MIC28515 75V/5A HLL Step-Down Evaluation Board User's Guide

Note the following details of the code protection feature on Microchip devices:

- Microchip products meet the specifications contained in their particular Microchip Data Sheet.
- Microchip believes that its family of products is secure when used in the intended manner and under normal conditions.
- There are dishonest and possibly illegal methods being used in attempts to breach the code protection features of the Microchip devices. We believe that these methods require using the Microchip products in a manner outside the operating specifications contained in Microchip's Data Sheets. Attempts to breach these code protection features, most likely, cannot be accomplished without violating Microchip's intellectual property rights.
- Microchip is willing to work with any customer who is concerned about the integrity of its code.
- Neither Microchip nor any other semiconductor manufacturer can guarantee the security of its code. Code protection does not mean that we are guaranteeing the product is "unbreakable." Code protection is constantly evolving. We at Microchip are committed to continuously improving the code protection features of our products. Attempts to break Microchip's code protection feature may be a violation of the Digital Millennium Copyright Act. If such acts allow unauthorized access to your software or other copyrighted work, you may have a right to sue for relief under that Act.

For information regarding Microchip's Quality Management Systems, please visit www.microchip.com/quality.

Trademarks

ISBN: 978-1-5224-8464-6

MIC28515 75V/5A HLL STEP-DOWN EVALUATION BOARD USER'S GUIDE

Table of Contents

NOTES:

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 MIC28515 75V/5A HLL Step-Down 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 MIC28515 75V/5A HLL Step-Down Evaluation Board as a development tool to emulate and debug firmware on a target board. The manual layout is as follows:

- **Chapter 1. "Product Overview"** – Important information about the MIC28515 75V/5A HLL Step-Down Evaluation Board.
- **Chapter 2. "Installation and Operation"** – Includes instructions on installing and starting the MIC28515 75V/5A HLL Step-Down Evaluation Board.
- **Appendix A. "Schematic and Layouts"** – Shows the schematic and layout diagrams for the MIC28515 75V/5A HLL Step-Down Evaluation Board.
- **Appendix B. "Bill of Materials (BOM)"** – Lists the parts used to build the MIC28515 75V/5A HLL Step-Down 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 MIC28515 75V/5A HLL Step-Down Evaluation Board. Another useful document is listed below. The following Microchip document is available and recommended as a supplemental reference resource:

- **MIC28515 Data Sheet – *"75V/5A Hyper Speed Control® Synchronous DC/DC Buck Regulator with External Mode Control"* (DS20005762)**

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

Users of Microchip products can receive assistance through several channels:

- 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 website at:
http://www.microchip.com/support.

DOCUMENT REVISION HISTORY

Revision C (June 2021)

The following is the list of modifications:

- Updated Figure 2-1.
- Minor editorial corrections.

Revision B (May 2017)

The following is the list of modifications:

- Updated the Evaluation Board Circuit Description.
- Updated the Board – Mid Copper Layer 2.

Revision A (March 2017)

- Initial Release of this Document.

NOTES:

Chapter 1. Product Overview

1.1 INTRODUCTION

This chapter provides an overview of the MIC28515 75V/5A HLL Step-Down Evaluation Board and covers the following topics:

- MIC28515 75V/5A HLL Step-Down Evaluation Board Overview
- MIC28515 75V/5A HLL Step-Down Evaluation Board Features
- What the MIC28515 75V/5A HLL Step-Down Evaluation Board Kit Contains

1.2 MIC28515 75V/5A HLL STEP-DOWN EVALUATION BOARD OVERVIEW

The MIC28515 75V/5A HLL Step-Down Evaluation Board is a constant frequency, synchronous buck switcher solution featuring a unique adaptive on-time control architecture. The MIC28515 operates over an input supply range of 4.5V to 75V. The output voltage is adjustable down to 0.6V with an ensured accuracy of ±1%. The device operates with a programmable switching frequency from 270 kHz to 800 kHz. The Mode pin allows the user to select either the Forced Continuous Conduction Mode (CCM) or Hyper Light Load (HLL) mode of operation for improved efficiency at light loads.

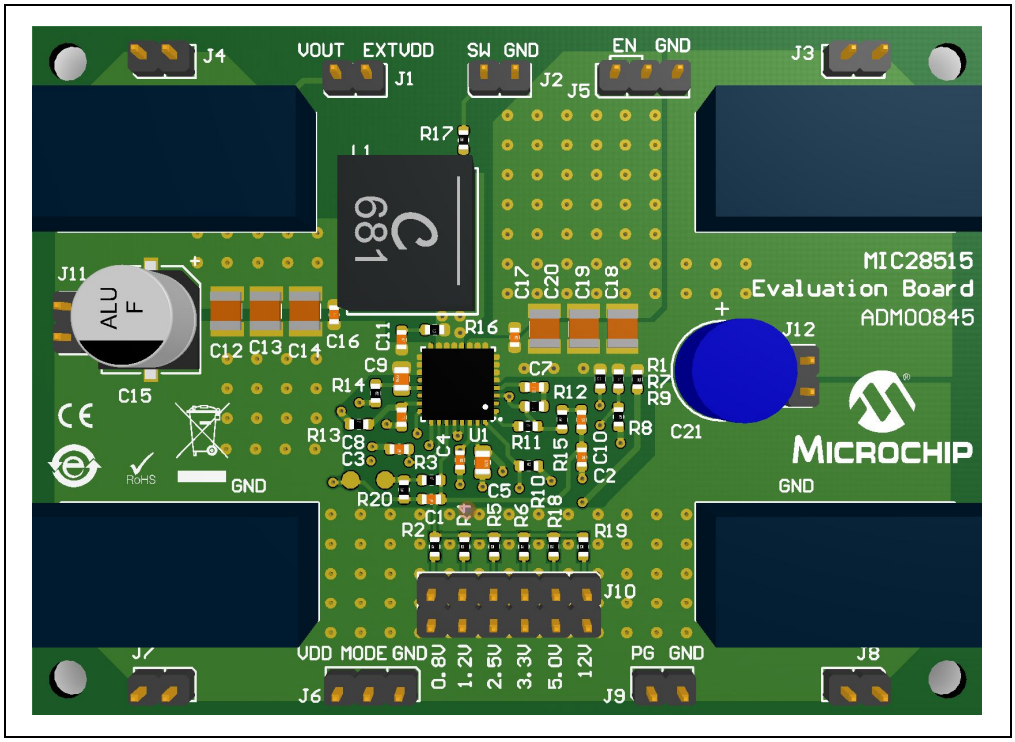


FIGURE 1-1: *MIC28515 75V/5A HLL Step-Down Evaluation Board.*

1.3 MIC28515 75V/5A HLL STEP-DOWN EVALUATION BOARD FEATURES

The MIC28515 75V/5A HLL Step-Down Evaluation Board:

- Features MODE selection through jumper J6, which allows the user to select either the CCM or HLL mode of operation.
- Features six selectable output voltages: 0.8V, 1.2V, 2.5V, 3.3V, 5V and 12V.
- Features an auxiliary Low Dropout Regulator (LDO), which improves the system efficiency by supplying the internal bias power from the output of the converter.
- Features a logic level Enable (EN) signal that can be used to enable or disable the controller.
- Can start up monotonically into a pre-biased output.
- Features an open-drain Power Good signal (PG), which signals when the output is in regulation.

