MIC24097 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 "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 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 MIC24097 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 MIC24097 Evaluation Board. The manual layout is as follows:

- **Chapter 1. "Product Overview"** - Important information about the MIC24097 Evaluation Board.
- **Chapter 2. "Installation and Operation"** – Includes instructions on installing and using the MIC24097 Evaluation Board.
- **Appendix A. "Schematic and Layouts"** – Shows the schematic and layout diagrams for the MIC24097 Evaluation Board.
- **Appendix B. "Bill of Materials"**– Lists the parts used to build the MIC24097 Evaluation Board.
- **Appendix C. "Waveforms and Performance Curves"** – Shows behavior and performance in numbers of the MIC24097 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	*<u>File>Save</u>*
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 MIC24097 Evaluation Board (EV28T12A). Another useful document is listed below. The following Microchip document is available and recommended as a supplemental reference resource:

- **MIC24097 Data Sheet – *"20V, 20A High Performance Switching Buck Regulators"* (DS2000DS-20006953A)**

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- **General Technical Support** – Frequently Asked Questions (FAQs), technical support requests, online discussion groups, Microchip consultant program member listing
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- Local Sales Office
- Field Application Engineer (FAE)
- Technical Support

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Technical support is available through the website at:
https://www.microchip.com/support

DOCUMENT REVISION HISTORY

Revision A (November 2024)

- Initial release of this document.

NOTES:

Chapter 1. Product Overview

1.1 INTRODUCTION

This chapter provides an overview of the MIC24097 Evaluation Board and covers the following:

- MIC24097 Device Overview
- MIC24097 Evaluation Board Features
- MIC24097 Evaluation Board Kit Contents

1.2 MIC24097 DEVICE OVERVIEW

The MIC24097 is a constant-frequency, synchronous buck converter featuring a unique adaptive on-time control architecture. The MIC24097 operates over an input supply range of 4.5V to 20V. The output voltage is adjustable down to 0.6V with an guaranteed accuracy of ±1%. The device operates with programmable switching frequency up to 800 kHz.

The MIC24097 is available in a 39-pin 6 mm x 7 mm VQFN package, with a -40°C to +125°C junction operating temperature range.

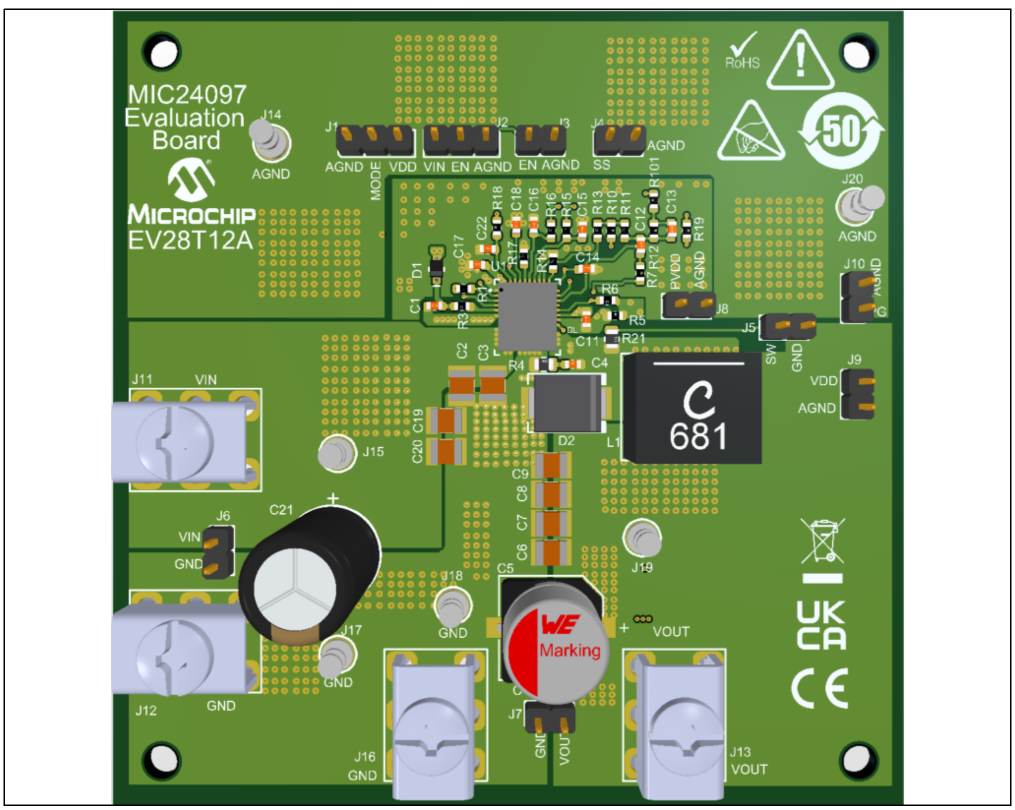


FIGURE 1-1: Typical MIC24097 Evaluation Board (Top 3D View).

1.3 MIC24097 EVALUATION BOARD FEATURES

The MIC24097 Evaluation Board features:

- Input voltage range: 4.5V to 20V (optimized for 12V Bus)
- Adjustable output from 0.6V to 12V (also limited by duty cycle)
- High current capability of 20A
- Adaptive Constant On Time Control
- Tight output voltage regulation
- 0.6V internal reference with ±1% accuracy (±0.5% over -40°C to +105°C)
- Up to 800 kHz switching frequency
- High voltage internal LDO for single supply operation
- Supports start-up into pre-bias output
- Internal compensator
- Precision enable function
- Programmable HLL/CCM operation using Mode pin
- Programmable soft start time
- Droop feature to support Adaptive Voltage Positioning (AVP) for improved load transient response
- Hiccup short circuit protection and programmable current limit
- Thermal shut down with hysteresis
- Compact size: 6 mm x 7 mm 39-pin QFN
- -40°C to +125°C junction temperature range

1.4 MIC24097 EVALUATION BOARD KIT CONTENTS

The MIC24097 Evaluation Board kit includes the following items:

- MIC24097 Evaluation Board PCB
- Important Information Sheet
- China RoHS Declaration

Chapter 2. Installation and Operation

2.1 INTRODUCTION

The MIC24097 Evaluation Board (EV28T12A) is fully assembled and tested to evaluate and demonstrate the MIC24097 capabilities. The board is based on a buck topology and can deliver 1V output voltage, with a maximum current of 20A when supplied with 5V-20V at the input. It should be noted that the board is tuned and optimized for a 1V/20A output.

2.1.1 Powering the MIC24097 Evaluation Board

The board's power supply requires an output capability of at least 10A and a voltage range of 5V to 20V, at a minimum of 40W. A proper resistor or an electronic load device capable to sustain output voltage and current can be used as a load (see Figure 2-1).

