

MCP1640
12V/50 mA Two Cells Input Boost Converter Reference Design
User's Guide

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MCP1640 12V/50 mA TWO CELLS INPUT BOOST CONVERTER REFERENCE DESIGN

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Preface

NOTICE TO CUSTOMERS

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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 MCP1640 12V/50 mA Two Cells Input Boost Converter 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 MCP1640 12V/50 mA Two Cells Input Boost Converter Reference Design as a development tool to evaluate the MCP1640 device's capability to boost low voltages to a high output value, using a single inductor. The manual layout is as follows:

- **Chapter 1. "Product Overview"** – Important information about the MCP1640 Input Boost Converter.
- **Chapter 2. "Installation and Operation"** – Includes instructions on how to get started with the MCP1640 Input Boost Converter and a description of the User's Guide.
- **Appendix A. "Schematic and Layouts"** – Shows the schematic and layout diagrams for the MCP1640 Input Boost Converter.
- **Appendix B. "Bill of Materials"** – Lists the parts used to build the MCP1640 Input Boost Converter.

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 the MCP1640 12V/50 mA Two Cells Input Boost Converter Reference Design. Other useful documents are listed below. The following Microchip document is available and recommended as a supplemental reference resource.

- **MCP1640/B/C/D Data Sheet – *"0.65V Start-up Synchronous Boost Regulator with True Output Disconnect or Input/Output Bypass Option"* (DS22234)**

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DOCUMENT REVISION HISTORY

Revision A (September 2011)

- Initial Release of this Document.

NOTES:

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Chapter 1. Product Overview

1.1 INTRODUCTION

This chapter provides an overview of the MCP1640 12V/50 mA Two Cells Input Boost Converter Reference Design and covers the following topics:

- MCP1640 Short Overview
- What is the MCP1640 12V/50 mA Two Cells Input Boost Converter Reference Design?
- What Does the MCP1640 12V/50 mA Two Cells Input Boost Converter Reference Design Kit Include?

1.2 MCP1640 SHORT OVERVIEW

The MCP1640 device is a compact, high-efficiency, fixed frequency, step-up DC-DC converter. It provides an easy-to-use power supply solution, with a minimum number of external components, for applications powered by one-cell, two-cell, or three-cell alkaline, NiCd, NiMH, one-cell Li-Ion or Li-Polymer batteries.

The MCP1640/C device automatically selects the best operating mode for efficiency, PWM (Pulse-Width Modulation) or PFM (Pulse Frequency Modulation). The MCP1640B/D device is running in PWM mode only and is ideal for noise sensitive applications. It has a low quiescent current (19 µA, PFM mode typical), a wide input voltage range (0.35 to 5.5V) and a low start-up voltage (0.65V at 1 mA load current). The MCP1640 device consumes less than 1 µA in Shutdown mode.

Microchip Technology Inc. provides the MCP1640 device in four variants, which help engineers to meet different system requirements. The devices and their available options are presented in Table 1-1.

TABLE 1-1: PART NUMBER SELECTION

Part Number	PWM/PFM Mode	PWM Mode	True Output Disconnect Shutdown Option	Input to Output Bypass Shutdown Option
MCP1640	X	—	X	—
MCP1640B	—	X	X	—
MCP1640C	X	—	—	X
MCP1640D	—	X	—	X

The MCP1640 is available in SOT23-6 and 8-LD DFN (2x3 mm) packages. For additional information on the MCP1640 device, refer to the *"MCP1640/B/C/D Data Sheet"* (DS22234).

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1.2.1 MCP1640 Key Features

- Up to 96% Typical Efficiency
- **800 mA Typical Peak Input Current Limit**:
  - I_{OUT} > 100 mA @ 1.2V V_{IN}, 3.3V V_{OUT}
  - I_{OUT} > 350 mA @ 2.4V V_{IN}, 3.3V V_{OUT}
  - I_{OUT} > 350 mA @ 3.3V $V_{IN,}$ 5.0V V_{OUT}
- Low Start-up Voltage: 0.65V, typical 3.3V V_{OUT} @ 1 mA
- Low Operating Input Voltage: 0.35V, typical 3.3V_{OUT} @ 1 mA
- **Adjustable Output Voltage Range: 2.0V to 5.5V**
- **Maximum Input Voltage ≤ V_{OUT} < 5.5V**
- Automatic PFM/PWM Operation (MCP1640/C):
  - PFM Operation Disabled (MCP1640B/D)
  - PWM Operation: 500 kHz
- Low Device Quiescent Current: 19 µA, typical PFM mode
- Internal Synchronous Rectifier
- Internal Compensation
- Inrush Current Limiting and Internal Soft-Start
- Selectable, Logic Controlled, Shutdown States:
  - True Load Disconnect Option (MCP1640/B)
  - Input to Output Bypass Option (MCP1640C/D)
- Shutdown Current (All States): < 1 µA
- Low Noise, Anti-Ringing Control
- Overtemperature Protection

