board?
- MIC23158/9 Evaluation Board Kit Contents

1.2 MIC23158/9 SHORT OVERVIEW

1.2.1 MIC23158/9 Key Features

The key features of the MIC23158/9 include:

- 2.7V to 5.5V Input Voltage
- Adjustable Output Voltage, Down to 1V
- Two Independent 2A Outputs
- Up to 94% Peak Efficiency
- 83% Typical Efficiency at 1 mA
- Two Independent Power Good Indicators
- Independent Programmable Soft-Start
- 45 µA Typical Quiescent Current
- 3 MHz PWM Operation in Continuous Conduction Mode
- Ultra-Fast Transient Response
- Output Pre-Bias Safe
- 0.1 µA Shutdown Current
- Thermal-Shutdown and Current-Limit Protection
- 20-pin 3 mm x 4 mm QFN Package
- Internal 225Ω Pull-Down Circuit on Output (MIC23159)
- –40°C to +125°C Junction Temperature

1.2.2 MIC23158/9 Overview

The MIC23158/9 is a high-efficiency, 3 MHz, dual 2A synchronous buck regulator with HyperLight Load® mode, power good output indicator, and programmable soft-start.

The MIC23159 also provides an auto discharge feature that switches in a 225Ω pull-down circuit on its output to discharge the output capacitor when disabled. Hyper-Light Load provides very high efficiency at light loads and ultra-fast transient response, which makes the MIC23158/9 perfectly suited for supplying processor core voltages. An additional benefit of this proprietary architecture is very low output ripple voltage throughout the entire load range with the use of small output capacitors.

The MIC23158/9 is designed for use with a very small inductor, down to 0.47 µH and an output capacitor as small as 2.2 µF that enables a total solution size less than 1 mm in height.

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The MIC23158/9 has a very low quiescent current of 45 µA and achieves a peak efficiency of 94% in continuous conduction mode. In discontinuous conduction mode, the MIC23158/9 can achieve 83% efficiency at 1 mA.

The MIC23158/9 is available in a 20-pin 3 mm x 4 mm QFN package with an operating junction temperature range from –40°C to +125°C.

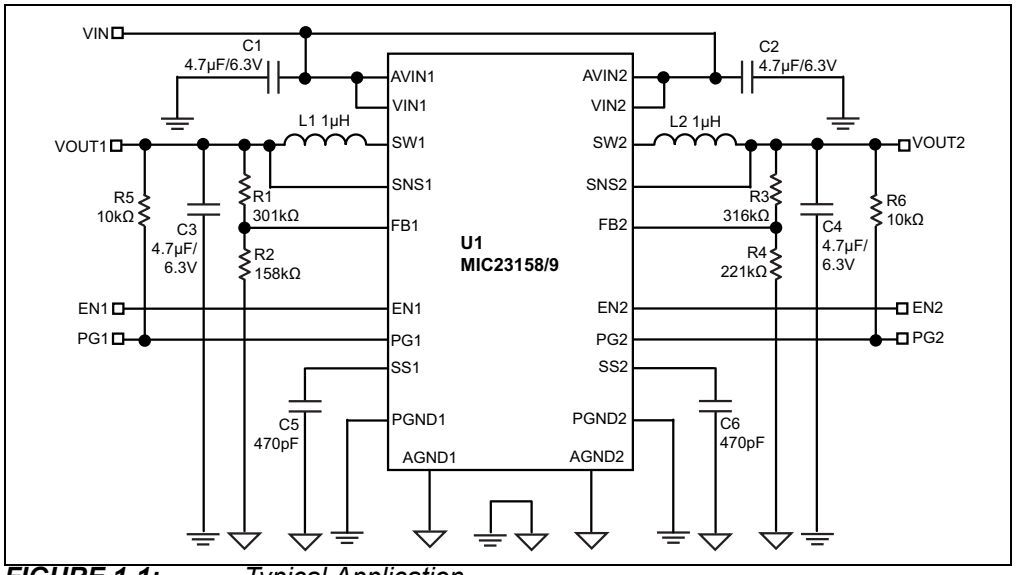

FIGURE 1-1: *Typical Application.*

1.3 WHAT IS THE MIC23158/9 EVALUATION BOARD?

The MIC23158/9 Evaluation Board has been developed to evaluate the capabilities of the MIC23158/9 family of devices. The board is populated with the MIC23159 device and it's set for the following voltages:

- Buck1: 1.8V.
- Buck2: 1.5V.

The evaluation board can be easily modified by interchanging the MIC23159 device with MIC23158.

The MIC23158/9 Evaluation Board features independent Enable connectors (EN1 and EN2) with individual pull-up resistors. To disable the regulators independently, a jumper must be placed on J1 (to disable regulator 1) or to J3 (to disable regulator 2).

To check the status of each regulator, power-good connectors are available for each regulator (J2 for regulator 1 and J4 for regulator 2).

The board can be powered from two independent voltage sources on VIN1 and VIN2, or a 0Ω resistor can be placed on R3 so that both converters be powered form the same voltage source.