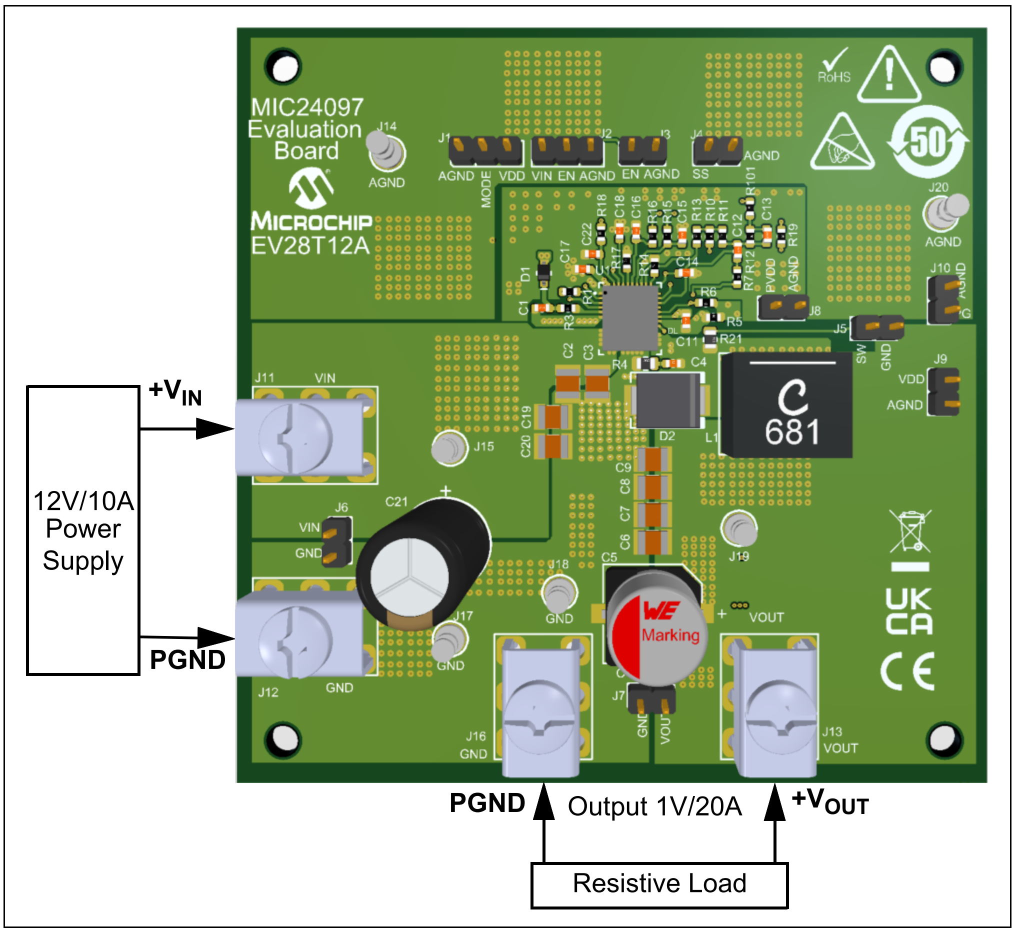


FIGURE 2-1: *MIC24097 Evaluation Board Connection Diagram.*

2.2 SETUP/CONFIGURATION

2.2.1 IC

To enable IC, a jumper should be placed on J2 between pin J2-2 (EN) and J2-3 (VIN).

2.2.2 Mode

To select CCM or DCM, a jumper should be placed on J1 between pin J1-2 (MODE) and J1-3 (VDD) for CCM or between pin J1-2 (MODE) and J1-1 (AGND) for DCM.

2.3 TEST

Apply 12V input voltage at VIN and PGND Terminals with measure output voltage which should be regulated to 1V for 0A load to 20A load.

2.4 CIRCUIT DESCRIPTION

This section describes the working principles and limitations that should be taken into account when using the MIC24097 Evaluation Board. The external components have been selected in order to optimize performance for the specific conditions of V_{IN} = 12V and V_{OUT} = 1V and output current capability to 20A. Although the application will behave correctly for other output and input voltages, further optimization (fine-tuning the inductors and ripple injection components) can be done in order to improve the efficiency and transient response. Please refer to the MIC24097 Data Sheet for the table with recommended values.

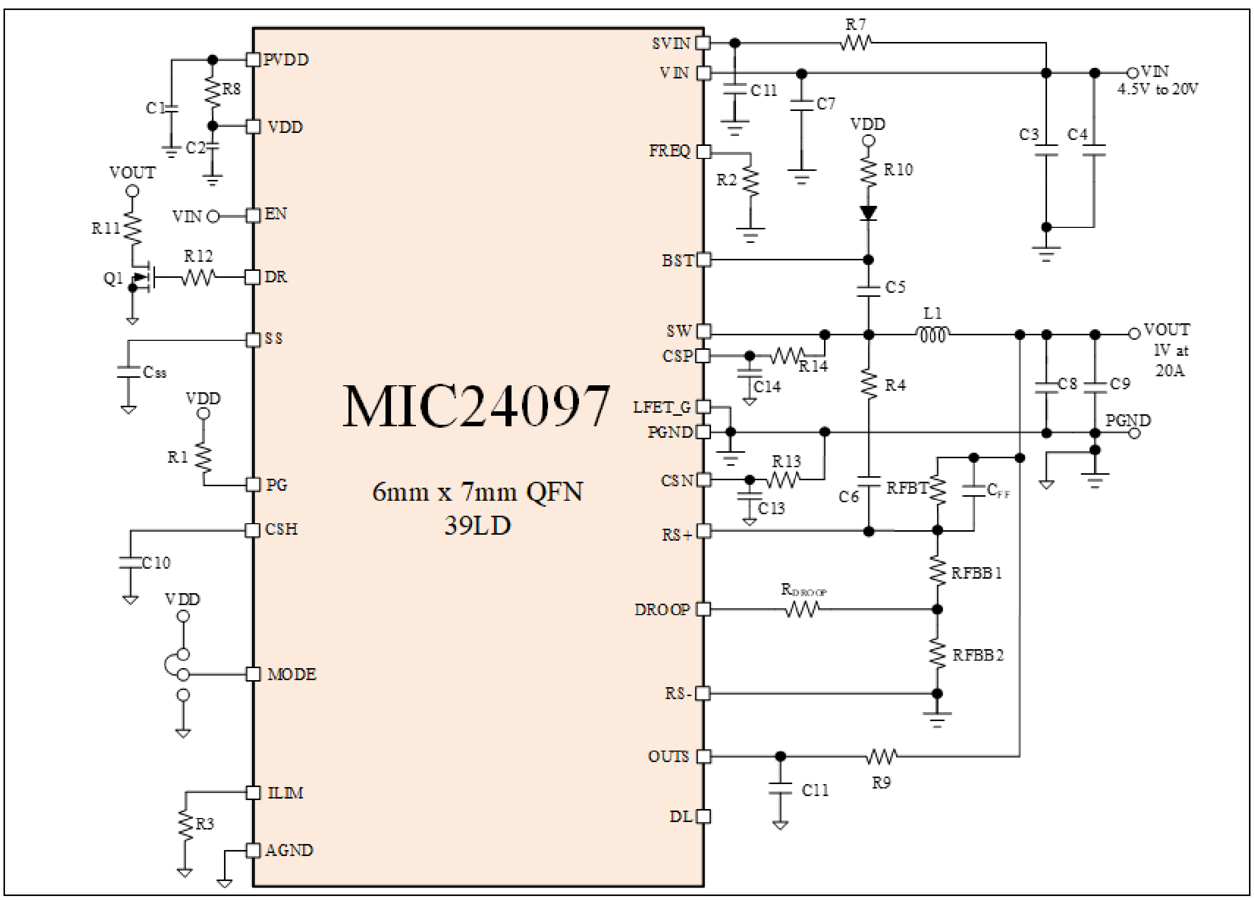


FIGURE 2-2: MIC24097 Application Circuit.

2.4.1 Output Voltage Setting

The output voltage can be adjusted using a resistor divider from output to AGND whose mid-point is connected to +RS pin as shown the Figure 2-2.

The output voltage can be calculated using below equation:

EQUATION 2-1:

$$V_{OUT} = \left(1 + \frac{R_{FBT}}{R_{RFBB1} + (R_{FBB2}||R_{DROOP})}\right) \cdot V_{REF}$$

Where:

$V_{REF} = 0.6V$

Note: Output voltage should not exceed voltage rating on the output capacitors.

Use the following table for setting various application voltages as shown in Figure 2-2.

Recommended Configuration Table (Refer to Figure 2-2)

V_{OUT}	R4	C6	V_{RIP_INJ}	R_{FBT}	R_{FBBB1}	R_{DROOP}	R_{FBBB2}	C_{FF}	L1	R_{FREQ} (R2)	Frequency
0.8V	5.1 kΩ	10 nF	180 mV	8.2 kΩ	24 kΩ	Open	100Ω	2.2 nF	400 nH	49.9 kΩ	400 kHz
1V	5.1 kΩ	10 nF	200 mV	8.2 kΩ	12 kΩ	Open	100Ω	2.2 nF	450 nH	49.9 kΩ	400 kHz
1.8V	10 kΩ	10 nF	200 mV	8.2 kΩ	4.22 kΩ	Open	100Ω	2.2 nF	1 µH	49.9 kΩ	400 kHz
3.3V	15 kΩ	10 nF	200 mV	8.2 kΩ	1.8 kΩ	Open	100Ω	2.2 nF	2 µH	49.9 kΩ	400 kHz
5V	24 kΩ	10 nF	140 mV	8.2 kΩ	1.13 kΩ	Open	100Ω	2.2 nF	2 µH	49.9 kΩ	400 kHz

2.4.2 SW Node

Test Point J5 (V_{SW}) is placed for monitoring the switching waveform, one of the most critical waveform for the converter.