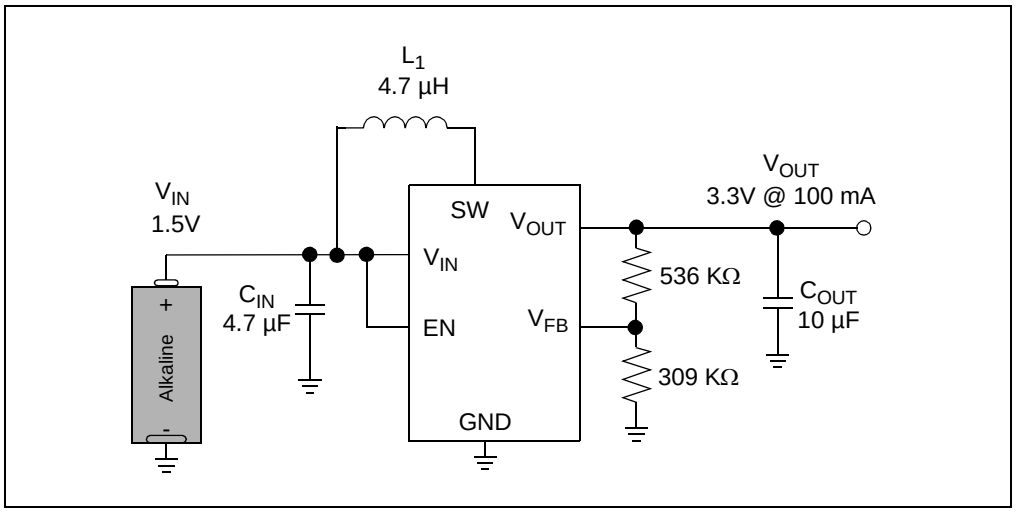


FIGURE 1-1: *Typical MCP1640 Single Cell Input Boost Converter.*

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1.3 WHAT IS THE MCP1640 12V/50 mA TWO CELLS INPUT BOOST CONVERTER REFERENCE DESIGN?

The MCP1640 12V/50 mA Two Cells Input Boost Converter Reference Design is designed to demonstrate the MCP1640 device's high-voltage boost capability above its typical output range of 5.5V. This board boosts the low-voltage input to 12V and up to 70 mA load. By changing the sense resistors (R_T and R_B on Figure 1-2), a lower/higher output than 12V will be obtained. The MCP1640 Input Boost Converter was developed to help engineers reduce product design cycle time.

At 2.0V input and 12V output, the board is capable of a maximum of 50 mA load current.

The N-MOS switch is connected between the inductor and the main switch, allowing the application to output higher voltage (see Figure 1-2).

The converter is configured as nonsynchronous; a Schottky diode is connected between the inductor and the High-Voltage Output (V_{OUT} High). At start-up, MCP1640 starts as the current generator for the Output Capacitor (C_{OUT}). Because at this time, the internal N-MOS switch is OFF, a Start-up Resistor (R_{Start}), connected in parallel with the N-MOS switch, should be used.

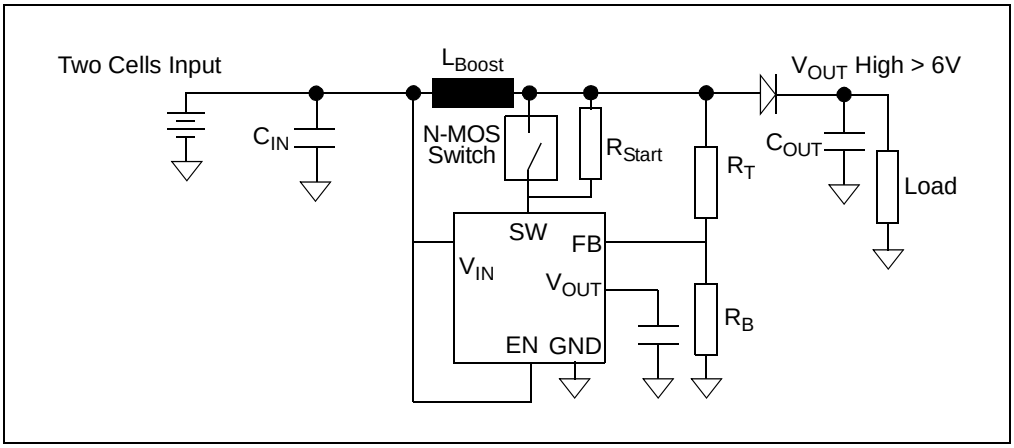


FIGURE 1-2: *MCP1640 12V/50 mA Two Cells Input Boost Converter Reference Design Block Diagram.*

1.4 WHAT DOES THE MCP1640 12V/50 mA TWO CELLS INPUT BOOST CONVERTER REFERENCE DESIGN KIT INCLUDE?

The MCP1640 Input Boost Converter kit includes:

- MCP1640 12V/50 mA Two Cells Input Boost Converter Reference Design, 102-00386
- Important Information Sheet

NOTES:

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Chapter 2. Installation and Operation

2.1 INTRODUCTION

The MCP1640 12V/50 mA Two Cells Input Boost Converter Reference Design is developed to demonstrate how the MCP1640 device can operate as a high output voltage DC-DC converter when powered from two batteries. This reference design allows boosting from the input range of 2.0V-5V to an output higher than 5.5V of the typical MCP1640 application. High-voltage outputs, such as 9V, 12V or 24V, can be generated from just two alkaline cells.

For this reference design, the output voltage is set at 12V. Typically, a minimum of a 50 mA load can be supported from a 2.0V input. The board can deliver more output current (up to 70 mA) if it is powered with 3.0V. A small 3x3x1 mm inductor offers a good efficiency of up to 75%. Good converter stability is obtained with the B option of MCP1640 (PWM Mode Only and True Output Disconnect options).

2.1.1 Board Features

The MCP1640 Input Boost Converter has the following features:

- Input Voltage: Two Alkaline or Lithium Cells, 2.0-3.0V Typical
  - Supports extended input range of 2.0V-5.0V
- Output Capability:
  - Dependent on the input voltage
  - 12V/50 mA typical @ 2.0V input
  - 12V/70 mA @ 3.3V input
- No Load Input Current: 0.2 mA @ 3.0V Input
- Efficiency: up to 75%
- PWM Operation at 500 kHz