1.4 MIC23158/9 EVALUATION BOARD KIT CONTENTS

The MIC23158/9 Evaluation Board kit includes:

- MIC23158/9 Synchronous Buck Regulator Evaluation Board (ADM00829)
- Information Sheet

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Chapter 2. Installation and Operation

2.1 INTRODUCTION

The MIC23158/9 Evaluation Board can be powered by:

- Two power supplies with at least 2A current capability each (15W total).
- One power supply with at least 4A current capability connected to both VIN1 and VIN2 or connected to either VIN1 or VIN2 when R3 is populated with a 0Ω resistor.

2.2 GETTING STARTED

To power up the MIC23158/9 Evaluation Board, the following steps must be completed:

1. Connect an external supply between VIN1 and GND1 terminals (for regulator 1) and between VIN2 and GND2 terminals (for regulator 2).
2. With the output of the power supply disabled, set its voltage to the desired input test voltage ($2.7V \le V_{IN} \le 5.5V$). An ammeter may be placed in series between the input supply and the VIN1 and VIN2 terminals. Be sure to monitor the supply voltage at the VIN1 and VIN2 terminal because the ammeter and/or power lead resistance can reduce the voltage supplied to the device.
3. Connect a load to the VOUT1 and GND1 and VOUT2 and GND2 terminals. The load can be either passive (resistive) or active (electronic load). An ammeter may be placed between the load and the output terminals. Ensure the output voltage is monitored at the VOUT1 and VOUT2 terminals.
4. The MIC23158/9 Evaluation Board has pull-up resistors to V_{IN}. By default, the output voltage will be enabled when an input supply of >2.7V is applied. To disable the device, apply a voltage below 0.4V to the EN terminals (J1 and/or J3).
5. Power good test points are provided to monitor the power good function (J2 and J4). The power good output will go high approximately 70 µs after the output voltage reaches 90% of its nominal voltage.

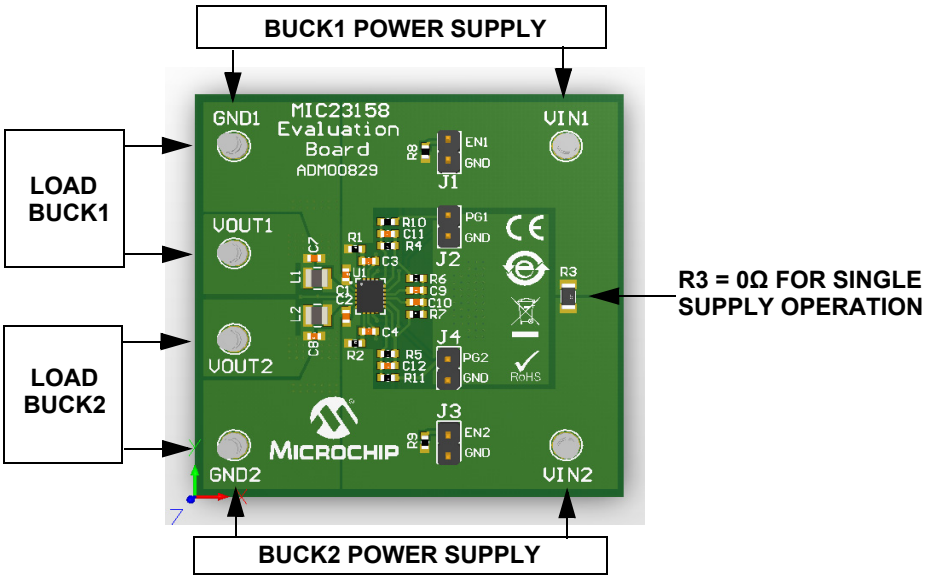

FIGURE 2-1: *MIC23158/9 Evaluation Board.*

2.3 EVALUATION BOARD DESCRIPTION

2.3.1 Soft-Start Capacitors (C9 and C10)

The MIC23159 has a nominal 296 kΩ resistor charging the capacitor on the SS pin. This enables the output to follow a controlled soft-start characteristic. Setting C9 and C10 to 470 pF sets the startup time to approximately 320 µs. The start-up time can be determined by Equation 2-1.

EQUATION 2-1:

$$T_{SS} = 296k\Omega \times \ln(10) \times C_{SS}$$

The action of the soft-start capacitor is to control the rise time of the internal reference voltage between 0% and 100% of its nominal steady state value.

2.3.2 Feedback Resistors (R4, R5, R6, and R7) for Adjustable Outputs

The output voltages are set nominally to 1.8V and 1.5V. These outputs can be changed by adjusting the upper resistor, R4 and R5, in the feedback potential divider. Therefore:

EQUATION 2-2:

$$R4 = R6 \times (V_O - V_{REF}) / V_{REF}$$

Where:

V_{REF} 0.62V

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EQUATION 2-3:

$$R5 = R7 \times (V_O - V_{REF}) / V_{REF}$$

Where:

V_{REF} 0.62V

Some example values are shown in Table 2-1:

TABLE 2-1: FEEDBACK RESISTOR VALUES FOR ADJUSTABLE OUTPUTS

V_{OUT}	R4 and R5	R6 and R7
1.2V	274 kΩ	294 kΩ
1.5V	316 kΩ	221 kΩ
1.8V	301 kΩ	158 kΩ
2.5V	324 kΩ	107 kΩ
3.3V	309 kΩ	71.5 kΩ

To prevent instability problems caused by the internal ripple injection, the recommended feedback resistor dividers should be used. The feed-forward capacitors (C11 and C12) are typically not fitted. The transient performance can be improved slightly by fitting a capacitor at C11 and C12 to inject fast output voltage deviations directly into the feedback comparator. This improved load regulation is at the expense of slightly increasing the amount of noise on the output at higher loads. Values between 100 pF and 1 nF are recommended to prevent instability.