The basic parameters of the evaluation board are:

- Input: 10V to 75V (optimized for 48V)
- Output: 0.8V, 1.2V, 2.5V, 3.3V, 5V or 12V Selectable through jumper J10 at 5A (default option is set to 5V)
- 300 kHz Switching Frequency (adjustable from 270 kHz to 800 kHz)

1.4 WHAT THE MIC28515 75V/5A HLL STEP-DOWN EVALUATION BOARD KIT CONTAINS

The MIC28515 75V/5A HLL Step-Down Evaluation Board includes the following items:

- MIC28515 75V/5A HLL Step-Down Evaluation Board (ADM00845)
- Important Information Sheet

Chapter 2. Installation and Operation

2.1 SYSTEM AND CONFIGURATION REQUIREMENTS

The MIC28515 75V/5A HLL Step-Down Evaluation Board requires only a single power supply with at least 5A current capability. The MIC28515 has an internal PV_{DD} LDO so no external linear regulator is required to power the internal biasing of the IC. In applications with V_{IN} < +5.5V, PV_{DD} should be tied to V_{IN} to bypass the internal linear regulator. The output load can either be a passive or an active load.

Note: The MIC28515 75V/5A HLL Step-Down Evaluation Board does not have reverse polarity protection. Applying a negative voltage to the V_{IN} and GND terminals may damage the device. The maximum V_{IN} of the board is rated at 75V. Exceeding 75V on the V_{IN} could damage the device.

2.2 BOARD SETUP

Follow these steps prior to using the MIC28515 75V/5A HLL Step-Down Evaluation Board:

1. Connect a supply to the V_{IN} and GND terminals, paying attention to the polarity and the supply range (10V < V_{IN} < 75V). Monitor I_{IN} with a current meter, and the input voltage at the V_{IN} and GND terminals with a voltmeter. Do not apply power until Step 4.
2. Connect a load to the V_{OUT} and GND terminals. The load can be either a passive (resistive) or an active (electronic) type. A current meter may be placed between the V_{OUT} terminal and load to monitor the output current. Ensure the output voltage is monitored at the V_{OUT} terminal.
3. Enable input. An EN connector is provided on the evaluation board for users to easily access the enable feature. Applying an external logic signal on the EN pin to pull it low, or using a jumper to short the EN pin to GND, will shut off the output of the MIC28515 75V/5A HLL Step-Down Evaluation Board.
4. Turn on the V_{IN} supply and verify that the output voltage is regulated to the specific selected voltage.

2.3 CIRCUIT DESCRIPTION

This section describes the working principles and limitations that should be taken into account when using the MIC28515 75V/5A HLL Step-Down Evaluation Board. The external components have been selected in order to optimize performance for the specific conditions of V_{IN} = 48V and V_{OUT} = 5V. Although the application will behave correctly for other output and input voltages, further optimization (fine-tuning of the inductor, output capacitors and ripple injection components) can be done in order to improve efficiency and transient response.

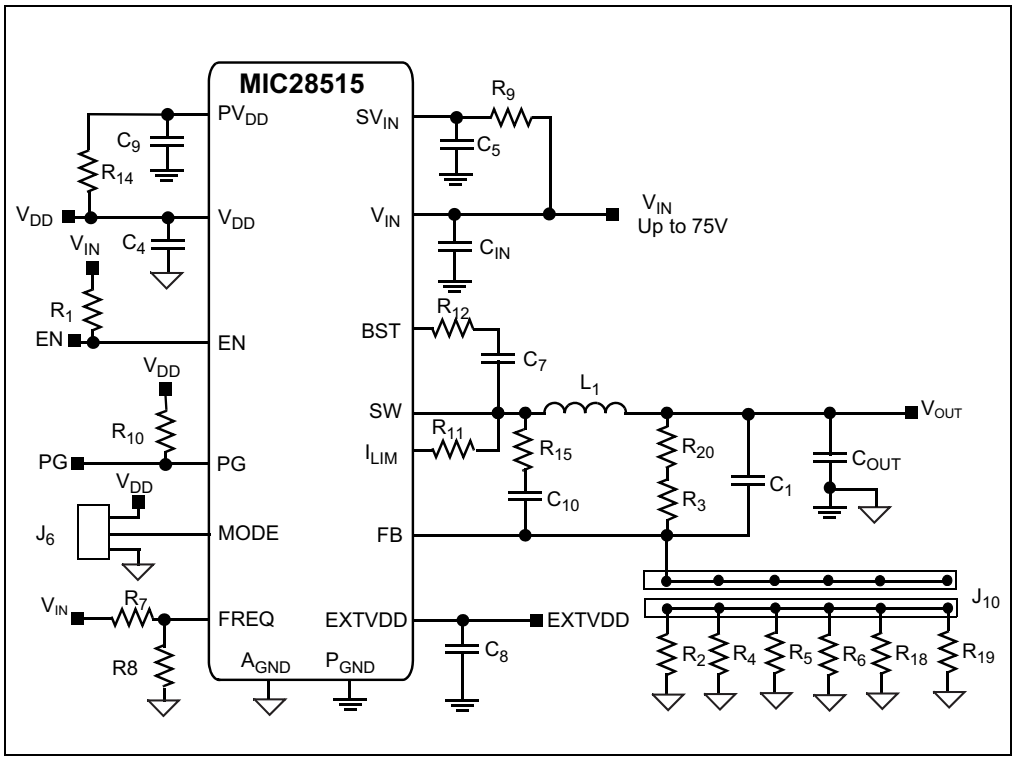


FIGURE 2-1: *Evaluation Board Circuit Description.*

2.3.1 Feedback Resistors

The output voltages available on the MIC28515 75V/5A HLL Step-Down Evaluation Board are: 0.8V, 1.2V, 2.5V, 3.3V, 5V and 12V, which are selectable using jumper J10.