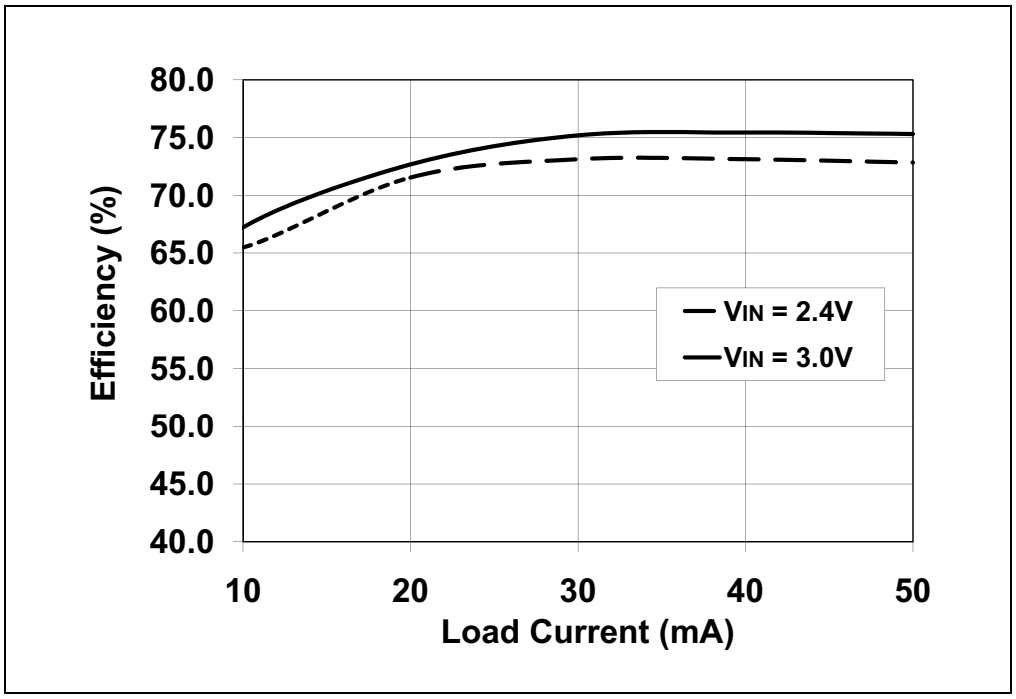


FIGURE 2-1: *Efficiency vs. Load Current for 12V Output at 2.4V and 3.0V Input.*

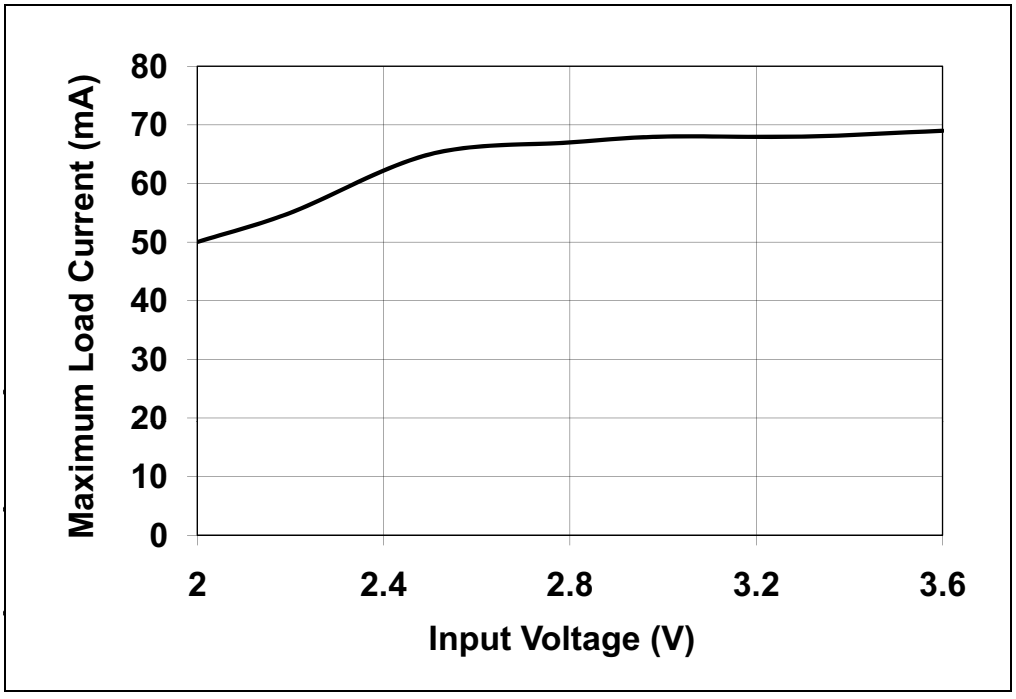


FIGURE 2-2: *Maximum Load Current vs. Input Voltage at 12V Output.*

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2.2 GETTING STARTED

The MCP1640 12V/50 mA Two Cells Input Boost Converter Reference Design is fully assembled and tested to evaluate and demonstrate the MCP1640 family of products.

2.2.1 Powering the MCP1640 12V/50 mA Two Cells Input Boost Converter Reference Design

The extended input range of the MCP1640 Input Boost Converter is 2.0 to 5.0V input. Good efficiency is obtained by supplying from two cells (primary and secondary batteries).

Input power connectors are placed on the left side of the board:

- V_{IN} for positive power
- GND for negative power

The maximum input voltage should not exceed 5.0V. The output voltage will be out of regulation for input voltages lower than 2.0V.

The output connector is called V_{OUT} and is referenced to GND. The minimum output current is 50 mA when the board is powered by two alkaline batteries that are close to the end of their run time, at approximately 1V each.

2.2.2 Board Testing

Because this board is boosting the input voltage, the input current is greater than the output current. The variable power supply for testing requires output capability of at least 1A and a voltage range of 2.0V to 5V.

To test the board, follow these steps:

1. Connect the power at V_{IN} and GND terminals of the board.
2. Set the power supply to 3.0V.
3. Connect a voltmeter and a 240Ω/0.5W resistor between V_{OUT} and GND connectors, as shown in Figure 2-3.
4. Check to be sure the voltmeter indicates 12V.
5. Set the power supply to 2.0V and verify if the output of the converter stays regulated (V_{OUT} = 12V).