2.3.3 Power Good

The evaluation board has a test point provided for monitoring the power good feature. This is an open drain connection with an on-board pull-up resistor of 10 kΩ to the output voltage. Power good is asserted high approximately 70 µs after the output voltage passes 90% of the nominal set voltage.

2.3.4 HyperLight Load Mode

MIC23158/9 uses a minimum on and off time proprietary control loop. When the output voltage falls below the regulation threshold, the error comparator begins a switching cycle that turns the PMOS on and keeps it on for the duration of the minimum-on-time. This increases the output voltage. If the output voltage is over the regulation threshold, then the error comparator turns the PMOS off for a minimum-off-time until the output drops below the threshold. The NMOS acts as an ideal rectifier that conducts when the PMOS is off. Using a NMOS switch instead of a diode allows for lower voltage drop across the switching device when it is on. The synchronous switching combination between the PMOS and the NMOS allows the control loop to work in discontinuous mode for light load operations. In discontinuous mode, the MIC23158 works in pulse frequency modulation (PFM) to regulate the output. As the output current increases, the off-time decreases, thus providing more energy to the output. This switching scheme improves the efficiency of MIC23158 during light load currents by only switching when it is needed.

As the load current increases, the MIC23158 goes into continuous conduction mode (CCM) and switches at a frequency centered at 3 MHz. The equation to calculate the load when the MIC23158 goes into continuous conduction mode may be approximated by Equation 2-4:

EQUATION 2-4:

$$I_{LOAD} > \left(\frac{(V_{IN} - V_{OUT}) \times D}{2L \times f}\right)$$

As shown in the equation above, the load at which MIC23158/9 transitions from Hyper-Light Load mode to PWM mode is a function of the input voltage (V_{IN}), output voltage (V_{OUT}), duty cycle (D), inductance (L), and frequency (f). The MIC23158 will switch at a relatively constant frequency around 3 MHz once the output current is over 180 mA.

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Appendix A. Schematics and Layout

A.1 INTRODUCTION

This appendix contains the following schematics and layout of the MIC23158/9 Buck Regulator Evaluation Board:

- Schematics - MIC23158/9 Evaluation Board
- Board – Top Silk
- Board – Top Copper and Silk
- Board – Top Copper
- Board – Bottom Copper
- Board - Bottom Copper and Silk
- Board - Bottom Silk

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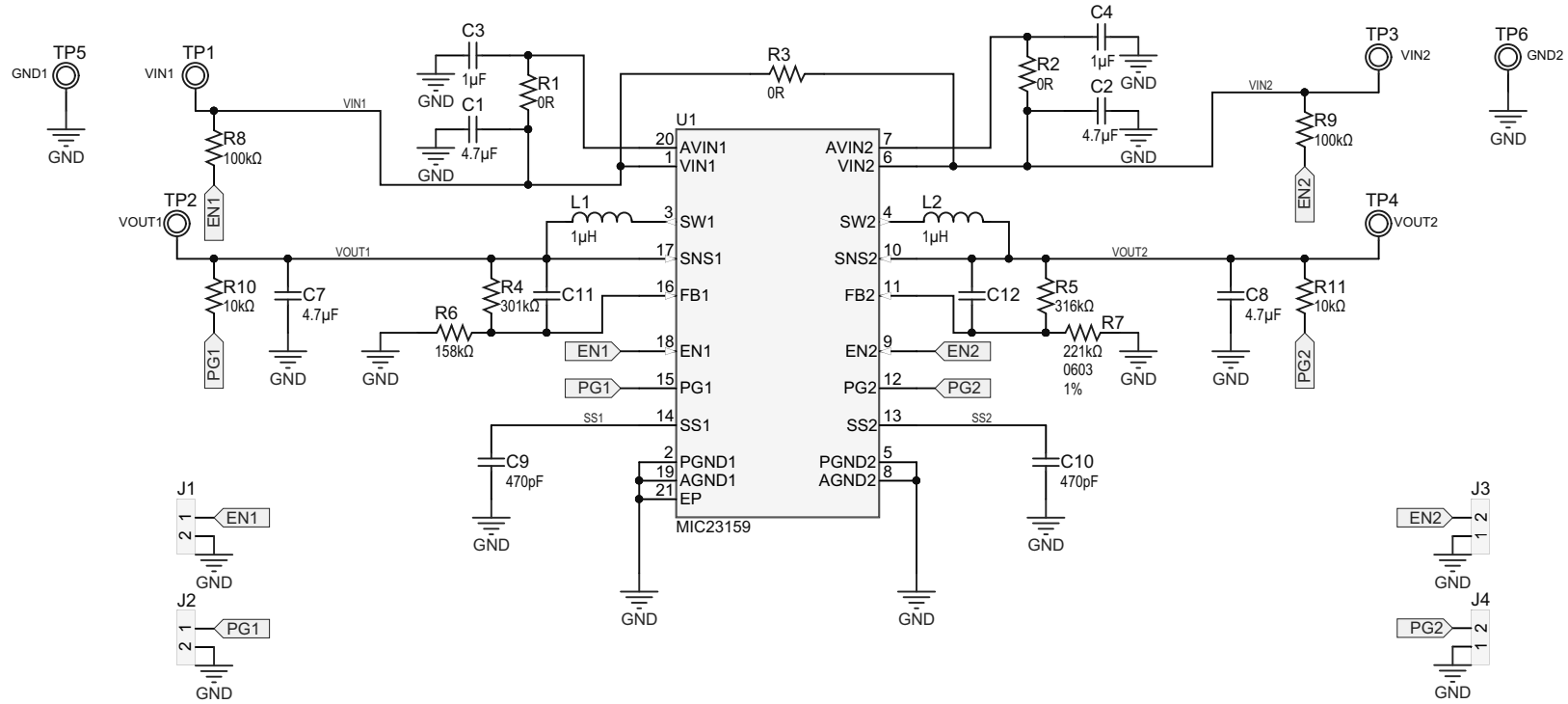
A.2 SCHEMATICS - MIC23158/9 EVALUATION BOARD