Voltages other than the ones already available can be set by modifying the R_{bot} resistors according to Equation 2-1.

EQUATION 2-1:

$$R_{bot} = \frac{R_3 \times V_{REF}}{V_{OUT} - V_{REF}}$$

Where:

V_{REF} = 0.6V

R_3 = 10 kΩ

Note: The output voltage should not be set to exceed 15V due to the 16V voltage rating on the output capacitors. For output voltage higher than 15V, output capacitors of a voltage rating higher than the set output voltage should be used.

2.3.2 SW Node

Test point J2 (V_{SW}) is placed for monitoring the switching waveform, one of the most critical waveforms for the converter.

2.3.3 Current Limit

The MIC28515 75V/5A HLL Step-Down Evaluation Board uses the low-side MOSFET $R_{DS(ON)}$ to sense inductor current. In each switching cycle of the MIC28515 converter, the inductor current is sensed by monitoring the voltage across the low-side MOSFET, during the off period of the switching cycle, with the low-side MOSFET on. An internal current source of 135 µA generates a voltage across the external Current-Limit Resistor, R_{CL}.

The I_{LIM} Pin Voltage (V_{ILIM}) is the difference of the voltage across the low-side MOSFET and the voltage across the resistor (V_{CL}). The sensed voltage, V_{ILIM}, is compared with the Power Ground (PGND) after a blanking time of 150 ns.

If the absolute value of the voltage drop across the low-side MOSFET is greater than the absolute value of the voltage across the current setting resistor (V_{CL}), the MIC28515 triggers the current-limit event. Consecutive eight current-limit events trigger the Hiccup mode. The hiccup sequence, including the Soft Start, reduces the stress on the internal MOSFETs, and protects the load and supply from severe short conditions.

The short-circuit current limit can be programmed by using the formula shown in Equation 2-2.

EQUATION 2-2:

$$R_{I1} = \frac{(I_{CLIM} + \Delta IL_{PP} \times 0.5) \times R_{DS(ON)}}{I_{CL}}$$

Where:

I_{CLIM} = Desired output current limit

ΔIL_{PP} = Inductor current peak-to-peak (usually 30% of the output current)

$R_{DS(ON)}$ = On resistance of low-side power MOSFET(25 mΩ)

I_{CL} = Current-limit source current, the typical value is 135 µA

It is mandatory to make sure that the inductor current used to charge the output capacitance during Soft Start is under the current limit; otherwise, the supply will go into Hiccup mode and may not finish the Soft Start successfully.

The MOSFET $R_{DS(ON)}$ can vary up to 30%-40% with temperature. Therefore, it is recommended to add a 30% margin to the I_{CLIM} in the above equation to avoid false current limiting due to an increased MOSFET junction temperature rise.

2.3.4 Loop Gain Measurement

Resistor R20 is placed in series with the regulator feedback path. The control loop gain can be measured by connecting an impedance analyzer across the resistor and selecting the resistor value between 10Ω to 50Ω.

2.3.5 Setting the Switching Frequency

The MIC28515 75V/5A HLL Step-Down Evaluation Board is an adjustable frequency, synchronous buck converter featuring a unique adaptive on-time control architecture. The switching frequency can be adjusted between 270 kHz and 800 kHz by changing the resistor divider network consisting of R_7 and R_8.

Equation 2-3 shows the estimated switching frequency:

EQUATION 2-3:

$$f_{SW} = f_0 \times \frac{R_8}{R_7 + R_8}$$

Where:

f_0 = Switching Frequency when FREQ pin is connected to the input voltage, f_0 is typically 800 kHz

The evaluation board design is optimized for a switching frequency of 300 kHz. If the switching frequency is programmed to either the lower end or the higher end, the design needs optimization.

2.3.6 MODE selection pin

In Continuous Conduction Mode (CCM), the inductor current can go negative at light loads. However, at light loads the MIC28515 is able to force the inductor current to operate in discontinuous mode when MODE is set to HLL mode. In HLL mode, the efficiency is optimized by shutting down all the nonessential circuits and minimizing the supply current. Jumper J6 can be used to select between the two modes of operation (MODE = V_{DD} for CCM or MODE = GND for HLL).

2.3.7 Auxiliary Bootstrap LDO (EXTVDD)

The MIC28515 75V/5A HLL Step-Down Evaluation Board features an auxiliary bootstrap LDO which improves the system efficiency by supplying the MIC28515 internal circuit bias power from the converter output voltage. This LDO is enabled when the voltage on the EXTVDD pin is above 4.6V (typical), and at the same time, the main LDO, which operates from V_{IN}, is disabled to reduce power consumption. If the regulator output voltage is ≥5V and ≤12V, use the output voltage to power the MIC28515, which will increase system efficiency. The J1 jumper can be shorted to use the output voltage as EXTVDD.