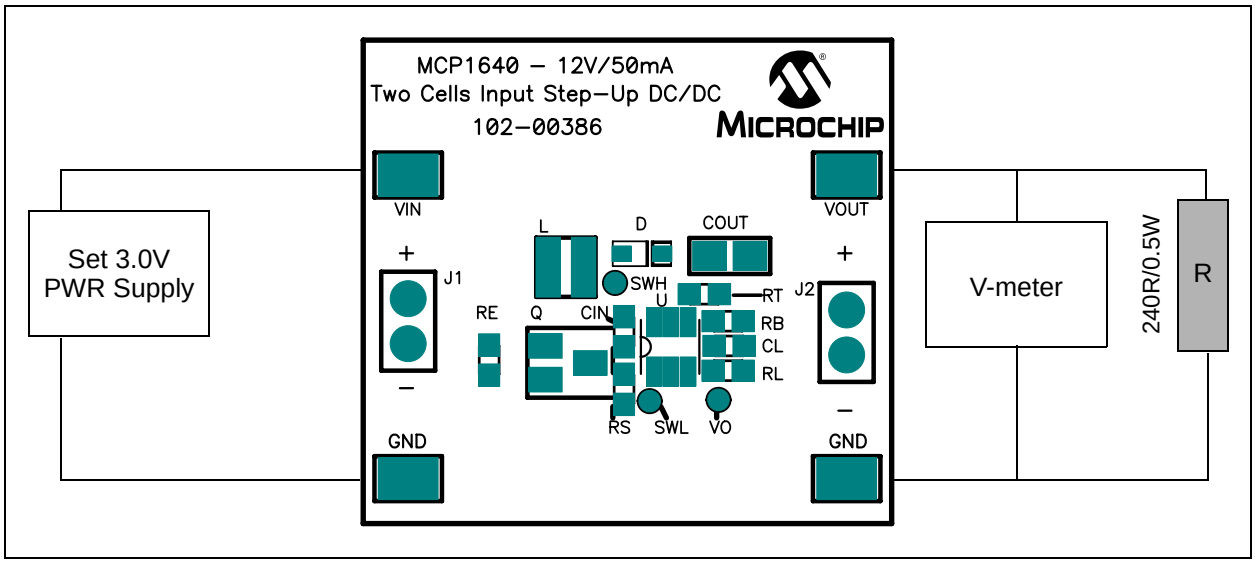


FIGURE 2-3: *MCP1640 12V/50 mA Two Cells Input Boost Converter Reference Design Setup Circuit.*

The board has several test points that help engineers analyze the switch node's waveforms or MCP1640's output:

- The high-voltage switch node test point (SWH).
- The test point of the MCP1640 device's switch node (SWL).
- VO test point shows the MCP1640 device's V_{OUT} pin (this output is unregulated).

The difference between SWH and SWL signals is their amplitude. For 12V output, the amplitude of SWL is approximately 5V, while SWH shows the sum of MCP1640's SW node (SWL signal) and external n-channel MOS voltage.

Figures 2-4 and 2-5 show the Discontinuous (25 mA load for 2.4V V_{IN}) and Continuous mode waveforms (60 mA load at 2.4V V_{IN}, where the inductor peak current is close to the maximum input peak current limit of the MCP1640 device, 800 mA). Once the 800 mA limit is reached, V_{OUT} value is decreasing (goes out of regulation). The mean value of the inductor current (I_L) is equal for a boost converter with the input current (except the current consumption of MCP1640).

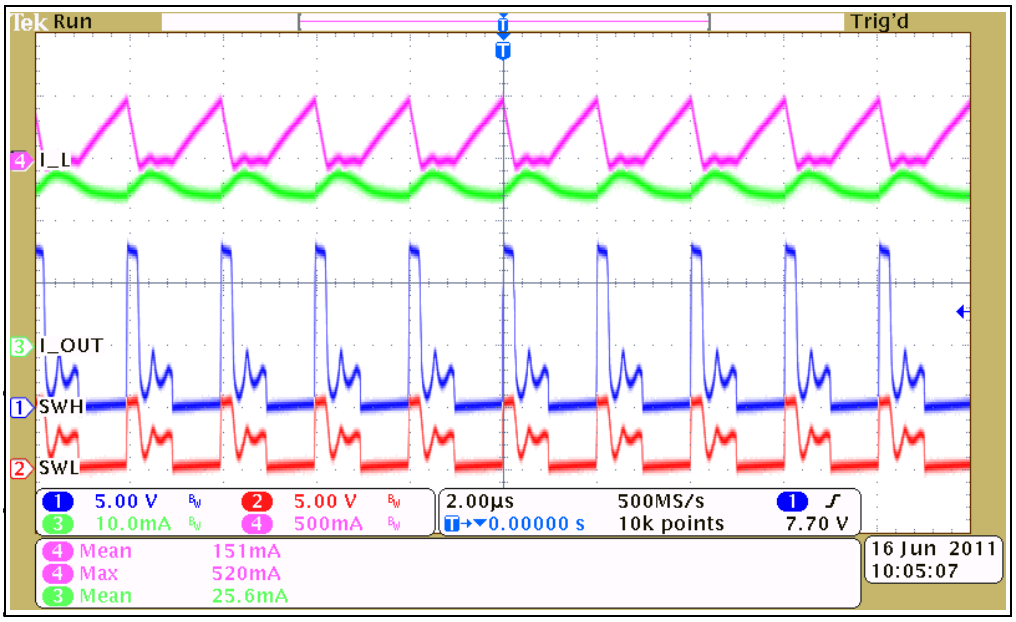


FIGURE 2-4: *MCP1640 12V/50 mA Two Cells Input Boost Converter Reference Design Test Points (SWH, SWL), Inductor (I_L) and Load Current (I_OUT) Waveforms for 25 mA Load and 2.4V Input in Discontinuous Mode.*