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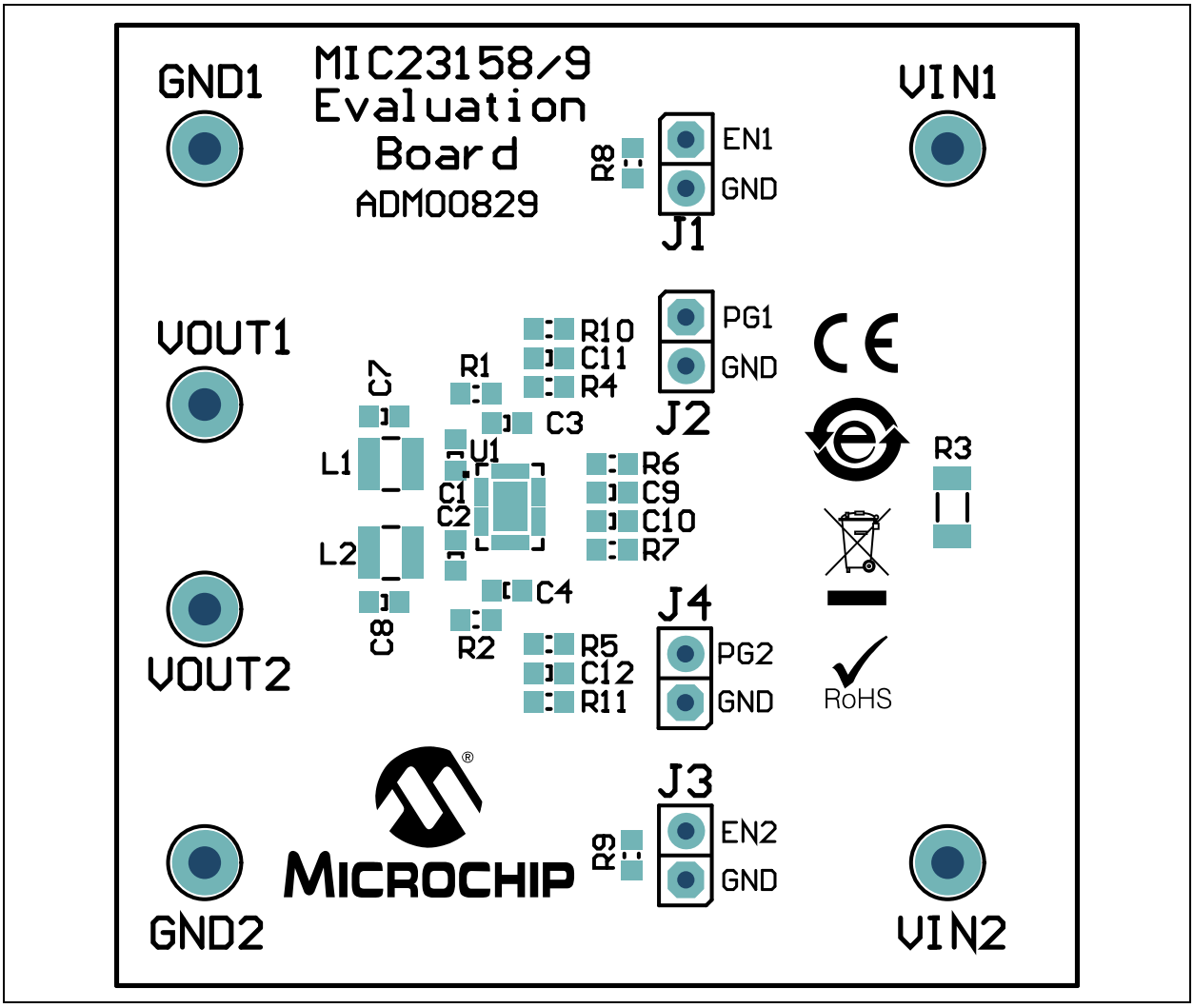
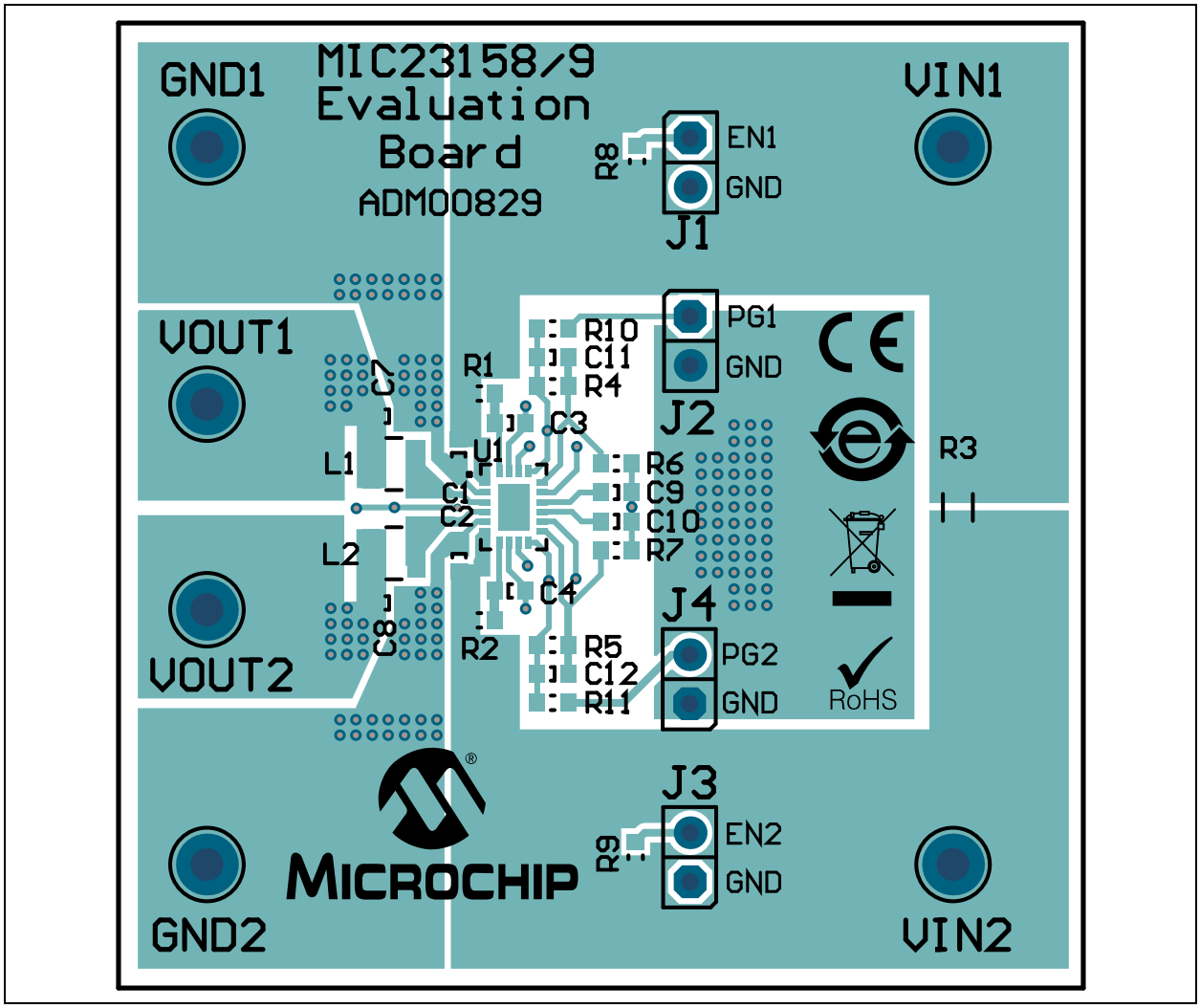
A.3 BOARD – TOP SILK