2.4.3 Current Limit

The MIC24097 uses the $R_{DS(ON)}$ of the internal low-side power MOSFET to sense over-current conditions. This method will avoid additional cost, use of additional board space and power losses taken by a discrete current sense resistor.

The MIC24097 uses the $R_{DS(ON)}$ of the low-side power MOSFET, or an additional sense resistor in series with the source of the low-side FET, to sense overcurrent conditions. The low-side power MOSFET $R_{DS(ON)}$ method will avoid additional cost, board space and power losses taken by a discrete current sense resistor.

The MIC24097 forces a constant current I_{CL} of typically 9.6 µA through the I_{LIM} pin to the resistor tied from I_{LIM} pin to ground to program V_{ILIM}. In each switching cycle of the MIC24097 converter, the inductor current is sensed by monitoring the low-side MOSFET during the OFF period. If the low-side MOSFET current is greater than the target ILIM threshold for 7 consecutive cycles, then the MIC24097 turns off the high-side MOSFET and a soft-start sequence is triggered.

The current limit threshold can be programmed by connecting a resistor from ILIM pin to AGND. The current limit resistor value can be calculated using the formula:

EQUATION 2-2:

$$R_{ILIM} = \frac{1.2V - 4 \times R_{DS(ON)} \times I_{LIM}}{I_{CL}}$$

Where:

I_{CL} = *Current Source for Current Limit = 9.6 µA*

I_{ILIM} = $I_{LOAD} + \Delta_{IL}$

Δ_{IL} = *Inductor Ripple Current*

R_{ILIM} = *Current Limit Programming Resistor*

2.4.4 Setting the Switching Frequency

The MIC24097 is an adjustable-frequency, synchronous buck controller featuring a unique adaptive on-time control architecture. The switching frequency can be adjusted between 270 kHz and 800 kHz by changing the R_{FREQ} resistor and is dictated by the following equation:

$$R_{FREQ} = \frac{20.1 \times 10^9}{f_{SW}}$$

f_{SW} is the switching frequency when R_{FREQ} is programming resistor.

f_{SW} is typically 400 kHz. For more precise setting, it is recommended to use Figure 2-3.

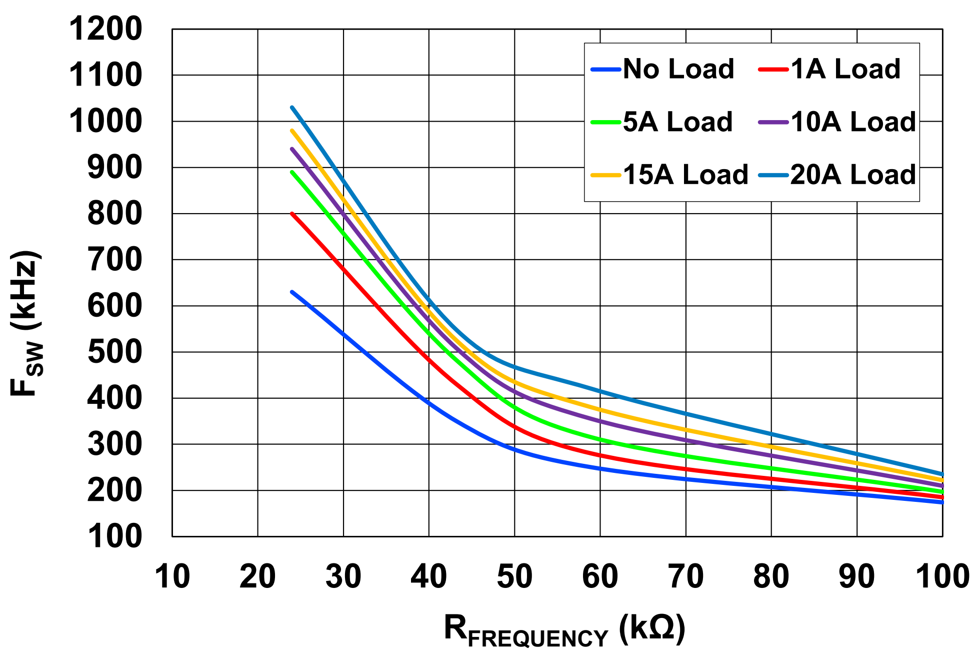


FIGURE 2-3: *Switching Frequency vs. Load vs. R_{FREQ} @ V_{IN} = 12V.*

2.4.5 Setting the Soft Start Time

The output Soft-Start time can be set by connecting a capacitor from SS to AGND from 2 ms to 100 ms as shown in Figure 2-4:

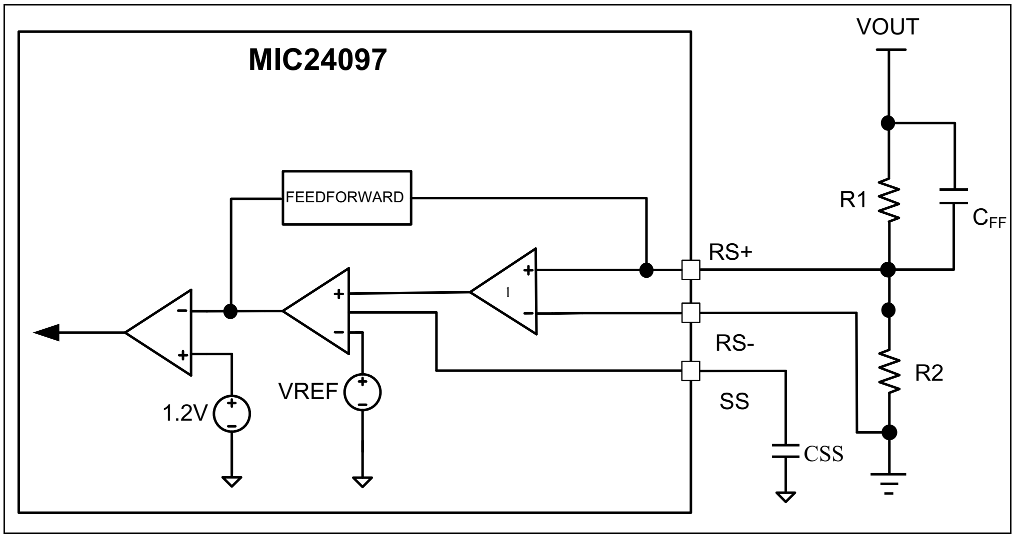


FIGURE 2-4: Setting the Soft-Start Time.

The value of the capacitor can be calculated using Equation 2-3:

EQUATION 2-3:

$$C_{SS} = \frac{I_{SS} \times t_{SS}}{V_{REF}}$$

Where:

C_{SS} = *Capacitor from SS pin to* A_{GND}
I_{SS} = *Internal Soft Start Current (1.3 µA typical)*
t_{SS} = *Output Soft Start Time*
V_{REF} = *0.6V*