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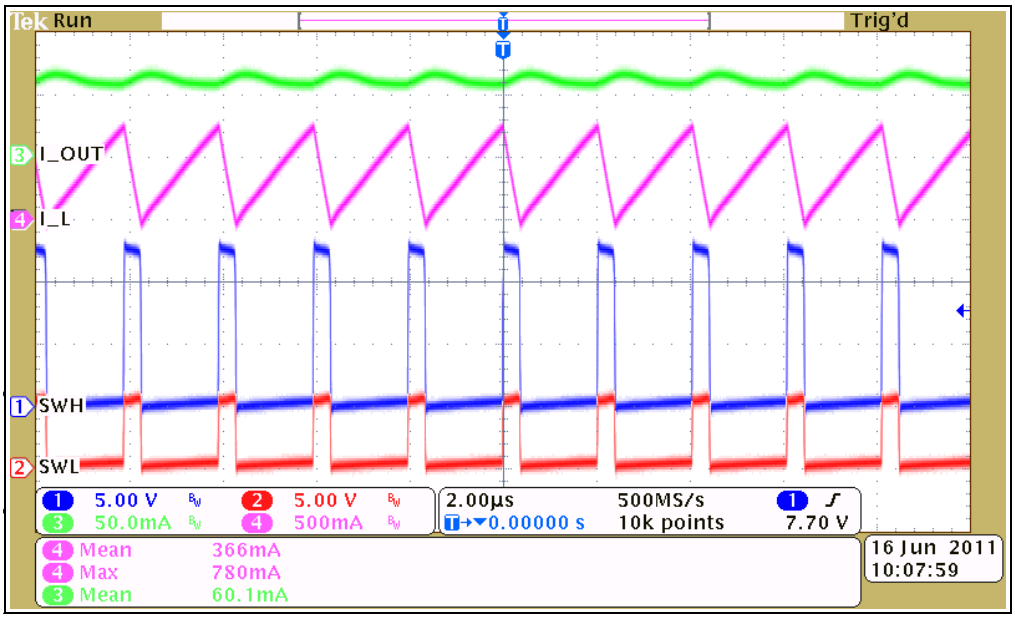


FIGURE 2-5: *MCP1640 12V/50 mA Two Cells Input Boost Converter Reference Design Test Points (SWH, SWL), Inductor (I_L) and Load Current (I_{OUT}) Waveforms for 60 mA Load and 2.4V Input in Continuous mode.*

2.2.3 How Does the MCP1640 12V/50 mA Two Cells Input Boost Converter Reference Design Works?

The board was designed to boost low voltage from two alkaline cells or NiCd/NiMH cells to high voltage. The topology used in this reference design is adapting a low-voltage boost converter into a high-voltage boost converter using a single inductor, instead of using a flyback topology that requires a more expensive flyback transformer. Another advantage is that the switching voltage spikes are kept below the safe value, 6V, for MCP1640 device's SW pin.

The converter is configured as nonsynchronous; an external diode, D, is connected between the inductor and the high-voltage output (V_{OUT}).

The two sense resistors, R_T and R_B, set the output (V_{OUT}) at 12.0V according to the following equation:

EQUATION 2-1:

$$R_T = R_B \times \left(\frac{V_{OUT}}{V_{FB}} - 1 \right)$$

Where:

V_{FB} = 1.21V
V_{FB} = Reference voltage of the FB pin
V_{OUT} = 12.0V
R_B = Resistor's value is selected by the designer

Note: The reference board is tested up to 24V output with a maximum load of 20 mA. The internal error amplifier is a transconductance type; its gain is not related to the feedback resistors' values.

Attention should be paid to the values of the sense resistors. When testing the board for other output voltage, a potential issue with higher value resistors is environmental contamination, which can create a leakage current path on the PCB. This will affect the feedback voltage and the output voltage regulation. Engineers should use resistors that are larger than 1 MΩ with precaution. In normal humidity conditions, the V_{FB} input leakage is very low and the resistors' values will not affect the stability of the system.

When the board is powered up, the internal MCP1640 device's start-up logic circuitry turns the internal rectifying switch on until the output capacitor, connected at the V_{OUT} pin (C_L), is charged to a value close to the input voltage. During start-up, the rectifying switch limits the maximum current. Because at start-up, the external n-channel MOS (Q) transistor is OFF, a start-up resistor (R_S) is bypassing it and the C_L cap is supplied. MCP1640 starts switching, and the external N-MOS is turned on, cascading the internal N-MOS switch of the MCP1640 to work with high voltage, more than 6V.

Notice that the MCP1640 is working internally as a synchronous rectifier and delivers on its output (Pin 5) a part of the total output power. This output is unregulated because the sense resistors, R_T and R_B, are connected to the high output voltage. The MCP1640 gets its start-up bias from V_{IN}. Once the output exceeds the input, bias comes from the output. The C_L capacitor is mandatory, because it smooths the output of MCP1640. This voltage is used to supply the internal blocks after start-up (including the compensation circuitry). In case of instability, a few mA loads may be required (R_L is not populated on the board; for 12V output, use a 2k or 3k resistor). On the output of MCP1640 (VO test point), a maximum 5 mA load can be connected. Exceeding the load produces unregulated board V_{OUT}.

The board works well in Discontinuous mode. However, once entered into Continuous mode, V_{OUT} goes out of regulation.

There is no undervoltage lockout feature for the MCP1640 family of devices. The device will start up at the lowest voltage possible and run down to the lowest voltage possible.

Note: Because this configuration is an nonsynchronous converter, the MCP1640 device's features, true disconnect output and short-circuit protection, will be lost for this reference board. In case of a short circuit, inductor L, and diode D, can be broken. Notice that the MCP1640 will not be affected.

