MIC9130
Power Over Ethernet IEEE802.3at PoE Plus PD Reference Design

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ISBN: 978-1-5224-2804-6

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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 MIC9130 Power Over Ethernet 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 MIC9130 Power Over Ethernet Reference Design as a compliant power solution. The manual layout is as follows:

- **Chapter 1. "Product Overview"** – Important information about the MIC9130 Power Over Ethernet Reference Design.
- **Chapter 2. "Installation and Operation"** – Includes instructions on installing and starting the MIC9130 Power Over Ethernet Reference Design.
- **Appendix A. "Schematic and Layouts"** – Shows the schematic and layout diagrams for the MIC9130 Power Over Ethernet Reference Design.
- **Appendix B. "Bill of Materials (BOM)"** – Lists the parts used to build the MIC9130 Power Over Ethernet Reference Design.
- **Appendix C. "Plots and Waveforms"** – Shows the MIC9130 Power Over Ethernet Reference Design waveforms and typical measurements.

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 MIC9130 Power Over Ethernet Reference Design. Another useful document is listed below. The following Microchip document is available and recommended as a supplemental reference resource:

- **MIC9130 Data Sheet – *"High-Voltage, High-Speed Telecom DC/DC Controller"* (DS20000000)**

THE MICROCHIP WEB SITE

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- **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

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- Local Sales Office
- Field Application Engineer (FAE)
- Technical Support

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

DOCUMENT REVISION HISTORY

Revision A (March 2018)

- Initial Release of this Document.

NOTES:

Chapter 1. Product Overview

1.1 INTRODUCTION

This chapter provides an overview of the MIC9130 Power Over Ethernet Reference Design and covers the following topics:

- MIC9130 Short Overview
- MIC9130 Key Features
- What Is the MIC9130 Power Over Ethernet Reference Design?
- What Does the MIC9130 Power Over Ethernet Reference Design Kit Include?

1.2 MIC9130 SHORT OVERVIEW

The MIC9130 is a current-mode PWM controller that efficiently converts –48V telecom voltages to logic levels. The MIC9130 features a high-voltage start-up circuit that allows the device to be connected to input voltages as high as 180V. The high input voltage capability protects the MIC9130 from line transients that are common in telecom systems. The start-up circuitry also saves valuable board space and simplifies designs by integrating several external components.

The MIC9130 is capable of high-speed operation. Typically the MIC9130 can control a sub-25ns pulse width on the gate out pin. Its internal oscillator can operate over 2.5 MHz, with even higher frequencies available through synchronization. The high-speed operation of the MIC9130 is made safe by the very fast, 34 ns response from current sense to output, minimizing power dissipation in a fault condition.

The MIC9130 allows for the designs of high-efficiency power supplies. It can achieve efficiencies of more than 90% at high-output currents. Its low 1.3 mA quiescent current allows high efficiency even at light loads.

The MIC9130 has a maximum duty cycle of 50%. For designs requiring a high duty cycle, refer to the MIC9131 data sheet. The MIC9130 is available in 16-pin SOP and QSOP package options.The rated junction temperature range is from –40°C to +125°C.

1.3 MIC9130 KEY FEATURES

- Input voltage up to 180V
- Internal oscillator capable of > 2.5 MHz operation
- Synchronization capability to 4 MHz
- Current sense delay of 34 ns
- Minimum pulse width < 25 ns
- 90% efficiency
- 1.3 mA quiescent current
- 1.0 µA shutdown current
- Soft-start
- Resistor programmable current sense threshold
- Selectable soft-start retry
- 4Ω sink, 12Ω source output driver

- Programmable undervoltage lockout
- Constant-frequency PWM current-mode control
- 16-pin SOIC and 16-pin QSOP packages

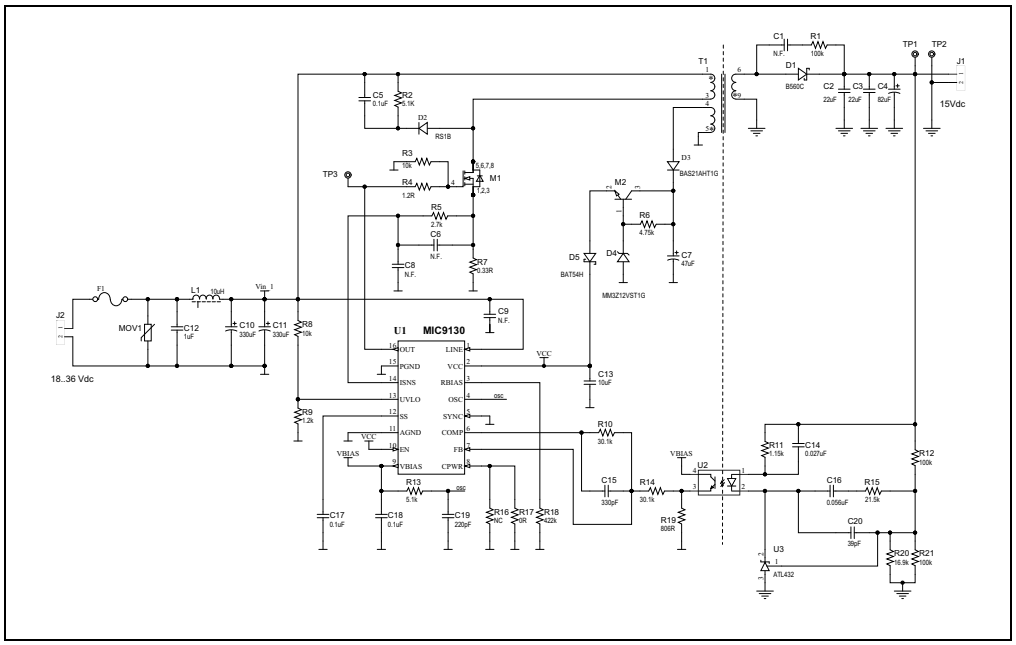


FIGURE 1-1: *MIC9130 Typical Application Circuit.*

1.4 WHAT IS THE MIC9130 POWER OVER ETHERNET REFERENCE DESIGN?

The MIC9130 Power over Ethernet, PoE, Powered Device (PD) Reference Design is designed to offer a complete IEEE802.3at PoE Plus compliant power solution.

The board includes an integrated solution (NCP1093), PoE signature and classification circuit, an EMI filter, and an isolated FLYBACK DC/DC converter using the MIC9130 controller. The MIC9130 is a high-speed current-mode PWM controller that features a high-voltage start-up circuit that enables the device to operate directly from 36V to 57V Power Sourcing Equipment (PSE) source voltage.

When a powered Ethernet cable is plugged into the board, the front-end handshaking circuit will apply the correct signature and classification impedances to accept power from the PSE. At the application of the power from the PSE, with input voltages between 36V and 57V, the DC/DC FLYBACK converter will engage and generate a 18.3V output with up to 1.7A of output current.