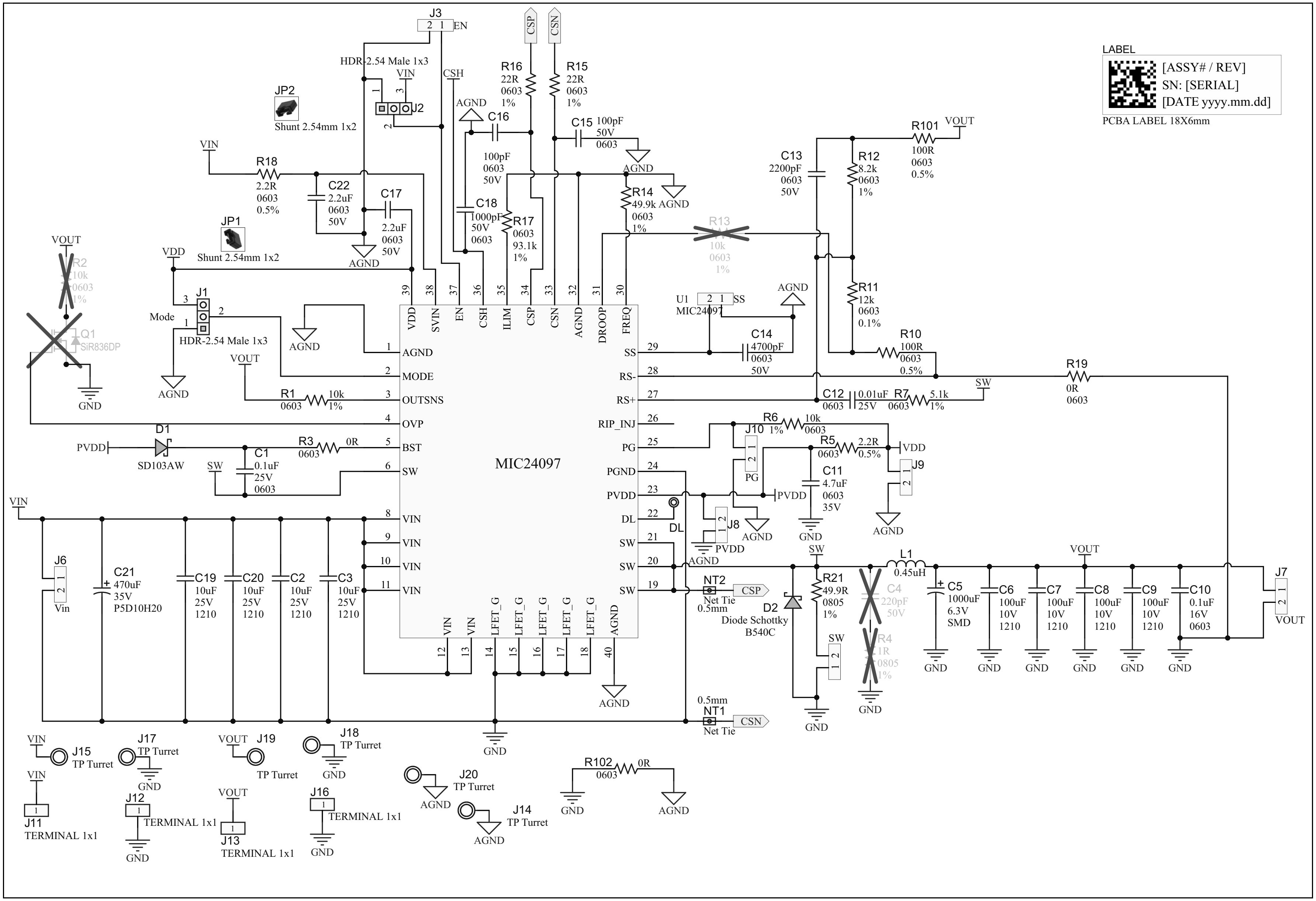
NOTES:

Appendix A. Schematic and Layouts

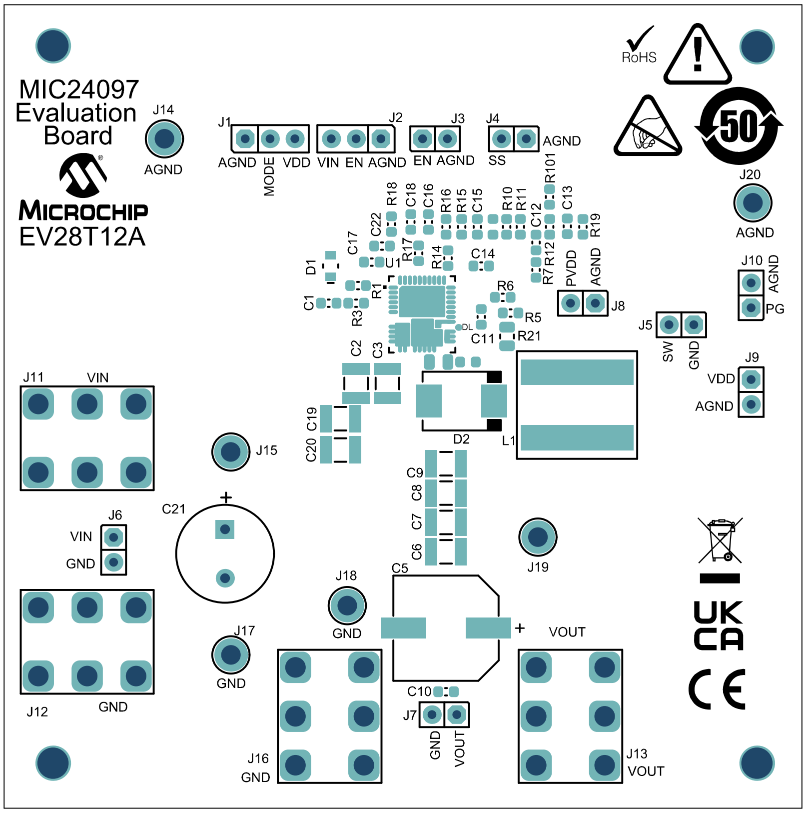
A.1 INTRODUCTION

This appendix contains the following schematics and layouts for the MIC24097 Evaluation Board:

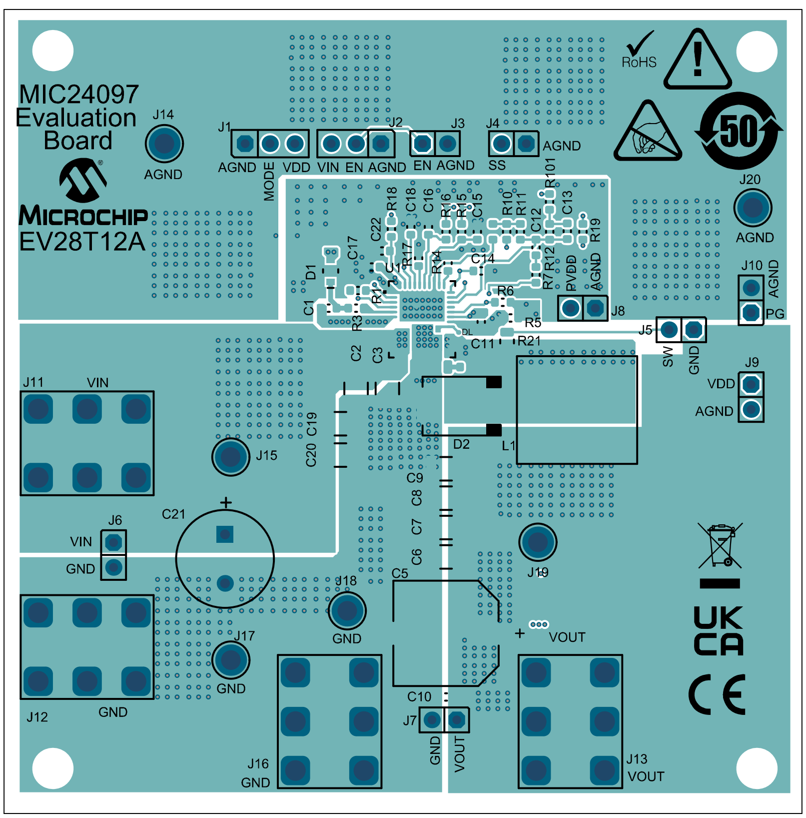
A.2 BOARD – SCHEMATIC



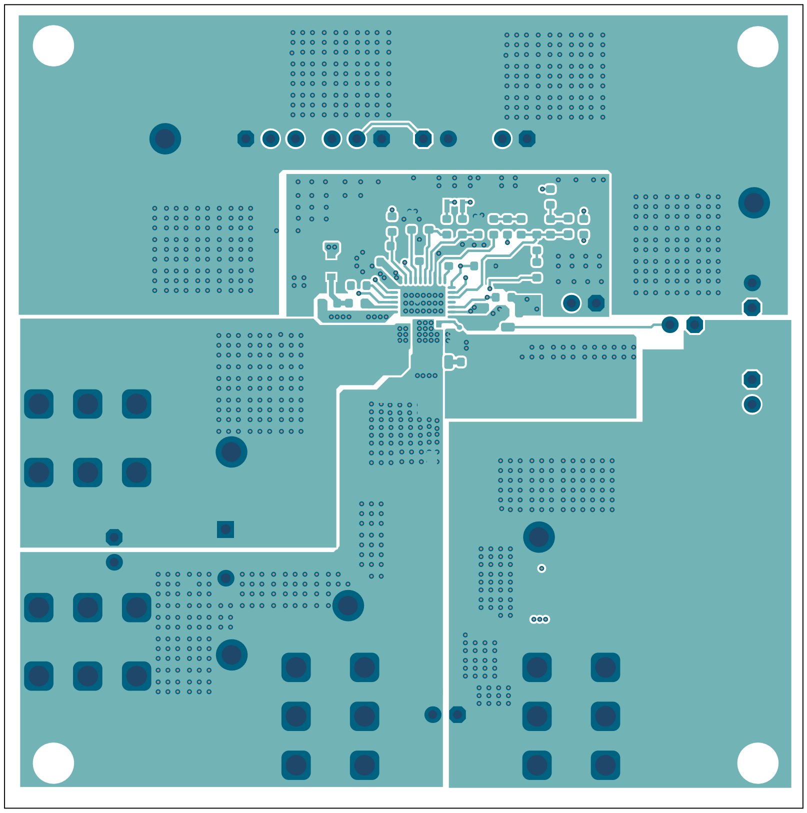
A.3 BOARD – TOP SILK



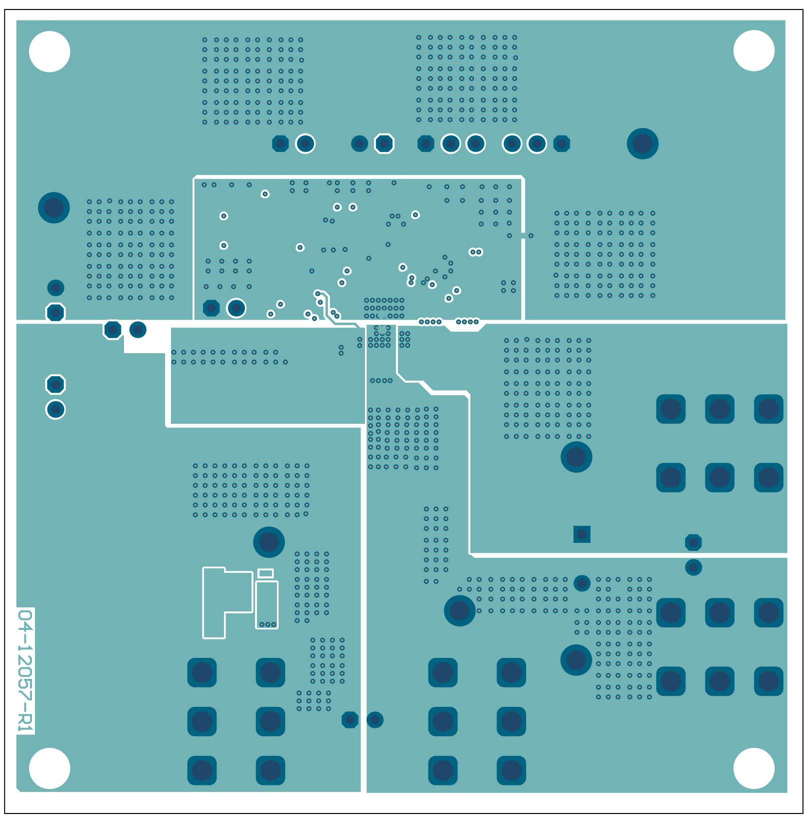
A.4 BOARD – TOP COPPER AND SILK



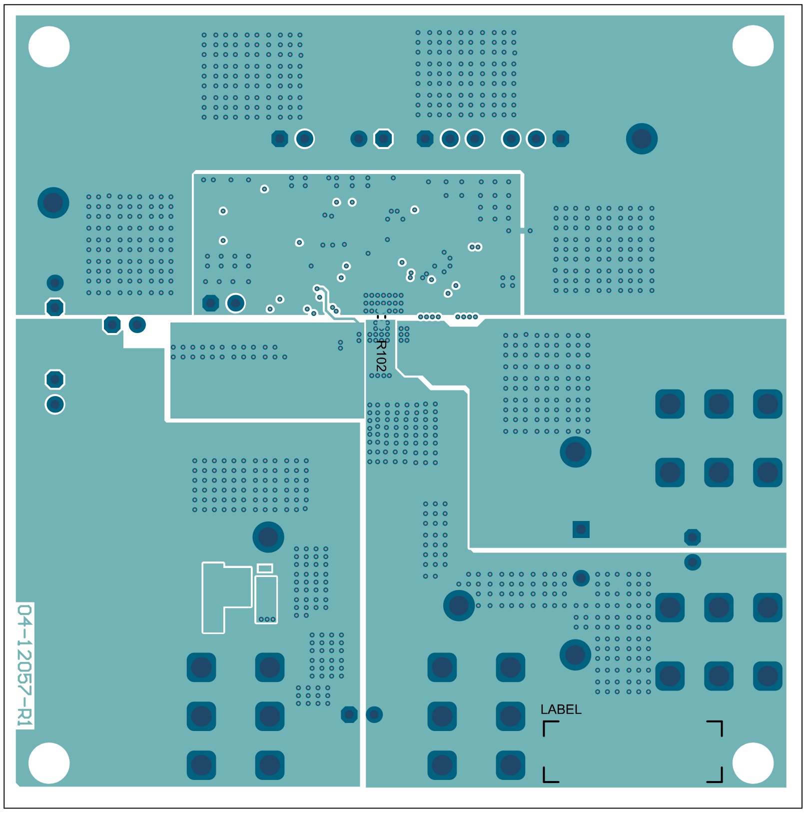
A.5 BOARD – TOP COPPER



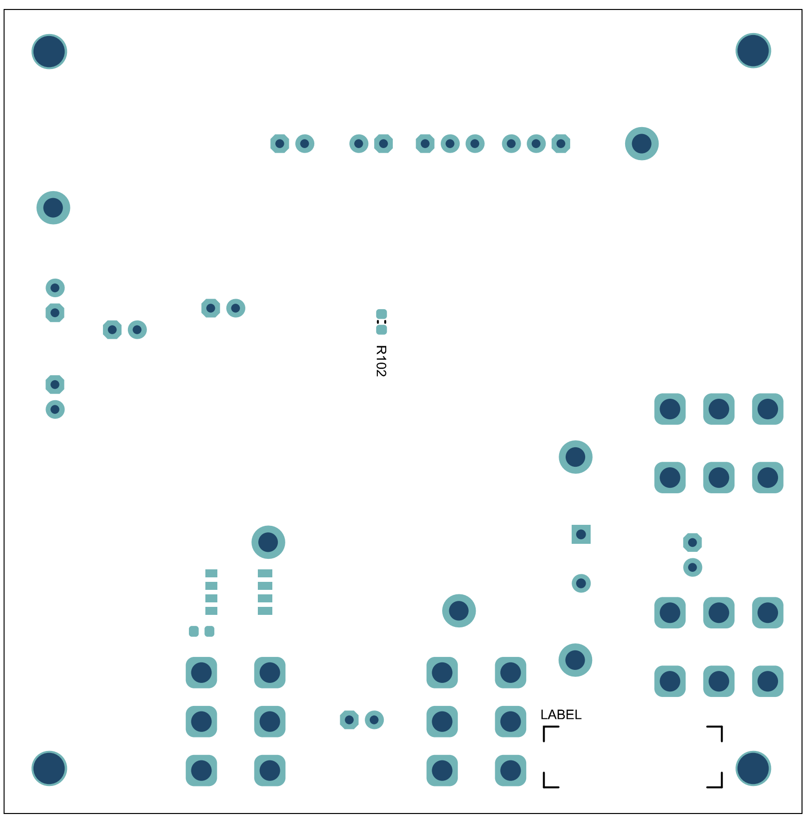
A.6 BOARD – BOTTOM COPPER



A.7 BOARD – BOTTOM COPPER AND SILK



A.8 BOARD – BOTTOM SILK



NOTES:

Appendix B. Bill of Materials

TABLE B-1: BILL OF MATERIALS (BOM)