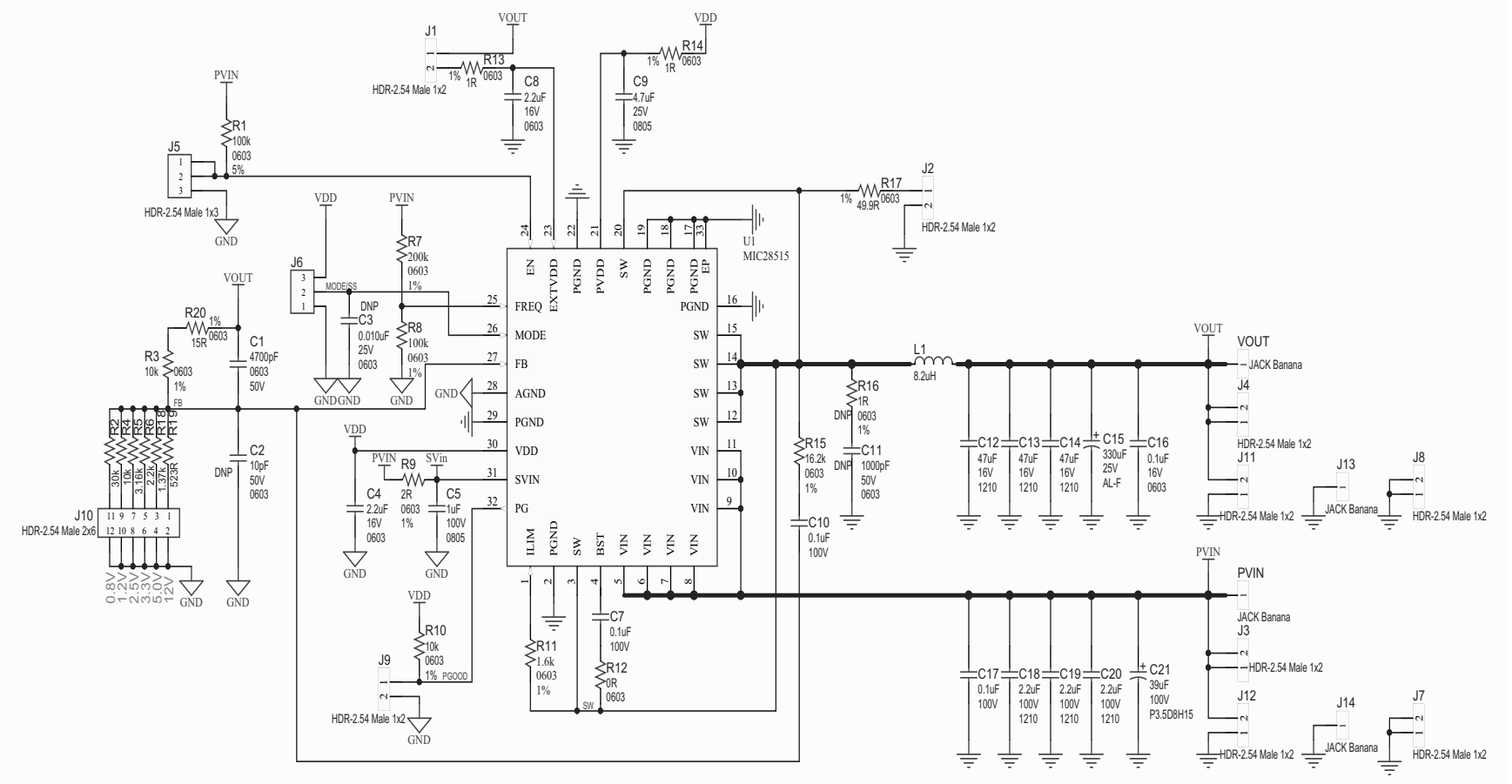
Appendix A. Schematic and Layouts

A.1 INTRODUCTION

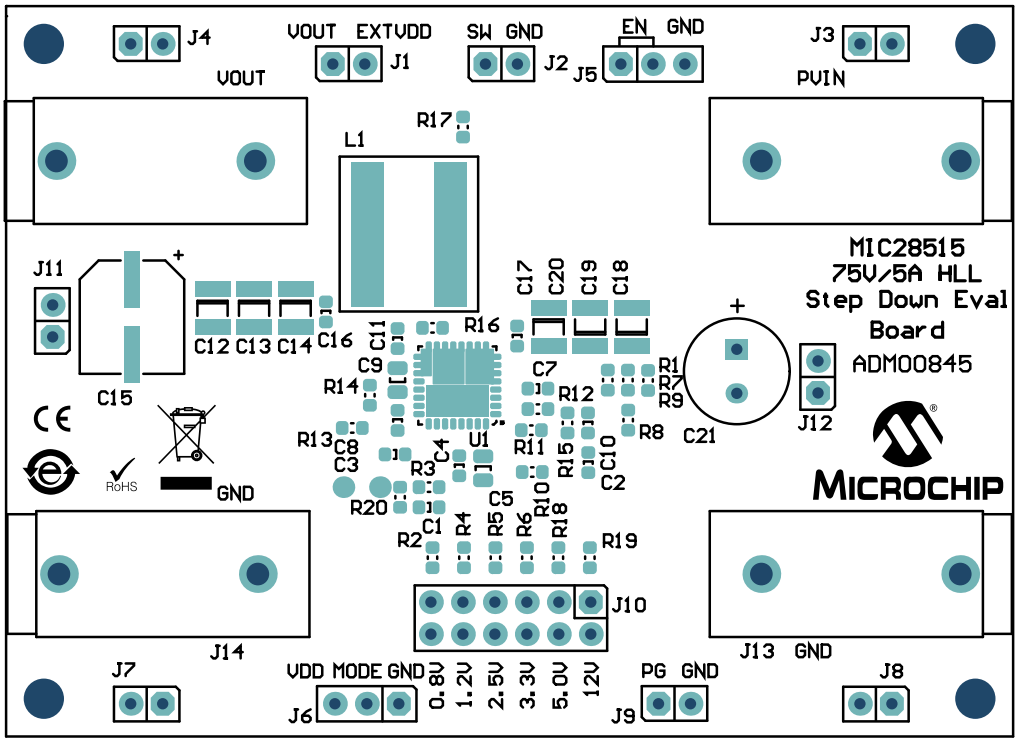
This appendix contains the following schematics and layouts for the MIC28515 75V/5A HLL Step-Down Evaluation Board:

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

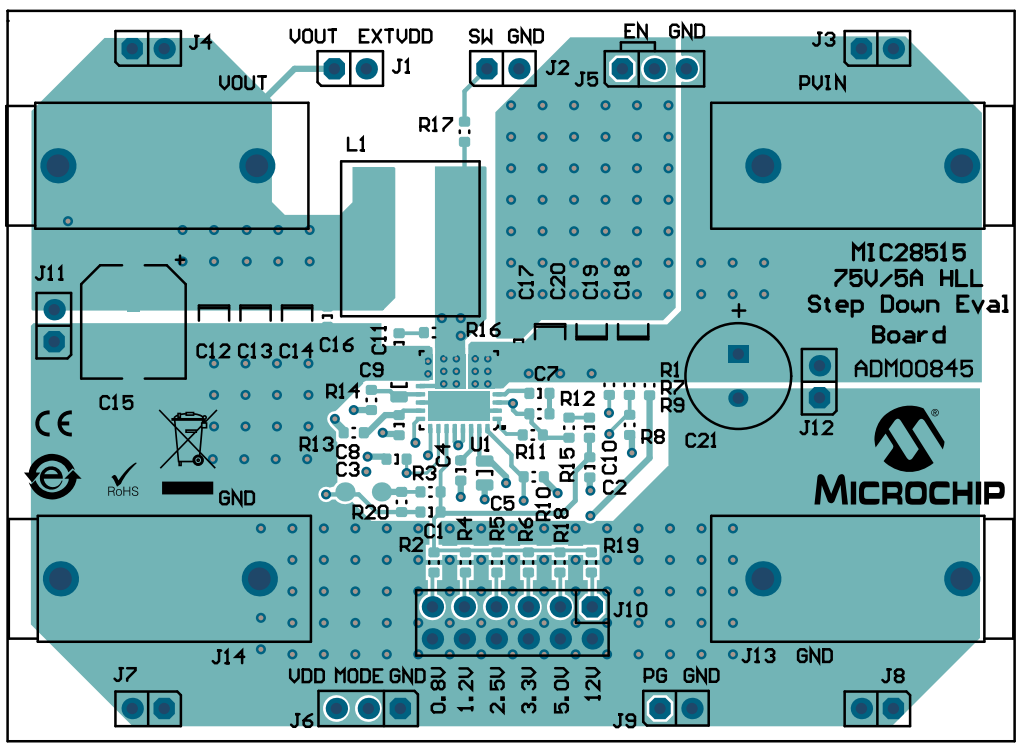
A.2 BOARD – SCHEMATIC



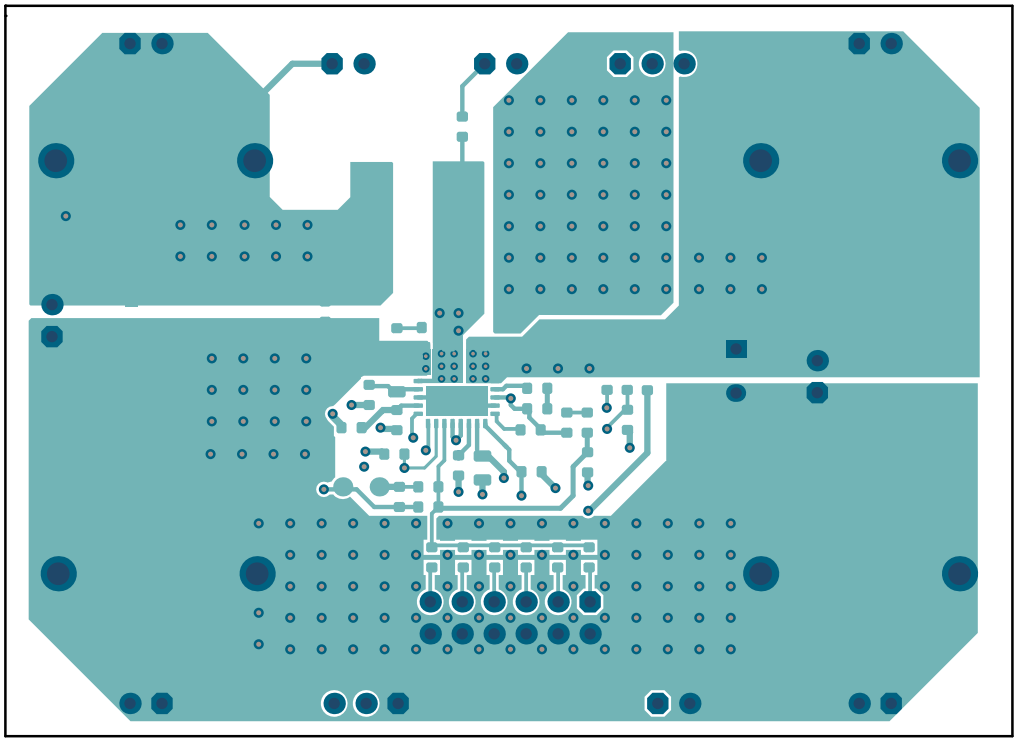
A.3 BOARD – TOP SILK



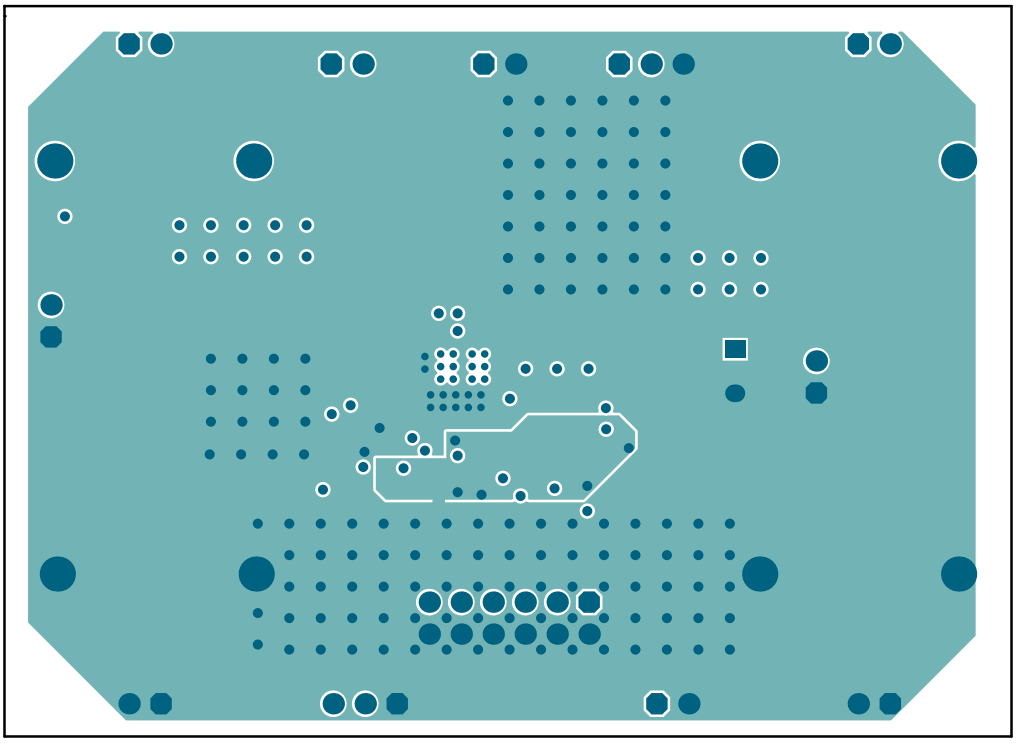
A.4 BOARD – TOP COPPER AND SILK



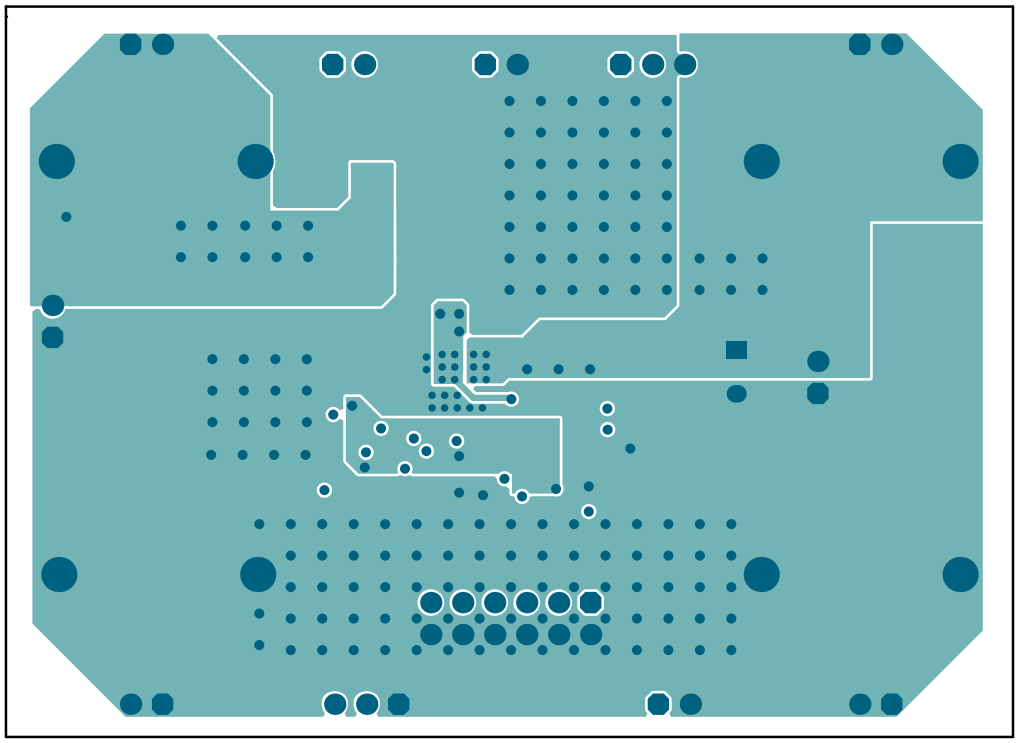
A.5 BOARD – TOP COPPER



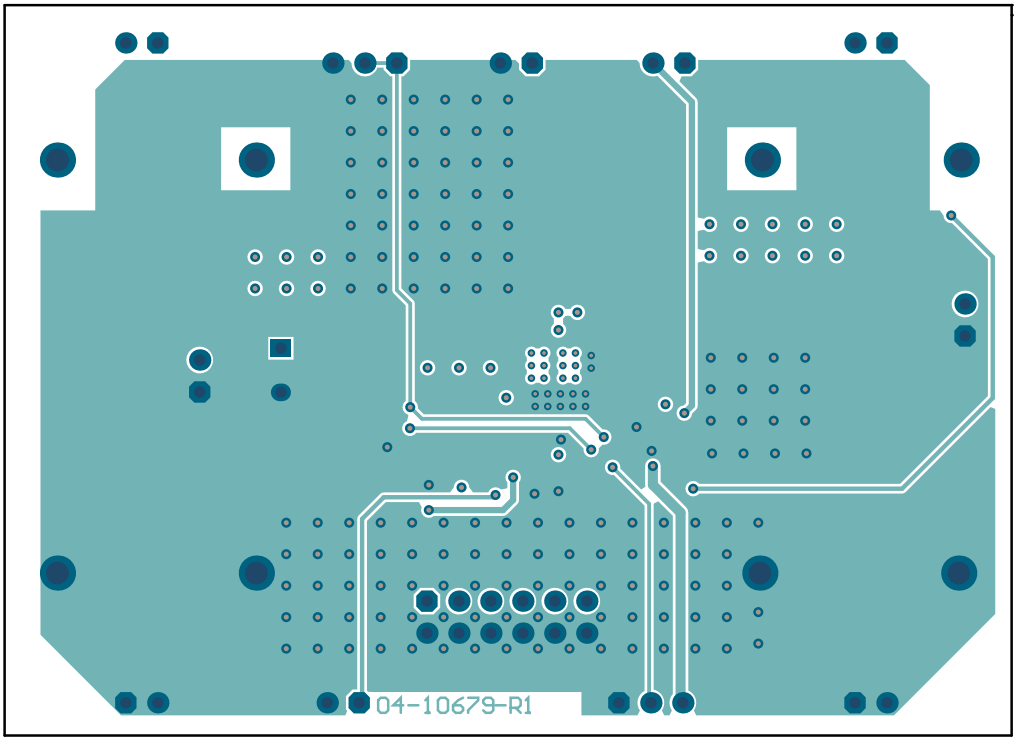
A.6 BOARD – MID COPPER LAYER 1



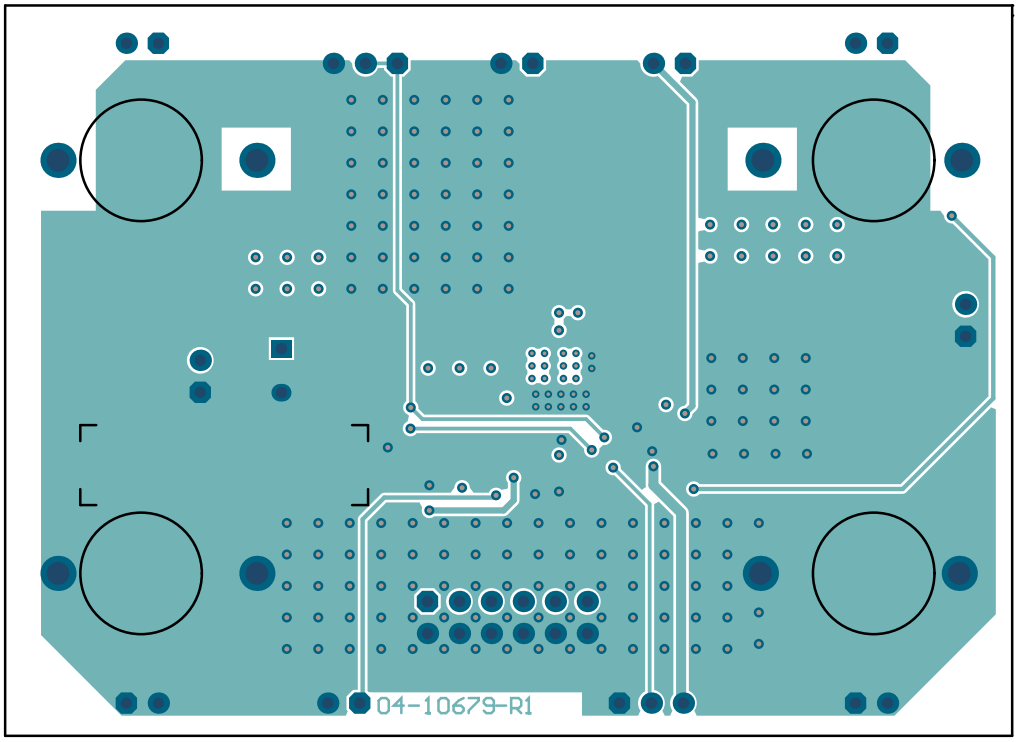
A.7 BOARD – MID COPPER LAYER 2



A.8 BOARD – BOTTOM COPPER



A.9 BOARD – BOTTOM COPPER AND SILK



Appendix B. Bill of Materials (BOM)

TABLE B-1: MIC28515 EVALUATION BOARD – BILL OF MATERIALS (BOM)

Qty.	Reference	Description	Manufacturer	Part Number
1	C1	Capacitor, ceramic, 4700 pF, 50V, 10%, X7R, SMD, 0603	KEMET	C0603C472K5RACTU
2	C4, C8	Capacitor, ceramic, 2.2 µF, 16V, 10%, X5R, SMD, 0603	TDK Corporation	C1608X5R1C225K
1	C5	Capacitor, ceramic, 1 µF, 100V, 10%, X7S, SMD, 0805	TDK Corporation	C2012X7S2A105K125AB
3	C7, C10, C17	Capacitor, ceramic, 0.1 µF, 100V, 10%, X7R, SMD, 0603	Murata Electronics North America, Inc.	GRM188R72A104KA35D
1	C9	Capacitor, ceramic, 4.7 µF, 25V, 20%, Y5V, SMD, 0805	TDK Corporation	C2012Y5V1E475Z
3	C12, C13, C14	Capacitor, ceramic, 47 µF, 16V, 20%, X5R, SMD, 1210	Yageo Corporation	CC1210MKX5R7BB476