This board is for use with IEEE802.3at PoE Plus enabled Switch/Routers which provide power to the Ethernet cable as defined in IEEE802.3at PoE Plus PSE requirements.

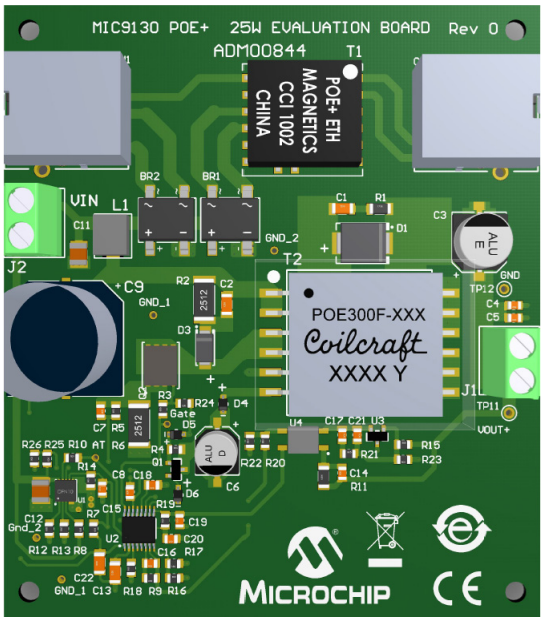


FIGURE 1-2: *ADM00844 3D View.*

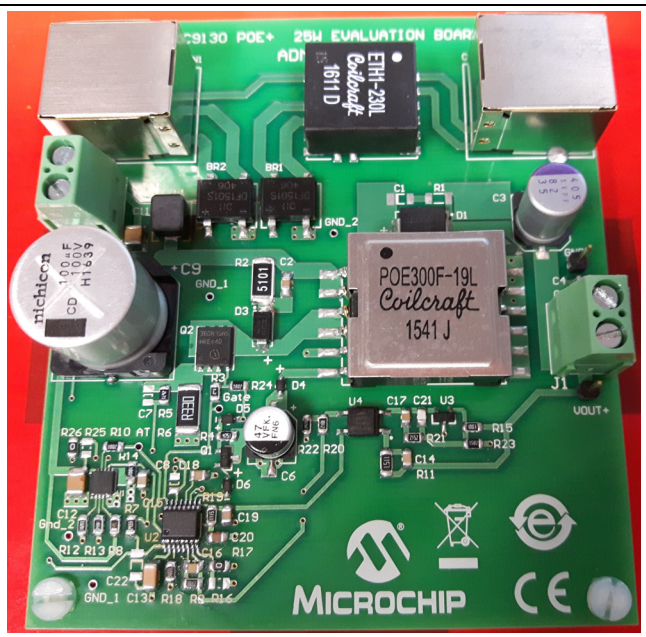


FIGURE 1-3: *ADM00844 Board.*

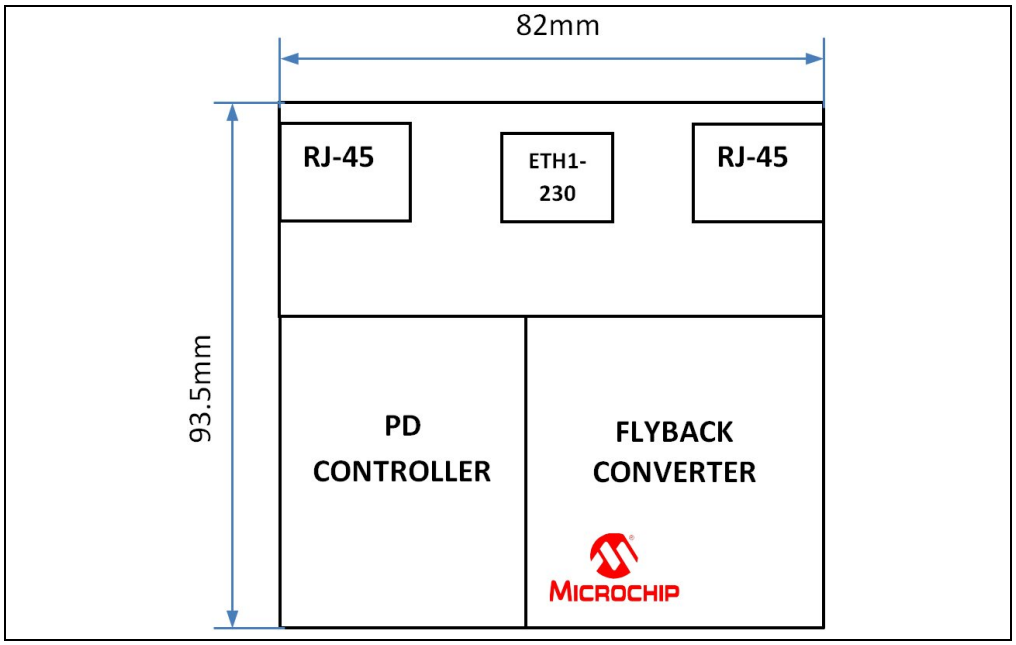


FIGURE 1-4: *Top View: ADM00844 Layout and Dimensions.*

1.5 WHAT DOES THE MIC9130 POWER OVER ETHERNET REFERENCE DESIGN KIT INCLUDE?

The MIC9130 Power Over Ethernet Reference Design kit includes the following items:

- MIC9130 Power Over Ethernet Reference Design (ADM00844)
- Important Information Sheet

Chapter 2. Installation and Operation

2.1 INTRODUCTION

Explanations are provided for board setup with PSE and discrete setup. The MIC9130 Power Over Ethernet Reference Design kit set is fully tested to evaluate and demonstrate a complete IEEE802.3at PoE Plus compliant power solution and the MIC9130 controller.

2.2 BOARD FEATURES

The MIC9130 Power Over Ethernet Reference Design (ADM00844), has the following features:

- Input voltage: 36V to 57V input voltage
- 18.3V output voltage
- Output capability: up to 1.7A
- RJ45 input and output connectors
- NCP1093 a PoE-PD IC that fully supports IEEE 802.3af/at specifications and includes a hot swap switch control and current limit block
- EMI filter
- Low cost single winding transformer
- MIC9130 DC/DC flyback converter
- > 3750VAC isolation
- 400 kHz fixed frequency PWM control
- Efficiency: over 90%
- Maximum output power: 30W

2.3 HOW DOES THE MIC9130 POWER OVER ETHERNET WORK?

When the RJ45 connector is plugged into a PSE, the front-end handshaking circuit applies the correct signature and classification impedances to gain power from the power source.