Qty	Reference	Description	Manufacturer	Part Number
1	C1	Capacitor, Ceramic, 0.1 µF, 25V, 20%, Y5V, SMD, 0603	Samsung Electro-Mechanics America, Inc.	CL10F104ZA8NNNC
4	C2, C3, C19, C20	Capacitor, Ceramic, 10 µF, 25V, 10%, X5R, SMD, 1210	TDK Corporation	C3225X5R1E106K250AA
1	C5	Capacitor, Aluminum, 1000 µF, 6.3V, 20%, 0.02R, SMD	Wurth Elektronik	875115160009
4	C6, C7, C8, C9	Capacitor, Ceramic, 100 µF, 10V, 20%, X5R, SMD, 1210	Murata Manufacturing Co., Ltd.	GRM32ER61A107ME20L
1	C10	Capacitor, Ceramic, 0.1 µF, 16V, 10%, X7R, SMD, 0603	Taiyo Yuden Co., Ltd.	EMK107B7104KA-T
1	C11	Capacitor, Ceramic, 4.7 µF, 35V, 10%, SMD, 0603	Samsung Electro-Mechanics America, Inc.	CL10A475KL8NRNC
1	C12	Capacitor, Ceramic, 0.01 µF, 25V, 10%, X7R, SMD, 0603	KEMET	C0603X103K3RACTU
1	C13	Capacitor, Ceramic, 2200 pF, 50V, 1%,C0G, SMD, 0603	Murata Manufacturing Co., Ltd.	GRM1885C1H222FA01D
1	C14	Capacitor, Ceramic, 4.7 nF, 50V, 10%, X7R, SMD, 0603	Wurth Elektronik	885012206087
2	C15, C16	Capacitor, Ceramic, 100 pF, 50V, 5%, NP0, SMD, 0603	Kyocera AVX	06035A101JAT2A
1	C17, C22	Capacitor, Ceramic, 2.2 µF, 50V, 10%, X5R, SMD, 0603	Murata Manufacturing Co., Ltd.	GRM188R61H225KE11D
1	C18	Capacitor, Ceramic, 1000 pF, 50V, 10%, X7R, SMD, 0603	KEMET	C0603C102K5RACAUTO
1	C21	Capacitor, Aluminum, 470 µF, 35V, 20%, RAD, P5D10H20	Taiwan Chinsan Electronics Industrial Co., Ltd.	EK1V471MP51016EU
1	D1	Diode, Schottky, 600 mV, 350 mA, 40V, SOD-323	Diodes Incorporated®	SD103AWS-7-F
1	D2	Diode, Schottky, B540C, 550 mV, 5A, 40V, DO-214AB_SMC	Diodes Incorporated®	B540C-13-F
2	J1, J2	Connector, Header-2.54 Male, 1x3 Gold, 5.84MH, Through Hole, Vertical	FCI	68000-103HLF
8	J3, J4, J5, J6, J7, J8, J9, J10	Connector, Header-2.54 Male, 1x2 Gold, 5.84MH, Through Hole, Vertical	FCI	68000-202HLF
4	J11, J12, J13, J16	Connector, Terminal, 30A, Female, 1x1, Through Hole, Vertica	Keystone® Electronics Corp.	XGL6060-332
6	J14, J15, J17, J18, J19, J20	Connector, Test Point, PIN, Tin, Through Hole	Harwin Plc.	H2121-01

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: BILL OF MATERIALS (BOM) (CONTINUED)

Qty	Reference	Description	Manufacturer	Part Number
1	L1	Inductor, 450 nH, 53A, 20%, SMD, L11.3W10H10	Coilcraft	XAL1010-451MED
2	R1, R6	Resistor, Thin Film, 10k, 1%, 1/16W, SMD, 0603	TE Connectivity	CPF0603F10KC1
3	R3, R19, R102	Resistor, Thick Film, 0R, 1/10W, SMD, 0603, AEC-Q200	Panasonic® - ECG	ERJ-3GEY0R00V
2	R5, R18	Resistor, Thin Film, 2.2R, 0.5%, 1/8W, SMD, 0603	Vishay®	TNPW06032R20DEEA
1	R7	Resistor, Thick Film, 5.1k, 1%, 1/10W, SMD, 0603, AEC-Q200	Vishay®	CRCW06035K10FKEA
2	R10, R101	Resistor, Thin Film, 100R, 0.5%, 1/16W, SMD, 0603	Susumu Co., Ltd.	RR0816P-101-D
1	R11	Resistor, Thin Film, 12K, 0.1%, 1/10W, SMD, 0603, AEC-Q200	Vishay®.	TNPW060312K0BEEA
1	R12	Resistor, Thick Film, 8.2k, 1%, 1/10W, SMD, 0603	Panasonic® - ECG	ERJ-3EKF8201V
1	R14	Resistor, Thick Film, 49.9k, 1%, 1/10W, SMD, 0603	Stackpole Electronics, Inc.	RMCF0603FT49K9
2	R15, R16	Resistor, Thick Film, 22R, 1%, 1/8W, SMD, 0603, AEC-Q200	Panasonic® - ECG	ERJ-H3EF22R0V
1	R17	Resistor, Thick Film, 93.1k, 1%, 1/10W, SMD, 0603, AEC-Q200	Panasonic® - ECG	ERJ-3EKF9312V
1	R21	Resistor, Thick Film, 49.9R, 1%, 1/8W, SMD, 0805	Panasonic® - ECG	ERJ-6ENF49R9V
1	**U1**	**Analog Switching Buck Regulator, 4.5V to 20V, VQFN-39**	**Microchip Technology Inc.**	**MIC24097T-E/SJC**
1	PCB	MIC24097 Evaluation Board - Printed Circuit Board	—	04-12057-R1

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

Qty	Reference	Description	Manufacturer	Part Number
2	JP1, JP2	Jumper, HW, 2.54 mm, 1x2	FCI	63429-202LF
1	LABEL	Label, PCBA, 18 x6 mm, Datamatrix Assy# / Rev / Serial / Date	ACT Logimark AS	505462

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

Qty	Reference	Description	Manufacturer	Part Number
1	C4	Capacitor, Ceramic, 220 pF, 50V, 5%, C0G, SMD, 0603, AEC-Q200	Kyocera AVX	06035A221J4T2A
1	Q1	Transistor, FET, N-Channel, 40V, 21A, 15.6W, PPAK, SO-8	Vishay®.	SIR836DP-T1-GE3
2	R2, R13	Resistor, Thin Film,10k, 1%, 1/16W, SMD, 0603	TE Connectivity	CPF0603F10KC1
1	R14	Resistor, Thin Film, 1R, 1%, 1/4W, SMD, 0805	Stackpole Electronics, Inc.	RNCP0805FTD1R00

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:

Appendix C. Waveforms and Performance Curves

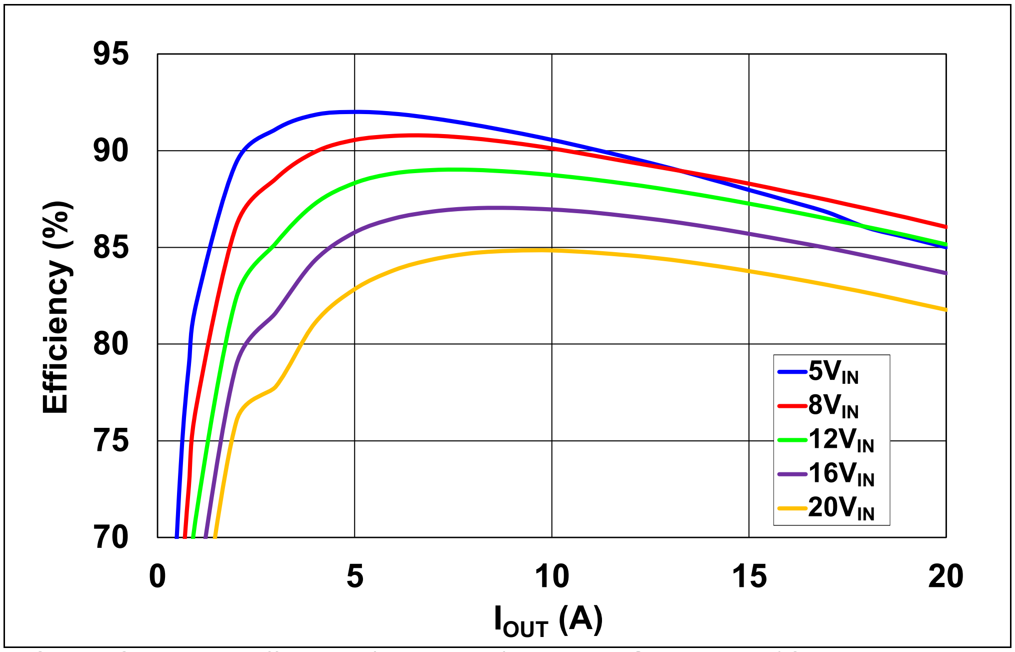


FIGURE C-1: *Efficiency (V_{OUT} = 1V) vs. Load @ Amb = 25°C, F_{SW} = 400 kHz, Mode = HLL.*