1	C15	Capacitor, aluminum. 330 µF, 25V, 20%, SMD, F	Nichicon Corporation	UWT1E331MNL1GS
1	C16	Capacitor, ceramic, 0.1 µF, 16V, 10%, X7R, SMD, 0603	AVX Corporation	0603YC104KAT2A
3	C18, C19, C20	Capacitor, ceramic, 2.2 µF, 100V, 10%, X7R, SMD, 1210	KEMET	C1210C225K1RACTU
1	C21	Capacitor, aluminum, 39 µF, 100V, 20%, RAD, P3.5D8H15	United Chemi-Con	EKZE101ELL390MH15D
9	J1, J2, J3, J4, J7, J8, J9, J11, J12	Connector, header-2.54 male, 1x2, gold, 5.84MH, TH, vertical	FCI	77311-118-02LF
2	J5, J6	Connector, header-2.54 male, 1x3, gold, 5.84MH, TH, vertical	FCI	68000-103HLF
1	J10	Connector, header-2.54 male, 2x6, gold, 5.84MH, TH, vertical	Samtec, Inc.	TSW-106-07-G-D
2	J13, J14	Connector, jack, banana, blue, female, 4.0 mm, TH, R/A	Multicomp Inc.	24.243.5
1	L1	Inductor, 8.2 µH, 17.1A, 20%, SMD, L11.3W10H10	Coilcraft	XAL1010-822MEB
1	PCB1	ADM00845 Printed Circuit Board	Microchip Technology Inc.	**04-10679-R1**
2	PV_{IN}, V_{OUT}	Connector, jack, banana, red, female, 4.0 mm, TH, R/A	Multicomp Inc.	24.243.1
1	R1	Resistor, TKF, 100 kΩ, 5%, 1/10W, SMD, 0603 (Don't Use, Duplicate, Use RSMT0026)	Panasonic® - ECG	ERJ-3GEYJ104V
1	R2	Resistor, TKF, 30 kΩ, 1%, 1/10W, SMD, 0603	Stackpole Electronics, Inc.	RMCF0603FT30K0

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-1: MIC28515 EVALUATION BOARD – BILL OF MATERIALS (BOM) (CONTINUED)