At the application of the power, the FLYBACK primary circuit is applied with 36V to 57V. This then converts power to the secondary circuit at 18.3V up to 1.7A.

For detailed explanation on DC/DC converter operation, refer to the MIC9130 data sheet.

2.4 SETUP AND TESTING THE BOARD PROCEDURE

2.4.1 Board Setup with PSE

Follow these steps to set up the board with available 802.3af compliant PSE:

1. Plug-in a IEEE 802.3af compliant powered Ethernet cable into RJ45_1 I input connector.
2. After the automatic handshake sequence, 18.3V are applied to post PL1.
3. Data from the input is available at output connector RJ45_2.

2.4.2 Board Discrete Setup

Follow these steps to set up the board discretely to emulate 802.3af power sourcing equipment:

1. Plug-in one end of CAT5 Ethernet cable into RJ45_1 connector, with the wires of the other end exposed.
2. Connect banana plug termination to brown, blue, orange, and green pairs.
3. Prepare test gear:
   a) One Power Supply Unit PSU capable of supplying 60V with a 1A current limit.
   b) Two Digital Volt Meters (DVMs) with 60V measuring capability
   c) Two Ampere meters: 300 µA to 400 mA range (input side), and 2.5A rated for output side.
   d) One Electronic Load, 18.3V capable set to 2A.
4. Apply test setup.
5. Turn ON all measurement devices.
6. Check Signature:
   a) Set PSU to 9V.
   b) Ammeter 1 should read between 280 µA to 368 mA (Class4).
7. Check Classification:
   a) Set PSU to: 14.5V to 20.5V range.
   b) Ammeter 1 should read between 36 mA to 44 mA (Class4).
8. DC/DC Power Supply Turn On and Start-up:
   a) Set PSU to: 36V to 57V range.
   b) DMV2 at the PL1 post should read 18.3V ± 1%.
   c) Ammeter 2 should read between 1.7A ± 1%.

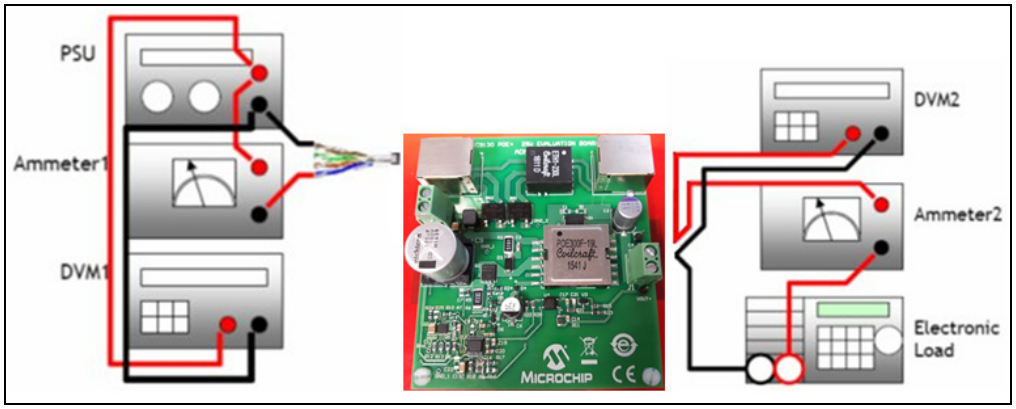


FIGURE 2-1: *Connection Diagram.*

2.5 POWERED DEVICE (PD) CONTROLLER CIRCUIT

The integrated PD interface supports the IEE 802.3af defined operating modes:

- Detection signature
- Current source classification
- Inrush current limits
- Operating current limits

2.5.1 Detection Signature

During the detection phase, the incremental equivalent resistance seen by PSE through the cable must be in the IEEE 802.3at standard specification range (23.70 kΩ to 26.30 kΩ) for a PSE voltage from 2.7V to 10.1V. In order to compensate for the nonlinear effect of the diode bridge and satisfy the specification at low PSE voltage, the NCP1093 presents a suitable impedance in parallel with 24.9 kΩ R_{DET} (R8) external resistor. During the detection phase, the DET pin is pulled to ground and goes in High Impedance mode (open-drain) once the device exits this mode, thus reducing the current consumption on the cable.

2.5.2 Classification

Once the PSE device has detected the PD device, the classification process begins. In classification, the PD regulates a constant current source that is set by the external resistor R_{CLASS} (R13) value on the CLASS pin.

The current source is defined as:

EQUATION 2-1:

$$I_{CLASS} = 9.8V / R_{CLASS}$$

Table 2-1 shows how to configure the MIC9130 Power Over Ethernet classification circuit to set a Classification Level.

TABLE 2-1: CLASSIFICATION CIRCUIT CONFIGURATION

Class	Input Current VIN = 15.4V to 20.5 V	PD Power Class	Component Modification
Class 0	0 mA - 4 mA	0.5W to 12.95W	R13 = 4k9
Class 1	9 mA - 12 mA	0.5W to 3.8W	R13 = 933
Class 2	7 mA - 20 mA	3.8W to 6.5W	R13 = 726
Class 3	26 mA - 30 mA	6.5W to 12.95W	R13 = 350
Class 4	36 mA - 44 mA	Not defined	R13 = 255

2.5.3 Front End Analog Handshaking Limits

Table 2-2 shows the designed limits of the board.

TABLE 2-2: ADM00844 LIMITS

Description	Test Condition	Min.	Max.
Signature Test (Resistance)	V_{IN} = 2.7V to 10.1V	23.7 kΩ	26.3 kΩ
Classification Test, Class 4 (Line Current)	V_{IN} = 14.5V to 20.5V	36 mA	44 mA
DC/DC Full Power (Line Current)	V_{IN} = 36V to 57V; I_{OUT} = 1.7A V_{OUT} = 18.3V	627 mA	994 mA

2.5.4 Power Mode

When the classification handshake is completed, the PSE and PD device move into Operating mode.