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Appendix A. Schematic and Layouts

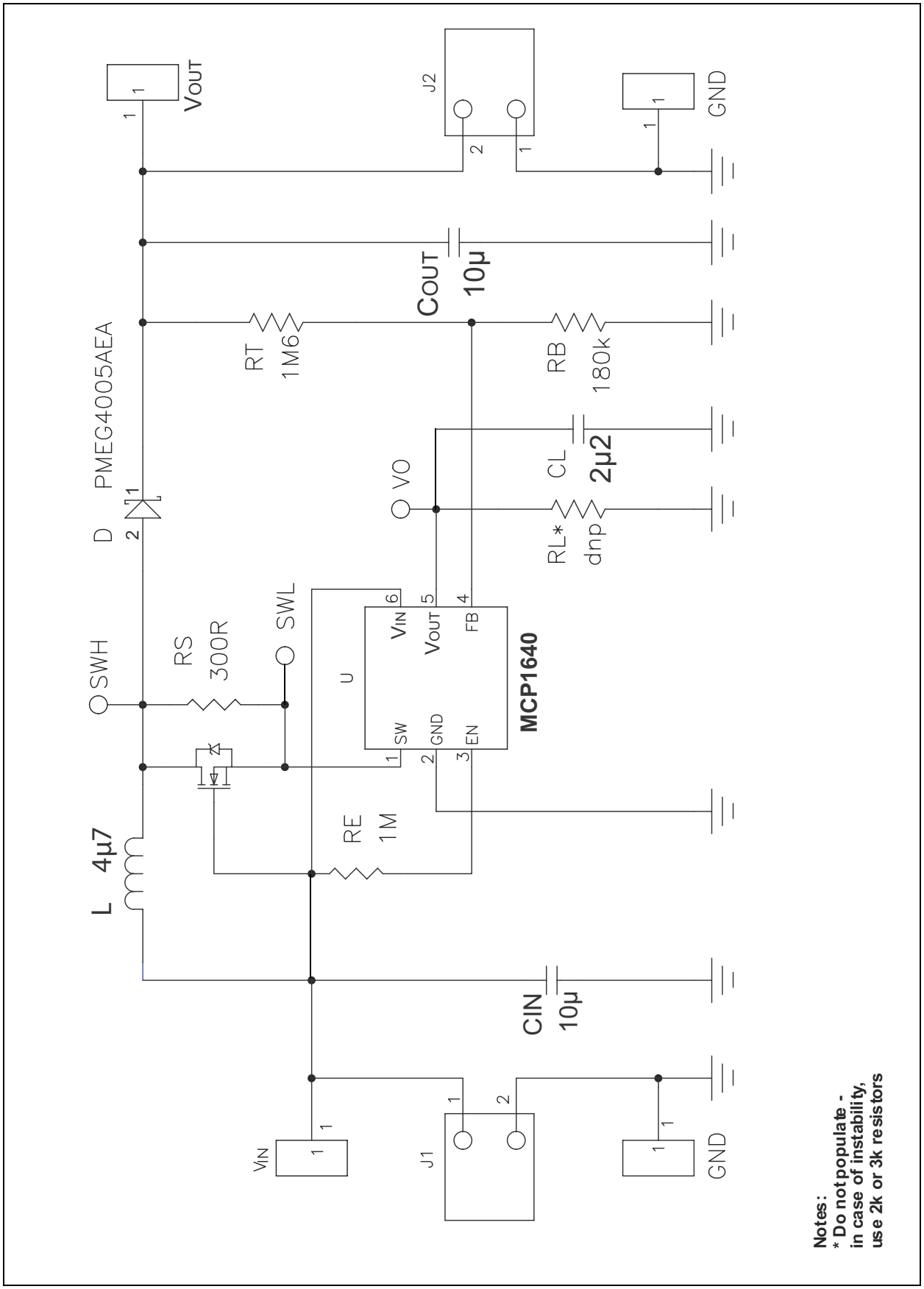
A.1 INTRODUCTION

This appendix contains the following schematics and layouts for the MCP1640 12V/50 mA Two Cells Input Boost Converter Reference Design:

- Board – Schematic
- Board – Top Silk and Pads
- Board – Top Copper and Pads
- Board – Bottom Copper and Pads

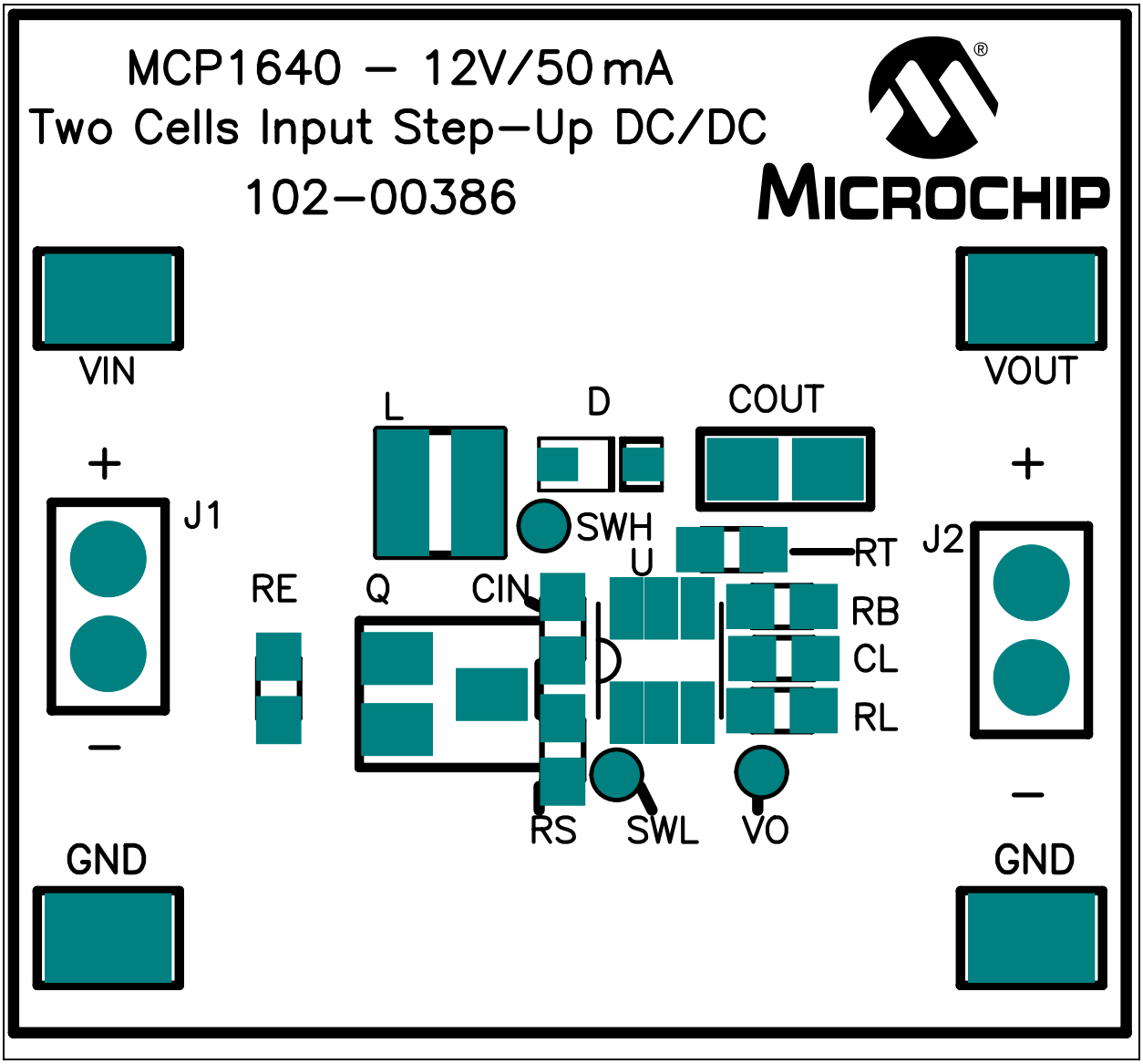
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A.2 BOARD – SCHEMATIC