Qty.	Reference	Description	Manufacturer	Part Number
3	R3, R4, R10	Resistor, TF, 10 kΩ, 1%, 1/8W, SMD, 0603	Vishay Beyschlag	MCT06030C1002FP500
1	R5	Resistor, TKF, 3.16 kΩ, 1%, 1/10W, SMD, 0603	Panasoni - ECG	ERJ-3EKF3161V
1	R6	Resistor, TKF, 2.2 kΩ, 1%, 1/10W, SMD, 0603	Panasonic - ECG	ERJ-3EKF2201V
1	R7	Resistor, TKF, 200 kΩ, 1%, 1/10W, SMD, 0603	Vishay Intertechnology, Inc.	CRCW0603200KFKEA
1	R8	Resistor, TF, 100 kΩ, 1%, 1/8W, SMD, 0603	Vishay Intertechnology, Inc.	MCT06030C1003FP500
1	R9	Resistor, TKF, 2R, 1%, 1/4W, SMD, 0603	Vishay/Dale	CRCW06032R00FKEAHP
1	R11	Resistor, SMD, 1.6 kΩ, 1%, 1/10W, 0603	Vishay/Dale	CRCW06031K60FKEA
1	R12	Resistor, TKF, 0R, 1/10W, SMD, 0603	Panasonic - ECG	ERJ-3GSY0R00V
2	R13, R14	Resistor, TKF, 1R, 1%, 1/10W, SMD, 0603	Yageo Corporation	RC0603FR-071RL
1	R15	Resistor, TKF, 16.2 kΩ, 1%, 1/10W, SMD, 0603	Panasonic - ECG	ERJ-3EKF1622V
1	R17	Resistor, TKF, 49.9R, 1%, 1/10W, SMD, 0603	Panasonic - ECG	ERJ-3EKF49R9V
1	R18	Resistor, TKF, 1.37 kΩ, 1%, 1/10W, SMD, 0603	Yageo Corporation	RC0603FR-071K37L
1	R19	Resistor, TKF, 523R, 1%, 1/10W, SMD, 0603	Yageo Corporation	ERJ3EKF5230V
1	R20	Resistor, TKF, 15R, 1%, 1/16W, SMD, 0603	Stackpole Electronics, Inc.	RMCF0603FT15R0
1	U1	MCHP Analog Switcher, Buck, MIC28515T-E/PHA VQFN-32	Microchip Technology Inc.	**MIC28515T-E/PHA**