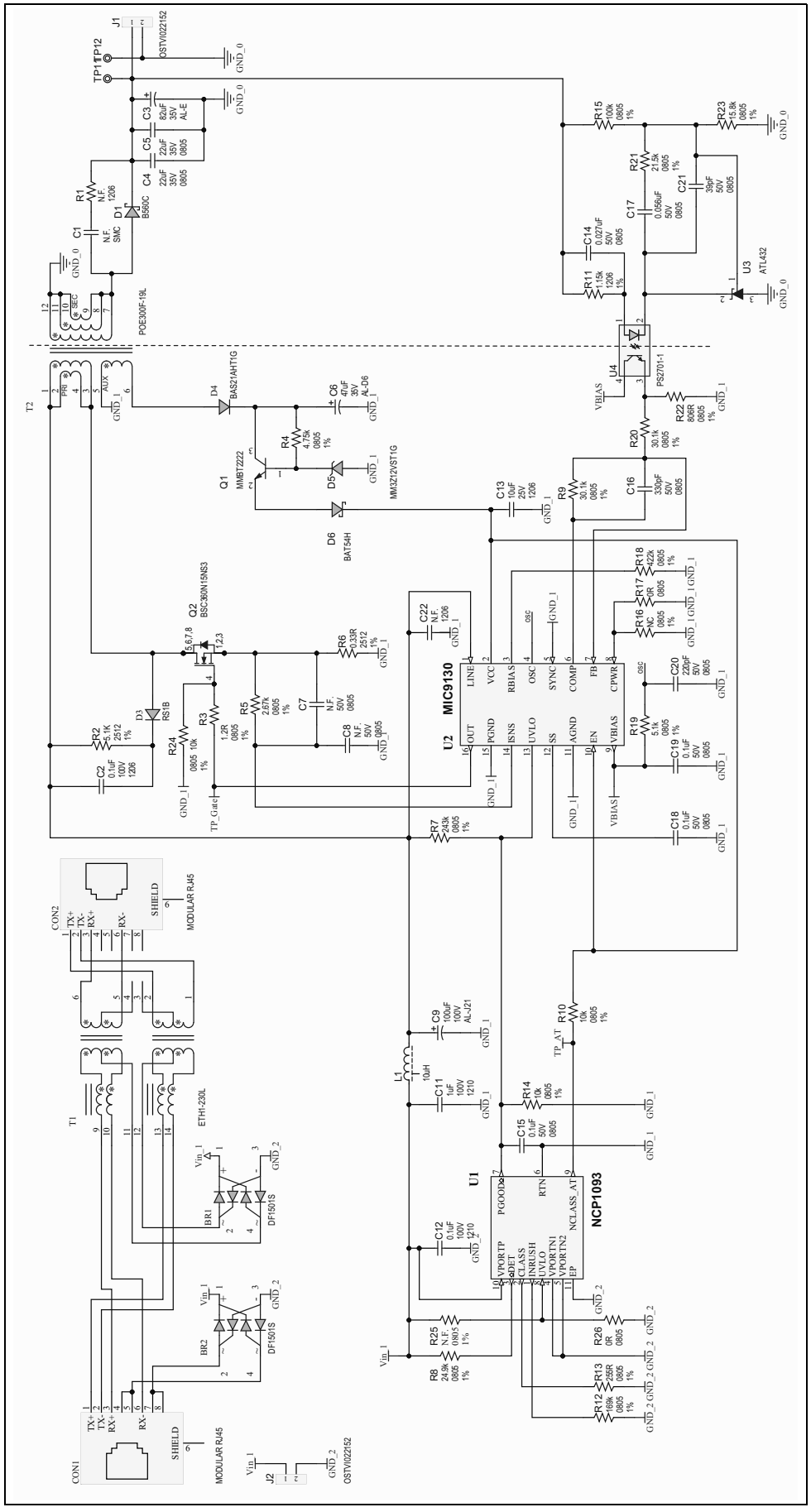
Appendix A. Schematic and Layouts

A.1 INTRODUCTION

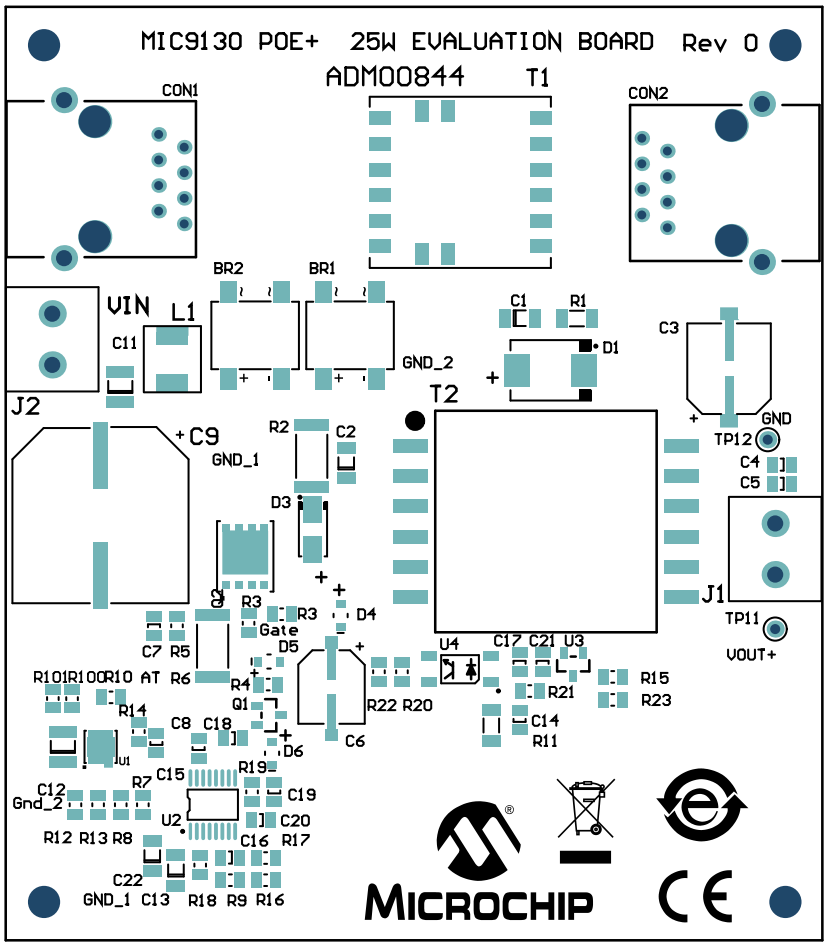
This appendix contains the following schematics and layouts for the MIC9130 Power Over Ethernet Reference Design:

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

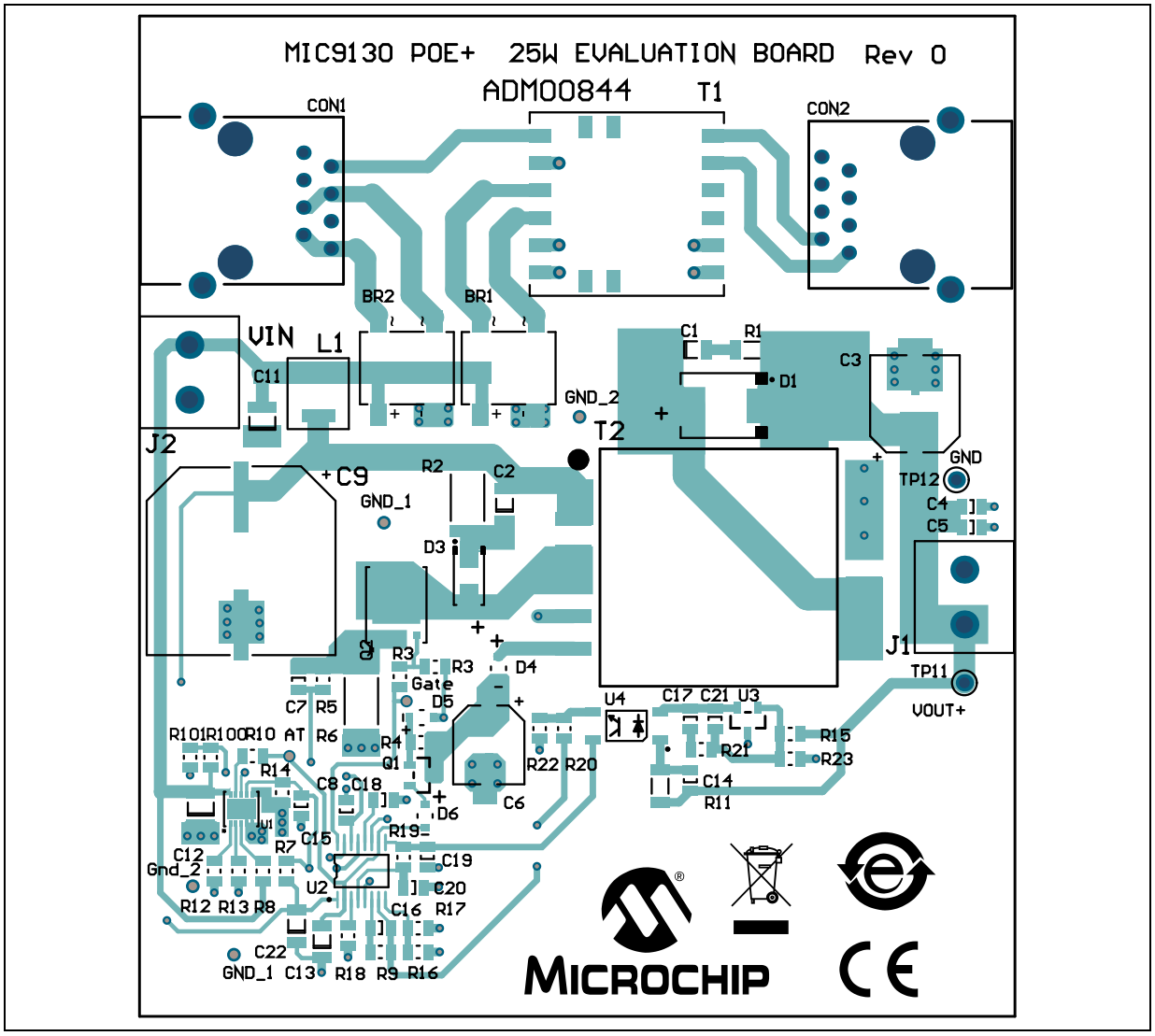
A.2 BOARD – SCHEMATIC



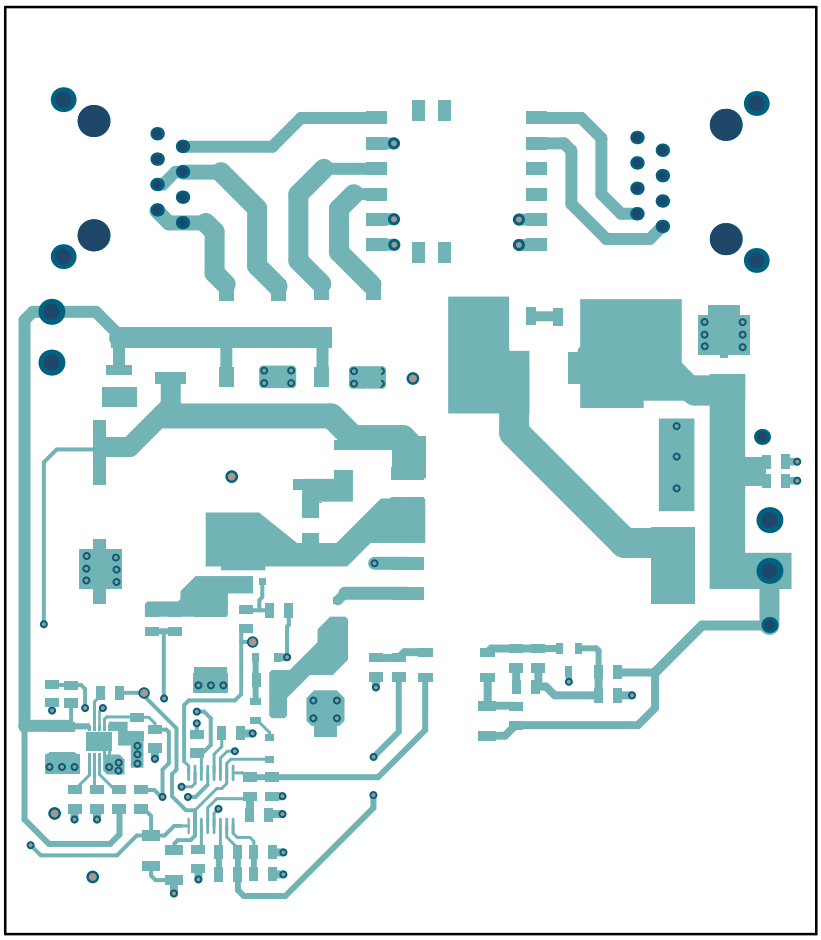
A.3 BOARD – TOP SILK LAYER



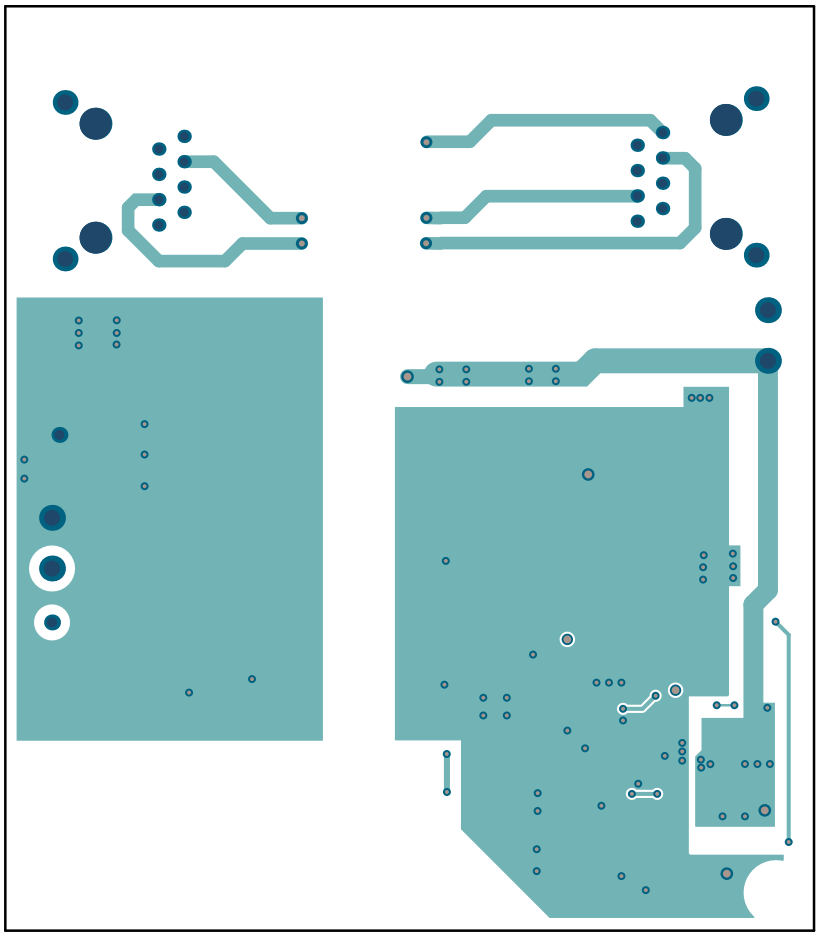
A.4 BOARD – TOP COPPER AND SILK LAYER



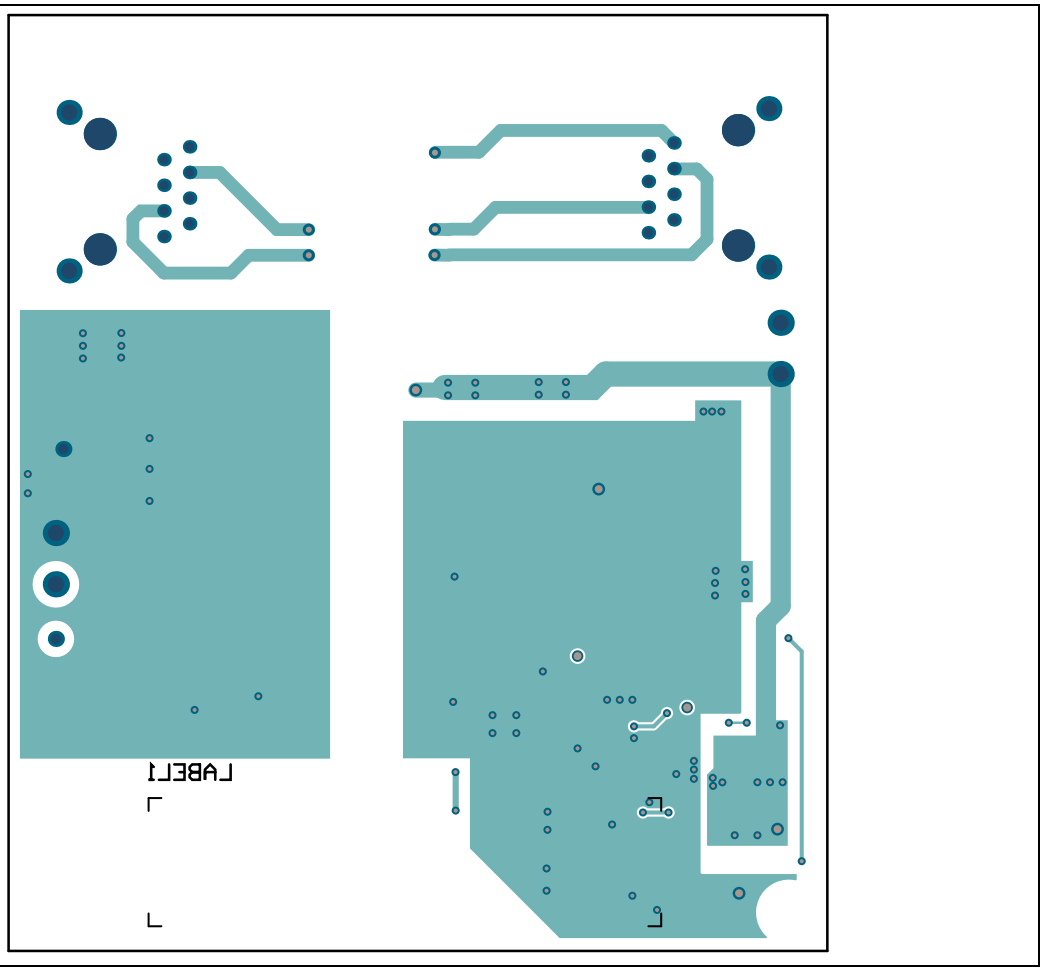
A.5 BOARD – TOP COPPER LAYER



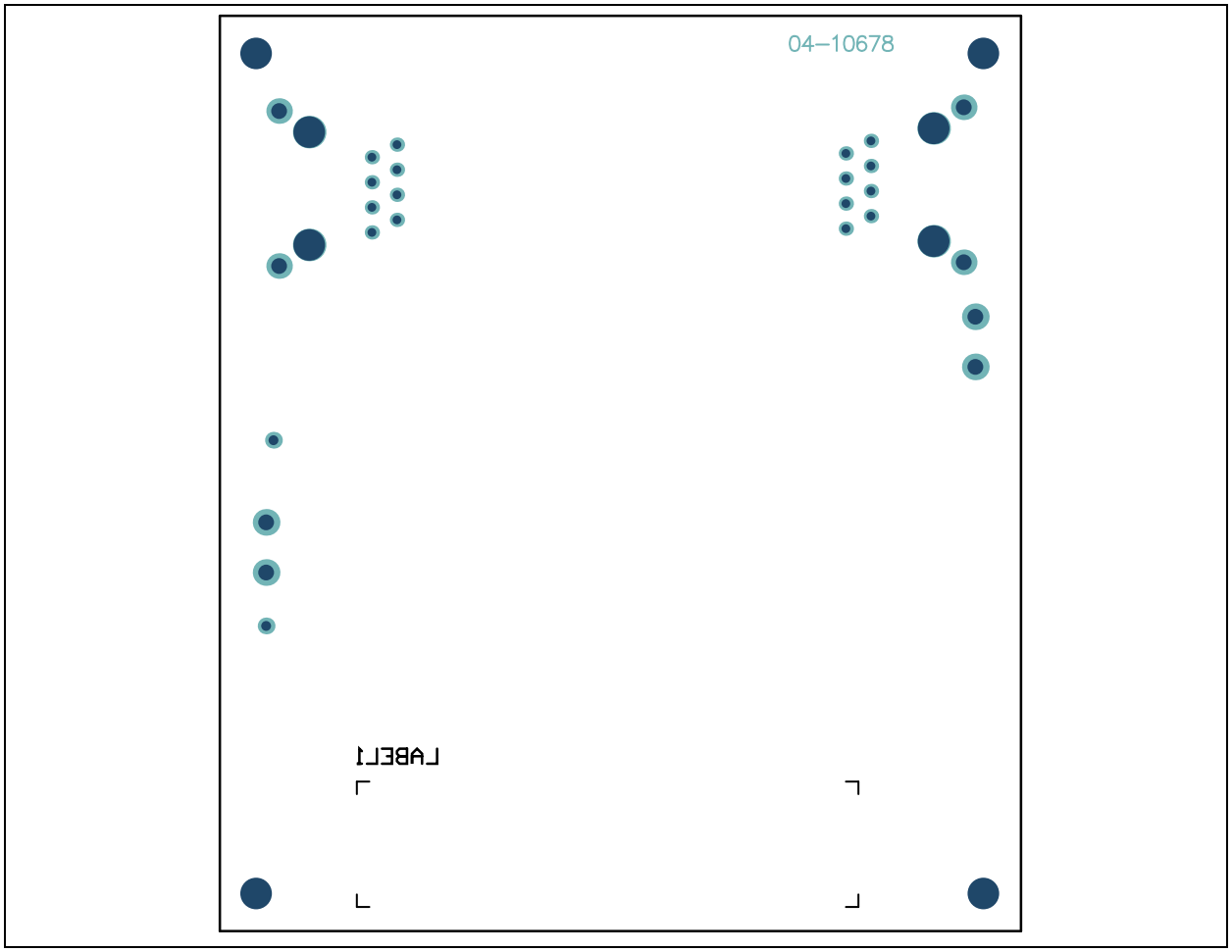
A.6 BOARD – BOTTOM COPPER LAYER



A.7 BOARD – BOTTOM COPPER AND SILK LAYER



A.8 BOARD – BOTTOM SILK LAYER



Appendix B. Bill of Materials (BOM)

TABLE B-1: BILL OF MATERIALS (BOM) FOR MIC9130 POWER OVER ETHERNET REFERENCE DESIGN (ADM00844)(1)

Qty.	Reference	Description	Manufacturer	Part Number
2	BR1, BR2	Bridge rectifier, single phase standard 100V, surface mount DF-S	Diodes Incorporated®	DF1501S-T
1	C1	Capacitor ceramic 10 µF, ±10%, 6.3V, X5R, 1206, (3216 Metric)	Yageo Corporation	CC1206KKX5R5BB106