A.4 BOARD – TOP COPPER AND SILK



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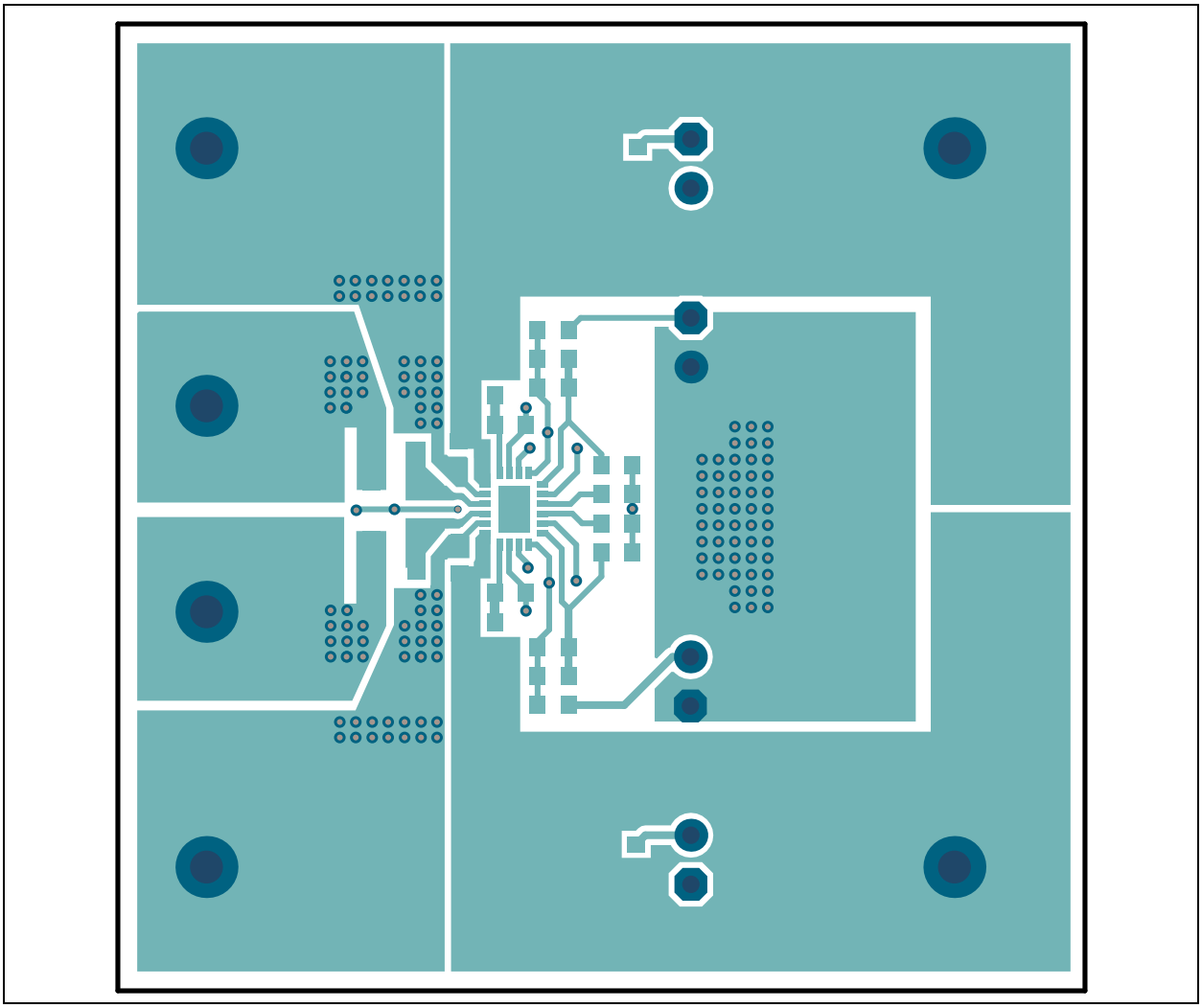
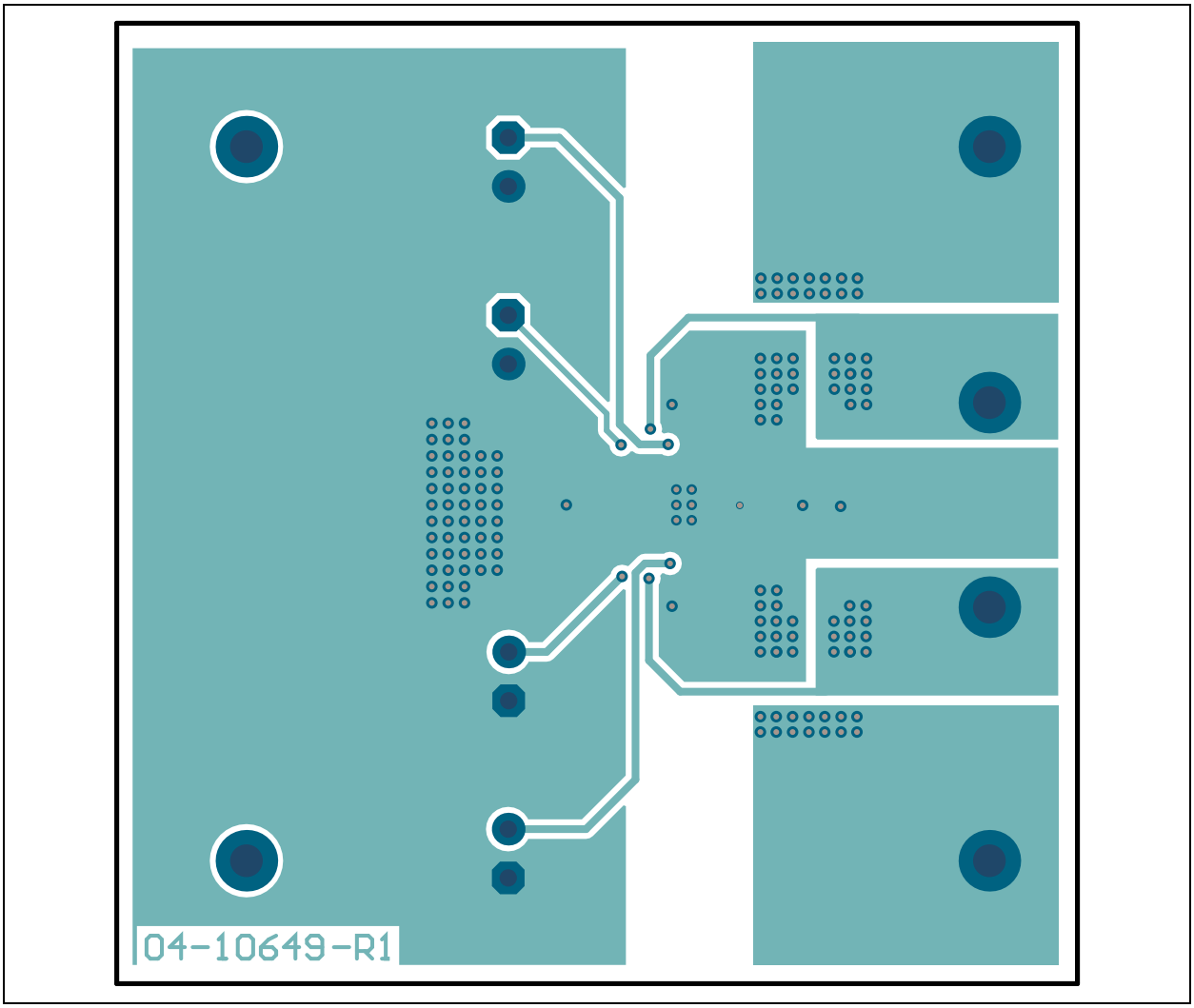
A.5 BOARD – TOP COPPER