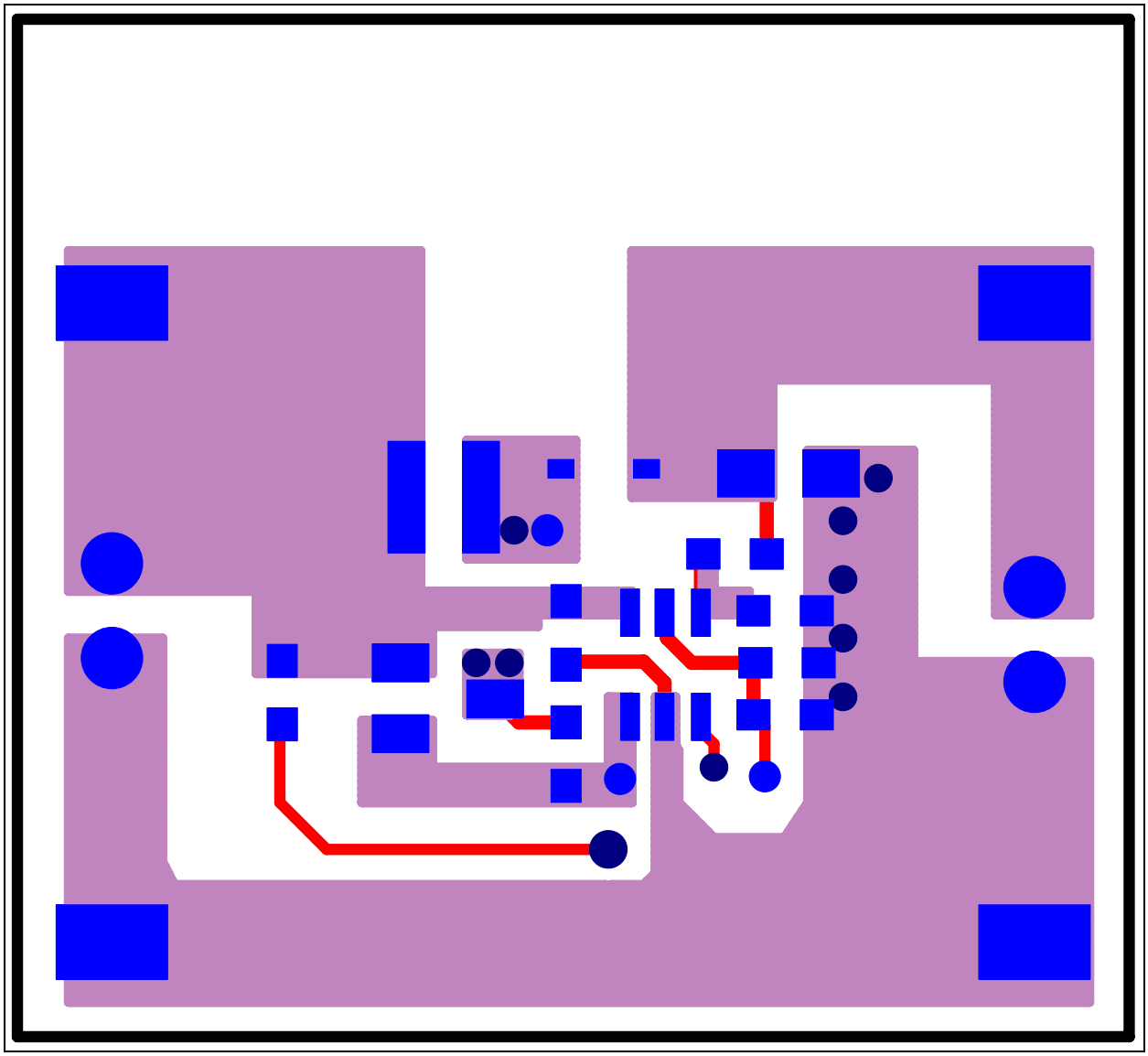


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A.3 BOARD – TOP SILK AND PADS