1	C2	Capacitor ceramic 0.1 µF, 100V, 10%, X7R, SMD, 1206	Yageo Corporation	CC1206KKX7R0BB104
1	C3	Aluminum polymer capacitor radial, 82 µF, 35V, Can-SMD, 20 mΩ, 5000 Hours at 105°C	Panasonic® - ECG	35SVPF82M
2	C4, C5	Capacitor ceramic 22 µF, 35V, 20%, JB, SMD, 0805	TDK Corporation	C2012JB1V226M125AC
1	C6	Aluminum electrolytic capacitors 47 µF, 35V, Radial, Can - SMD, 1000 Hours at 105°C	Nichicon Corporation	UWT1V470MCL1GS
5	C7, C8, C15, C18, C19	Capacitor ceramic 0.1 µF, 50V, 10%, X7R, SMD, 0805	Yageo Corporation	CC0805KRX7R9BB104
1	C9	Capacitor aluminum 100 µF, 100V, 20%, SMD, J21	Nichicon Corporation	UCD2A101MNQ1MS
1	C11	Capacitor ceramic 1 µF, 100V, 20%, X7R, SMD, 1210	TDK Corporation	C3225X7R2A105M200AA
1	C12	Capacitor ceramic 0.1 µF, 100V, 10%, X7R, SMD, 1210	KEMET	C1210C104K1RACTU
1	C13	Capacitor ceramic10 µF, ±10%, 16V, X7R, 1206, (3216 Metric)	Yageo Corporation	CC1206KKX7R7BB106