A.6 BOARD – BOTTOM COPPER



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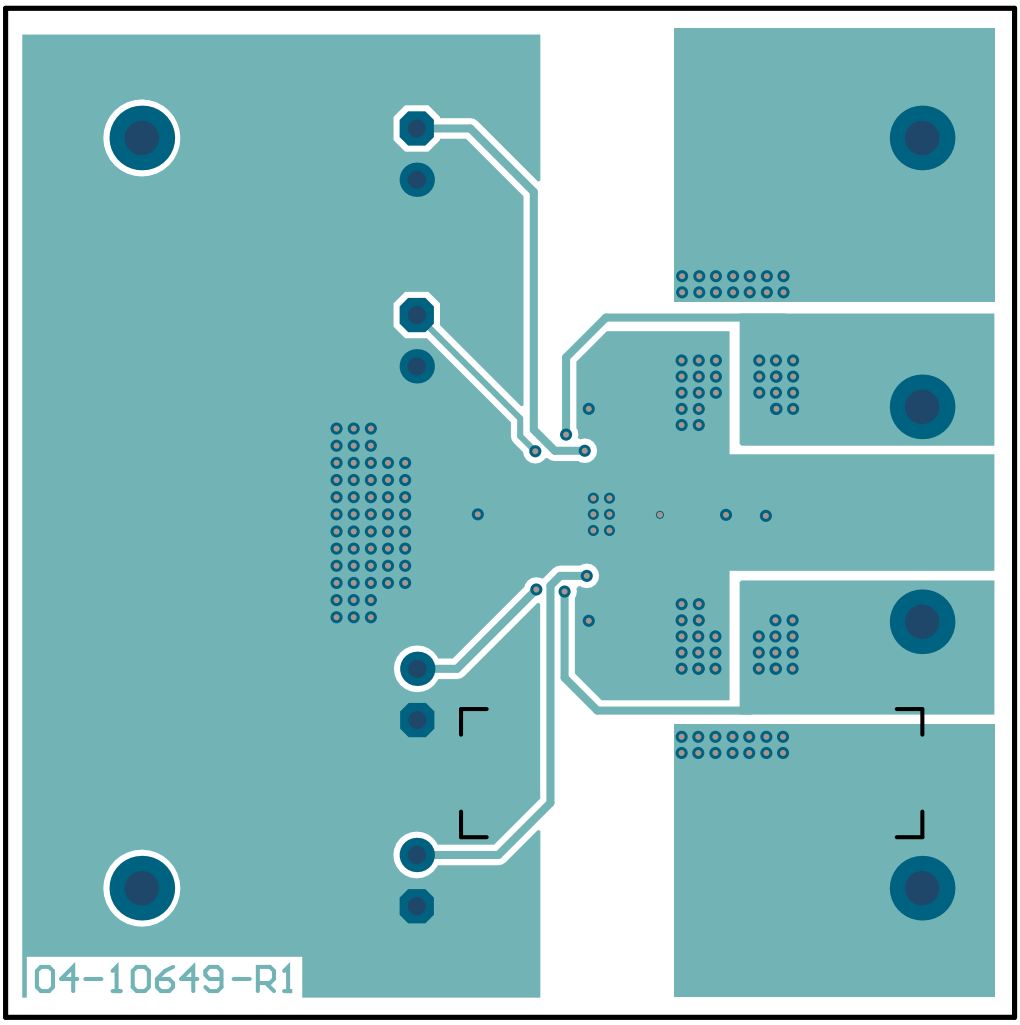
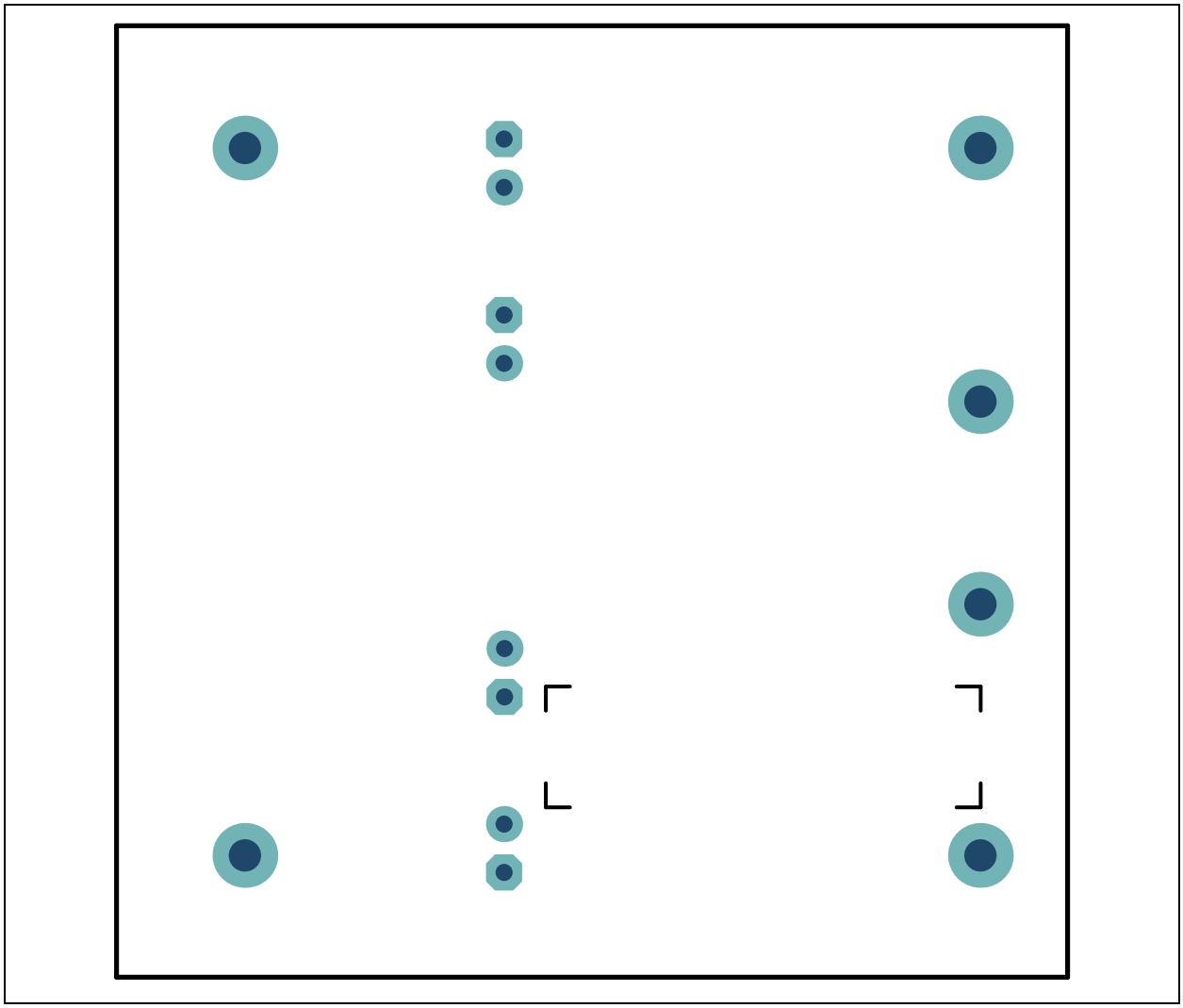
A.7 BOARD - BOTTOM COPPER AND SILK