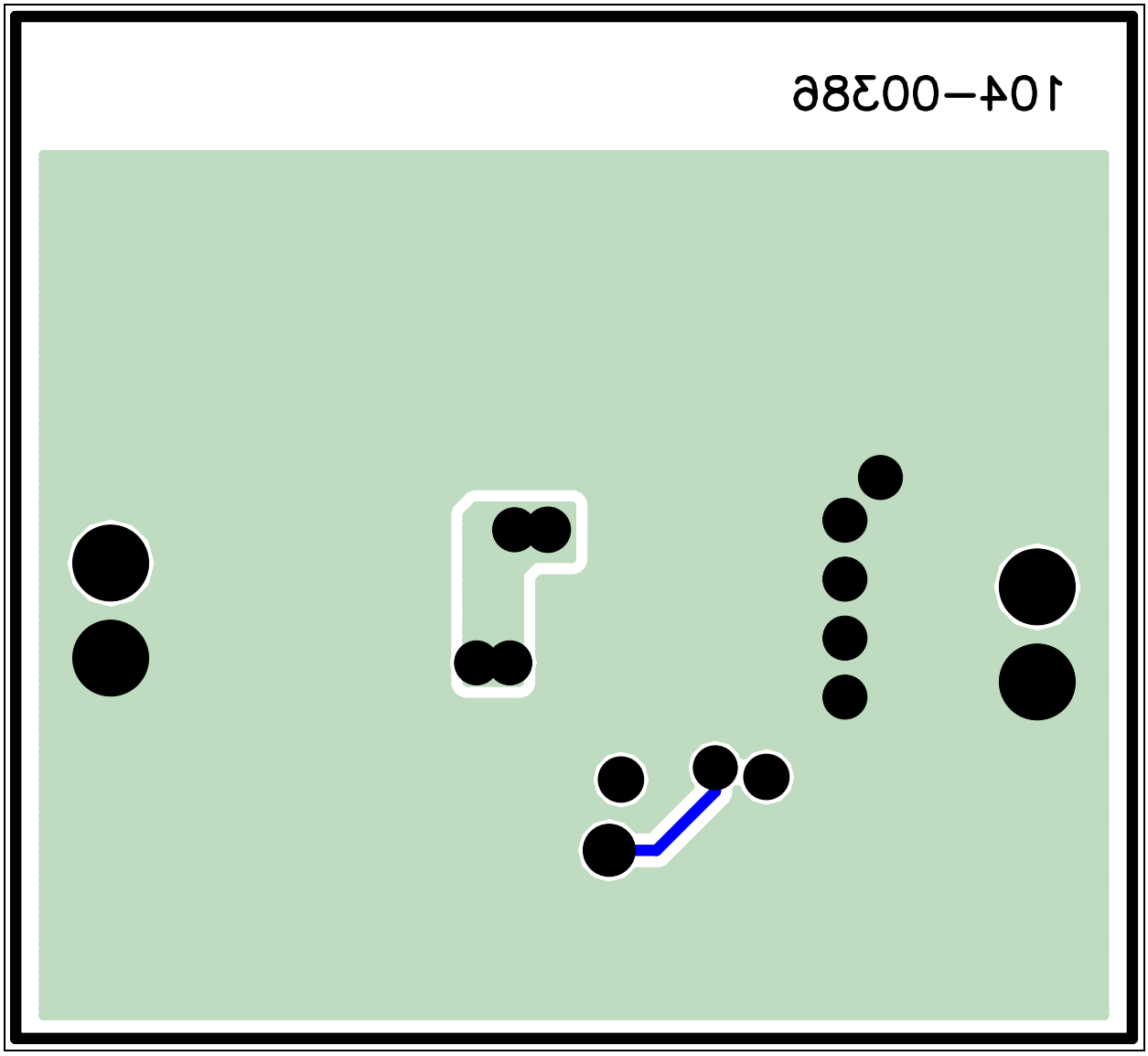


A.4 BOARD – TOP COPPER AND PADS



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A.5 BOARD – BOTTOM COPPER AND PADS



NOTES:

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Appendix B. Bill of Materials

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

Qty	Reference	Description	Manufacturer	Part Number
1	C_{IN}	CAP. CER 10 µF 6.3V X5R 20% 0603	TDK® Corporation	C1608X5R0J106M
1	C_{OUT}	CAP. CER 10 µF 16V X5R 0805	TDK Corporation	C2012X5R1C106M
1	C_L	CAP. CER 2.2 µF 6.3V X5R 20% 0603	TDK Corporation	C1608X5R0J225M
1	D	SCHOTTKY RECT. 40V 0.5A SOD323	NXP Semiconductors	PMEG4005AEA,115
0	J1, J2	DO NOT POPULATE CONN. HEADER 2POS .100" R/A TIN	Molex®	90121-0122
1	L	INDUCTOR POWER 4.7 µH 1.1A SMD	TDK Corporation	VLS3015ET-4R7M
1	PCB	RoHS-compliant bare PCB, MCP1640 12V/50 mA Two Cells Input Boost Converter Reference Design	—	104-00386
1	Q	MOSFET N-CH 30V 2.2A SSOT3	Fairchild Semiconductor®	FDN337N
1	R_E	RES. 1.0M OHM 1/10W 5% 0603 SMD	Panasonic® – ECG	ERJ-3GEYJ105V
1	R_S	RES. 300 OHM 1/10W 5% 0603 SMD	YAGEO®	RC0603JR-07300RL
0	R_L	DO NOT POPULATE RES. 1.0k OHM 1/10W 5% 0603 SMD	Panasonic – ECG	ERJ-3GEYJ102V
1	R_B	RES. 180k OHM 1/10W .5% 0603 SMD	YAGEO	RT0603DRD07180KL
1	R_T	RESISTOR 1.60M OHM 1/10W 1% 0603	Panasonic – ECG	ERJ-3EKF1604V
1	U1	MCP1640 PWM Synchronous Boost Converter – SOT23-6	Microchip Technology Inc.	**MCP1640BT-I/CHY**
4	V_{IN}, V_{OUT}, GND(s)	PC TEST POINT TIN SMD	Harwin PLC.	S1751-46R
4	—	3M – SJ5382TRANS – FEET, STICK ON, PK144	3M	SJ5382TRANS

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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