1	C14	Capacitor ceramic 0.027 µF, 50V, 10%, X7R, SMD, 0805	Yageo Corporation	CC0805KRX7R9BB273
1	C16	Capacitor ceramic 330 pF, 50V, 10%, X7R, SMD, 0805	Yageo Corporation	CC0805KRX7R9BB331
1	C17	Capacitor ceramic 0.056 µF, 50V, 10%, X7R, SMD, 0805	KEMET	C0805C563K5RACTU
1	C20	Capacitor ceramic 220 pF, 50V, C0G/NPO, 0805	Yageo Corporation	CC0805JRNPO9BN221
1	C21	Capacitor ceramic 39 pF, 50V, 10%, C0G, SMD, 0805	KEMET	C1210C104K1RACTU
1	C22	Capacitor ceramic 2.2 µF, 100V, 10%, X7S, SMD, 1206	TDK Corporation	C3216X7S2A225K160AB
2	CON1, CON2	Jack modular connector, 8p8c (RJ45, Ethernet), 90°Angle (Right) Shielded, Cat3	Molex®	956223981
1	D1	Diode schottky, B560C, 5A, 60V, SMD, DO-214AB_SMC	Diodes Incorporated®	B560C-13-F

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)FOR MIC9130 POWER OVER ETHERNET REFERENCE DESIGN (ADM00844)[1]