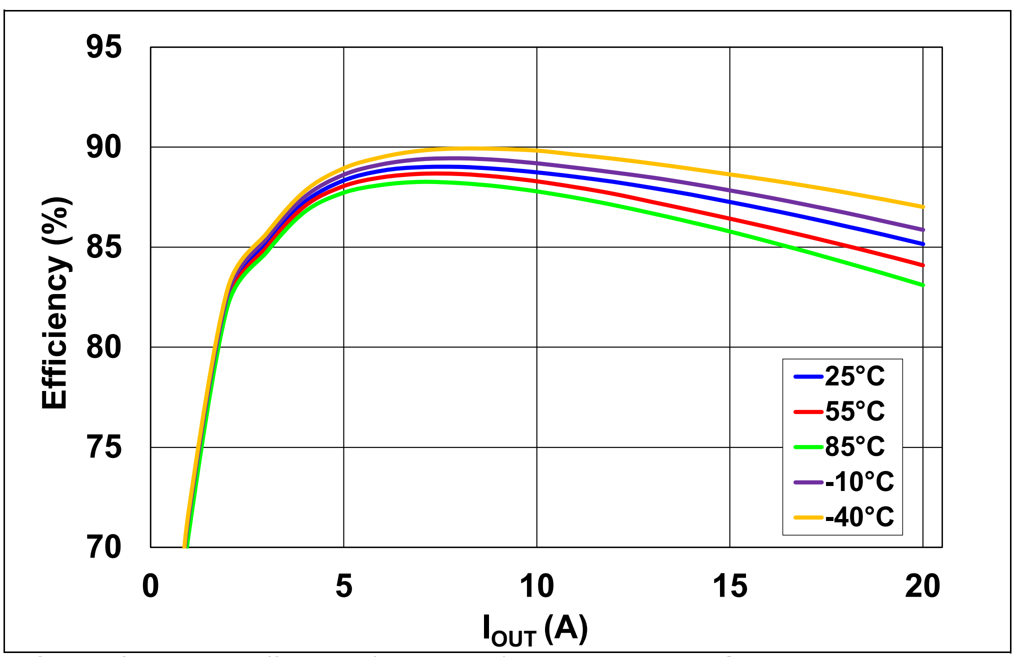


FIGURE C-2: *Efficiency (V_{OUT} = 1V) vs. Temperature @ V_{IN} = 12V, F_{SW} = 400 kHz.*

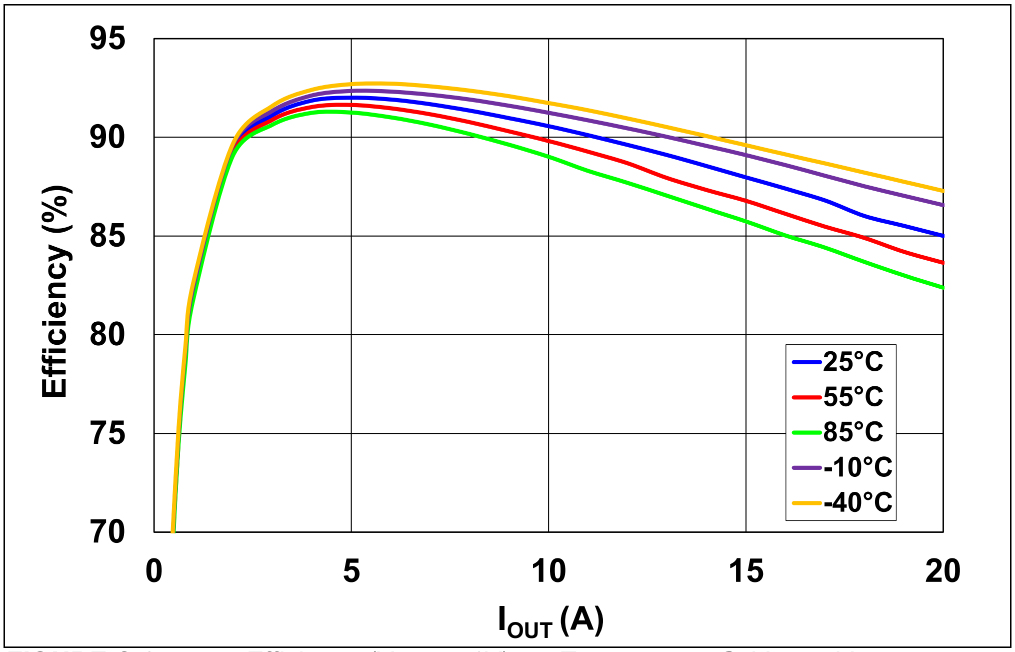


FIGURE C-3: *Efficiency (V_{OUT} = 1V) vs. Temperature @ V_{IN} = 5V, F_{SW} = 400 kHz.*

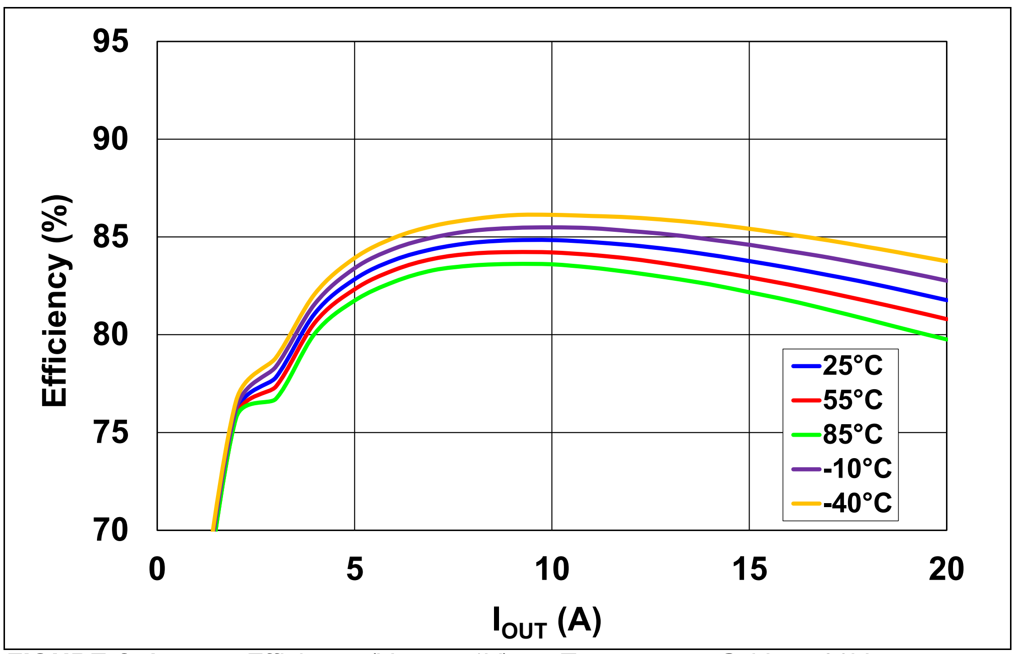


FIGURE C-4: *Efficiency (V_{OUT} = 1V) vs. Temperature @ V_{IN} = 20V, F_{SW} = 400 kHz.*