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) - DO NOT POPULATE PARTS

Qty.	Reference	Description	Manufacturer	Part Number
1	C2	Capacitor, ceramic, 10 pF, 50V, 0.5 pF, C0G, SMD, 0603	TDK Corporation	C1608C0G1H100D
1	C3	Capacitor, ceramic, 0.010 µF, 25V, 10%, X7R, SMD, 0603	Yageo Corporation	CC0603KRX7R8BB103
1	C11	Capacitor, ceramic, 1000 pF, 50V, 20%, X7R, SMD, 0603	KEMET	C0603C102M5RAC
1	R16	Resistor, TKF, 1R, 1%, 1/10W, SMD, 0603	Yageo Corporation	RC0603FR-071RL

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) - MECHANICAL PARTS

Qty.	Reference	Description	Manufacturer	Part Number
2	JP1, JP2	Mechanical hardware jumper, 2.54 mm, 1x2, handle gold	TE Connectivity, Ltd.	881545-2
4	PAD1, PAD2, PAD3, PAD4	Mechanical hardware, rubber pad, cylindrical, D9.53H5.97	3M	SJ61A2

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.

Worldwide Sales and Service

AMERICAS

Corporate Office
2355 West Chandler Blvd.
Chandler, AZ 85224-6199
Tel: 480-792-7200
Fax: 480-792-7277
Technical Support:
http://www.microchip.com/support
Web Address:
www.microchip.com

Atlanta
Duluth, GA
Tel: 678-957-9614
Fax: 678-957-1455

Austin, TX
Tel: 512-257-3370

Boston
Westborough, MA
Tel: 774-760-0087
Fax: 774-760-0088

Chicago
Itasca, IL
Tel: 630-285-0071
Fax: 630-285-0075

Dallas
Addison, TX
Tel: 972-818-7423
Fax: 972-818-2924

Detroit
Novi, MI
Tel: 248-848-4000

Houston, TX
Tel: 281-894-5983

Indianapolis
Noblesville, IN
Tel: 317-773-8323
Fax: 317-773-5453
Tel: 317-536-2380

Los Angeles
Mission Viejo, CA
Tel: 949-462-9523
Fax: 949-462-9608
Tel: 951-273-7800

Raleigh, NC
Tel: 919-844-7510

New York, NY
Tel: 631-435-6000

San Jose, CA
Tel: 408-735-9110
Tel: 408-436-4270

Canada - Toronto
Tel: 905-695-1980
Fax: 905-695-2078

ASIA/PACIFIC

Australia - Sydney
Tel: 61-2-9868-6733

China - Beijing
Tel: 86-10-8569-7000

China - Chengdu
Tel: 86-28-8665-5511

China - Chongqing
Tel: 86-23-8980-9588

China - Dongguan
Tel: 86-769-8702-9880

China - Guangzhou
Tel: 86-20-8755-8029

China - Hangzhou
Tel: 86-571-8792-8115

China - Hong Kong SAR
Tel: 852-2943-5100

China - Nanjing
Tel: 86-25-8473-2460

China - Qingdao
Tel: 86-532-8502-7355

China - Shanghai
Tel: 86-21-3326-8000

China - Shenyang
Tel: 86-24-2334-2829

China - Shenzhen
Tel: 86-755-8864-2200

China - Suzhou
Tel: 86-186-6233-1526

China - Wuhan
Tel: 86-27-5980-5300

China - Xian
Tel: 86-29-8833-7252

China - Xiamen
Tel: 86-592-2388138

China - Zhuhai
Tel: 86-756-3210040

ASIA/PACIFIC

India - Bangalore
Tel: 91-80-3090-4444

India - New Delhi
Tel: 91-11-4160-8631

India - Pune
Tel: 91-20-4121-0141

Japan - Osaka
Tel: 81-6-6152-7160

Japan - Tokyo
Tel: 81-3-6880- 3770

Korea - Daegu
Tel: 82-53-744-4301

Korea - Seoul
Tel: 82-2-554-7200

Malaysia - Kuala Lumpur
Tel: 60-3-7651-7906

Malaysia - Penang
Tel: 60-4-227-8870

Philippines - Manila
Tel: 63-2-634-9065

Singapore
Tel: 65-6334-8870

Taiwan - Hsin Chu
Tel: 886-3-577-8366

Taiwan - Kaohsiung
Tel: 886-7-213-7830

Taiwan - Taipei
Tel: 886-2-2508-8600

Thailand - Bangkok
Tel: 66-2-694-1351

Vietnam - Ho Chi Minh
Tel: 84-28-5448-2100

EUROPE

Austria - Wels
Tel: 43-7242-2244-39
Fax: 43-7242-2244-393

Denmark - Copenhagen
Tel: 45-4485-5910
Fax: 45-4485-2829

Finland - Espoo
Tel: 358-9-4520-820

France - Paris
Tel: 33-1-69-53-63-20
Fax: 33-1-69-30-90-79

Germany - Garching
Tel: 49-8931-9700

Germany - Haan
Tel: 49-2129-3766400

Germany - Heilbronn
Tel: 49-7131-72400

Germany - Karlsruhe
Tel: 49-721-625370

Germany - Munich
Tel: 49-89-627-144-0
Fax: 49-89-627-144-44

Germany - Rosenheim
Tel: 49-8031-354-560

Israel - Ra'anana
Tel: 972-9-744-7705

Italy - Milan
Tel: 39-0331-742611
Fax: 39-0331-466781

Italy - Padova
Tel: 39-049-7625286

Netherlands - Drunen
Tel: 31-416-690399
Fax: 31-416-690340

Norway - Trondheim
Tel: 47-7288-4388

Poland - Warsaw
Tel: 48-22-3325737

Romania - Bucharest
Tel: 40-21-407-87-50

Spain - Madrid
Tel: 34-91-708-08-90
Fax: 34-91-708-08-91

Sweden - Gothenberg
Tel: 46-31-704-60-40

Sweden - Stockholm
Tel: 46-8-5090-4654

UK - Wokingham
Tel: 44-118-921-5800
Fax: 44-118-921-5820