A.8 BOARD - BOTTOM SILK



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Appendix B. Bill of Materials (BOM)

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

Qty.	Reference	Description	Manufacturer	Part Number
4	C1, C2, C7, C8	CAP CER 4.7 µF 16V 10% X5R SMD 0603	TDK Corporation	C1608X5R1C475K080AC
2	C3, C4	CAP CER 1 µF 16V 10% X5R SMD 0603	TDK Corporation	C1608X5R1C105K
2	C9, C10	CAP CER 470 pF 100V 5% C0G SMD 0603	TDK Corporation	CGA3E2C0G2A471J080AA
4	J1, J2, J3, J4	CON HDR-2.54 Male 1x2 Gold 5.84 MH TH VERT	FCI	77311-118-02LF
2	L1, L2	INDUCTOR 1 µH 2.3A 20% SMD 2520	TDK Corporation	MLP2520W1R0MT0S1
4	PAD1, PAD2, PAD3, PAD4	MECH HW RUBBER PAD Hemisphere D6.4 H1.9 CLEAR	3M	SJ5382
2	R1, R2	RES TKF 0R 1/10W SMD 0603	Panasonic	ERJ-3GSY0R00V
1	R4	RES TF 301 kΩ 0.5% 1/16W SMD 0603	Susumu	RR0816P-3013-D-47D
1	R5	RES TKF 316 kΩ 1% 1/10W SMD 0603	Panasonic	ERJ-3EKF3163V
1	R6	RES TKF 158 kΩ 1% 1/10W SMD 0603	Yageo	RC0603FR-07158KL
1	R7	RES TKF 221 kΩ 1% 1/10W SMD 0603	Panasonic	ERJ-3EKF2213V
2	R8, R9	RES TF 100 kΩ 1% 1/8W SMD 0603	Vishay	MCT06030C1003FP500
2	R10, R11	RES TF 10 kΩ 1% 1/8W SMD 0603	Vishay	MCT06030C1002FP500
6	TP1, TP2, TP3, TP4, TP5, TP6	CON TP PIN Tin TH	Harwin	H2121-01
1	U1	Dual 2A Buck Regulator MIC23159YML-TR VQFN-20	Microchip Technology Inc.	MIC23159YML-TR

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.

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