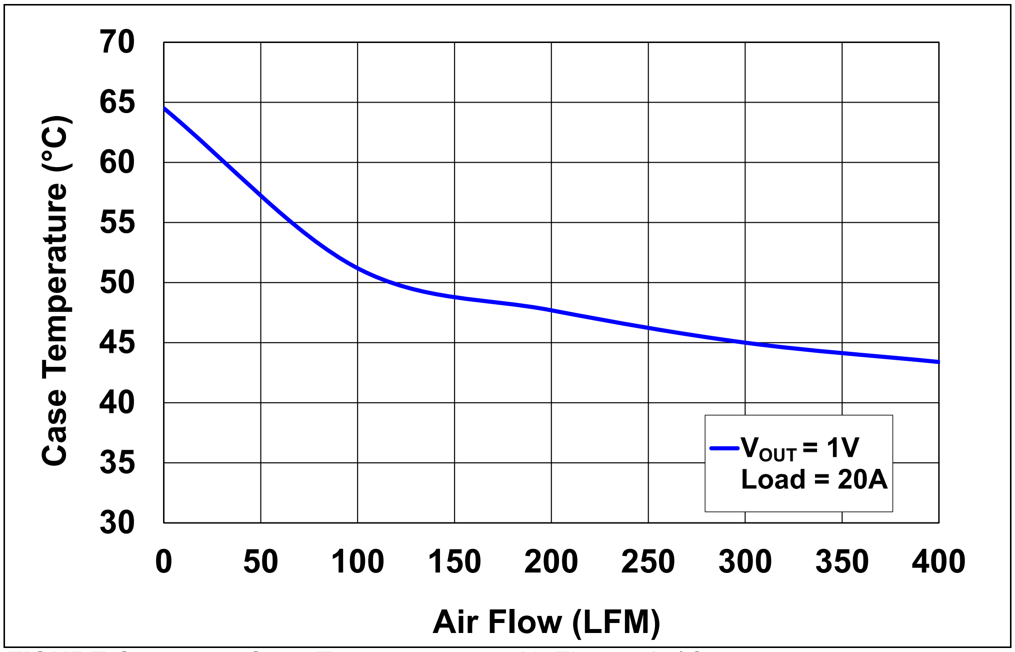


FIGURE C-5: *Case Temperature vs. Air Flow at 25°C.*

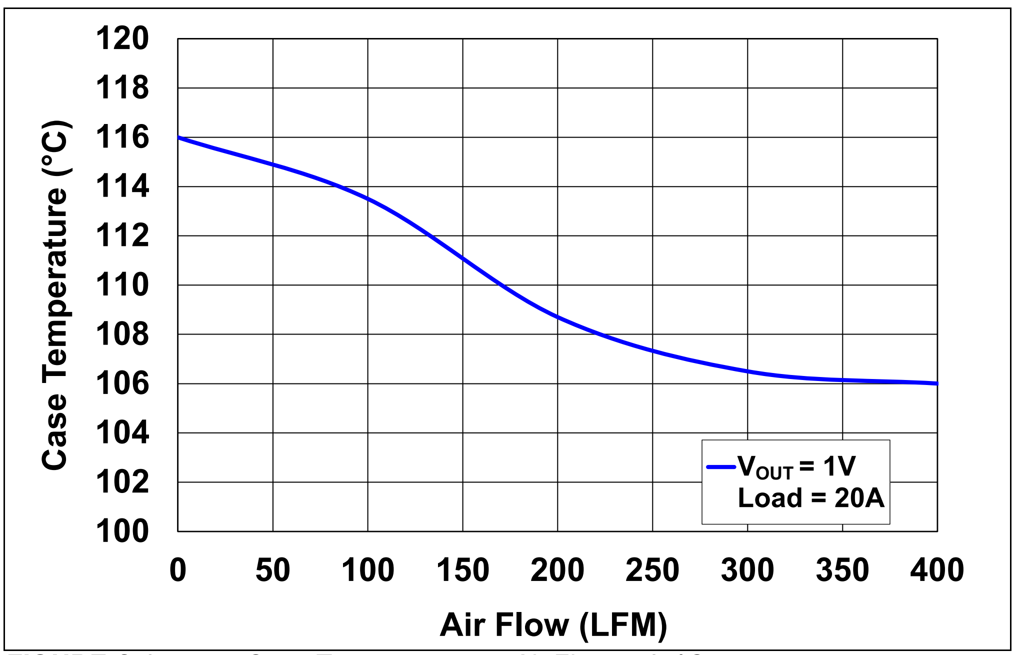


FIGURE C-6: *Case Temperature vs. Air Flow at 85°C.*

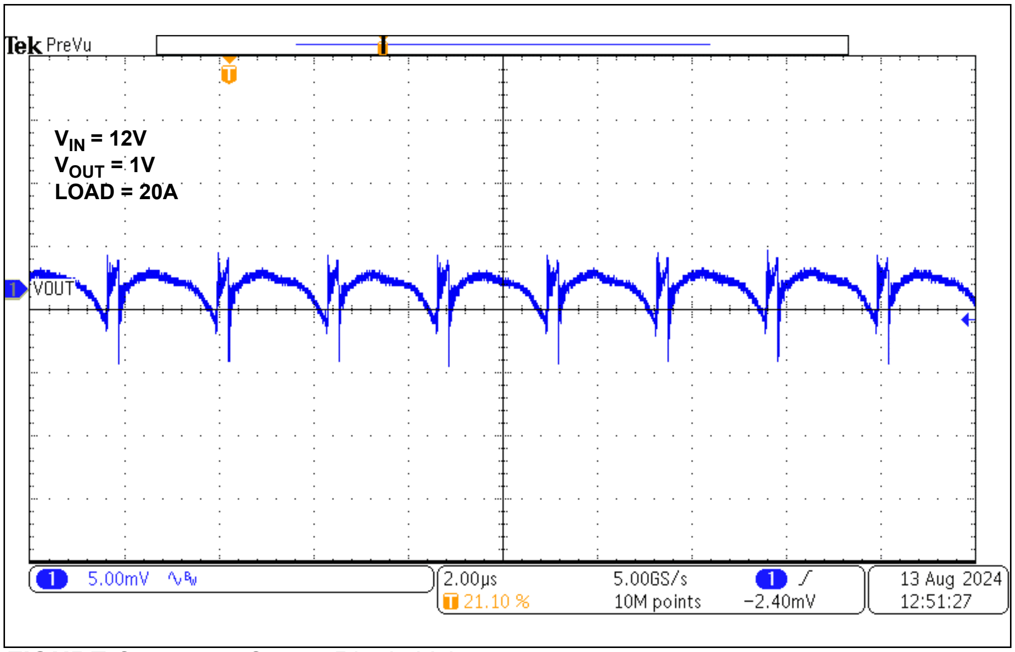


FIGURE C-7: *Output Ripple Voltage.*

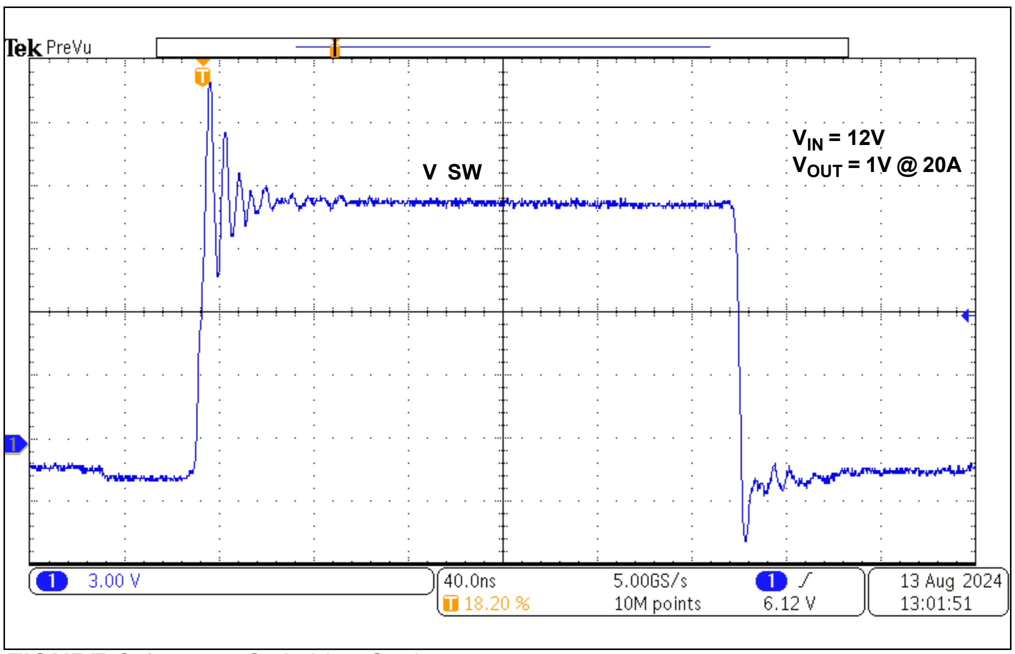


FIGURE C-8: *Switching Cycle.*

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