Qty.	Reference	Description	Manufacturer	Part Number
1	D3	Diode standard, 100V, 1A, surface mount, SMA	Diodes Incorporated®	RS1B-13-F
1	D4	Diode standard, 250V, 200 mA (DC), surface mount, SOD-232	ON Semiconductor®	BAS21AHT1G
1	D5	Diode zener, 12V, 200MW, SOD323	ON Semiconductor®	MM3Z12VST1G
1	D6	Diode schottky, BAT54H, 30V, 0.2A, SMD, SOD-323	ON Semiconductor®	NSVBAT54HT1G
2	J1, J2	2 position wire-to-board terminal block, horizontal with board, 5.08 mm, through hole	On-Shore Technology, Inc.	OSTVI022152
1	L1	Inductor Hi SRF, Shlded, 10 uH, 1.7A, 10%, SMD 1812	Coilcraft	1812PS-103KLB
1	PCB	MIC9130 Power Over Ethernet Reference Design Printed Circuit Board	Microchip Technology Inc.	**04-10678**
1	Q1	Bipolar transistors, BJT SS SOT23, GP, XSTR, NPN, 30V	ON Semiconductor®	MMBT2222ALT3G
1	Q2	N-Channel, 150V, 33A (Tc), 74W (Tc), surface mount, PG-TDSON-8	Infineon Technologies AG	BSC360N15NS3GATMA1
1	R1	Resistor, TKF, 100k, 1%, 1/4W, SMD, 1206	Panasonic® - ECG	ERJ-8ENF1003V
1	R2	Resistor, TKF, 5.1k, 1%, 1W, SMD, 2512	Panasonic® - ECG	ERJ1TNF5101U
1	R3	Resistor, TKF, 1.2R, 1%, 1/8W, SMD, 0805	Panasonic® - ECG	ERJ-6RQF1R2V
1	R4	Resistor, TKF, 4.75K, 1%, 1/8W, SMD, 0805	Panasonic® - ECG	ERJ-6ENF4751V
1	R5	Resistor, TKF, 2.67k, 1%, 1/8W, SMD, 0805	Yageo Corporation	RC0805FR-072K67L
1	R6	Resistor, TKF, 0.33R, 1%, 1W, SMD, 2512	Vishay/Dale	WSL2512R3300FEA
1	R7	Resistor, TKF, 243k, 1%, 1/8W, SMD, 0805	Yageo Corporation	RC0805FR-07243KL
1	R8	Resistor, TF, 24.9k, 1%, 1/4W, SMD, 0805	Stackpole Electronics, Inc,	RNCP0805FTD24K9
2	R9, R20	Resistor, TKF, 30.1k, 1%, 1/8W, SMD, 0805	Yageo Corporation	RC0805FR-0730K1L
3	R10, R14, R24	Resistor, TKF, 10k, 1%, 1/8W, SMD, 0805	Panasonic® - ECG	ERJ-6ENF1002V
1	R11	Resistor, TKF, 1.15K, 1%, 0.25W, SMD, 1206	Yageo Corporation	RC1206FR-071K15L
2	R12, R16	Resistor, TKF, 169k, 1%, 1/8W, SMD, 0805	Panasonic® - ECG	ERJ-6ENF1693V
1	R13	Resistor, TKF, 255R, 1%, 1/8W, SMD, 0805	Yageo Corporation	RC0805FR-07255RL
1	R15	Resistor, TKF, 100k, 1/8W, 1%, SMD, 0805	Panasonic® - ECG	ERJ-6ENF1003V
2	R17, R26	Resistor, TKF, 0R, 1/8W, SMD, 0805	Panasonic® - ECG	ERJ-6GEY0R00V
1	R18	Resistor, TKF, 422k, 1%, 1/8W, SMD, 0805	Panasonic® - ECG	ERJ-6ENF4223V
1	R19	Resistor, SMD, 5.1 kΩ, 1%, 1/8W, 0805	TE Connectivity, Ltd.	CRG0805F5K1
1	R21	Resistor, TKF, 21.5k, 1%, 1/8W, SMD, 0805	Yageo Corporation	RC0805FR-0721K5L
1	R22	Resistor, TKF, 806R, 1%, 1/8W, SMD, 0805	Yageo Corporation	RC0805FR-07806RL
1	R23	Resistor, TKF, 15.8k, 1%, 1/8W, SMD, 0805	Yageo Corporation	RC0805FR-0715K8L
1	R25	Resistor, TKF, 64.9k, 1%, 1/8W, SMD, 0805	Vishay/Dale	CRCW080564K9FKEA
1	T1	Signal transformer ETH1, 30W, 2 pairs PoE plus magnetic module, SMD	Coilcraft	ETH1-230L
1	T2	Flyback transformer, 1:0.56,1:0.33, 36V–72V, SMD	Coilcraft	POE300F-19L

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)FOR MIC9130 POWER OVER ETHERNET REFERENCE DESIGN (ADM00844)(1)

Qty.	Reference	Description	Manufacturer	Part Number
1	U1	Power over Ethernet controller, 1-Channel, 802.3at (PoE+), 802.3af (PoE) 10-DFN (3 x 3)	ON Semiconductor®	NCP1093MNRG
1	U2	MCHP ANALOG PWM CONTROLLER, 2.5 MHz, MIC9130YQS, QSOP-16	Microchip Technology Inc.	MIC9130YQS
1	U3	IC POWER, ATL432AQDBZR, Shunt Voltage Reference, SOT-23-3	Texas Instruments	ATL432AQDBZR
1	U4	IC PHOTO HCPL-181 4-SMD	Avago Technologies	HCPL-181-00CE

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. Plots and Waveforms

C.1 FLYBACK CONVERTER PERFORMANCE

V_{IN} = 36V to 57V.

Efficiency ~85% at full load.

$V_{(OUT\ RIPPLE)}$ < 150 mV.

Load Regulation = 0.1% at V_{IN} = 48V.

C.2 BOARD SET TYPICAL WAVEFORMS

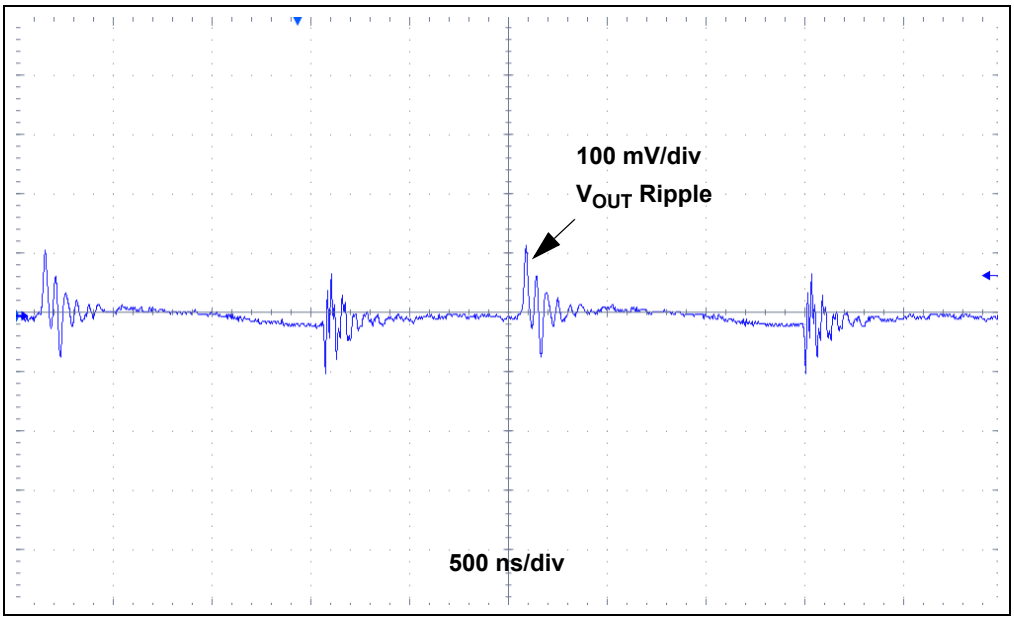


FIGURE C-1: *V_{OUT} Ripple.*

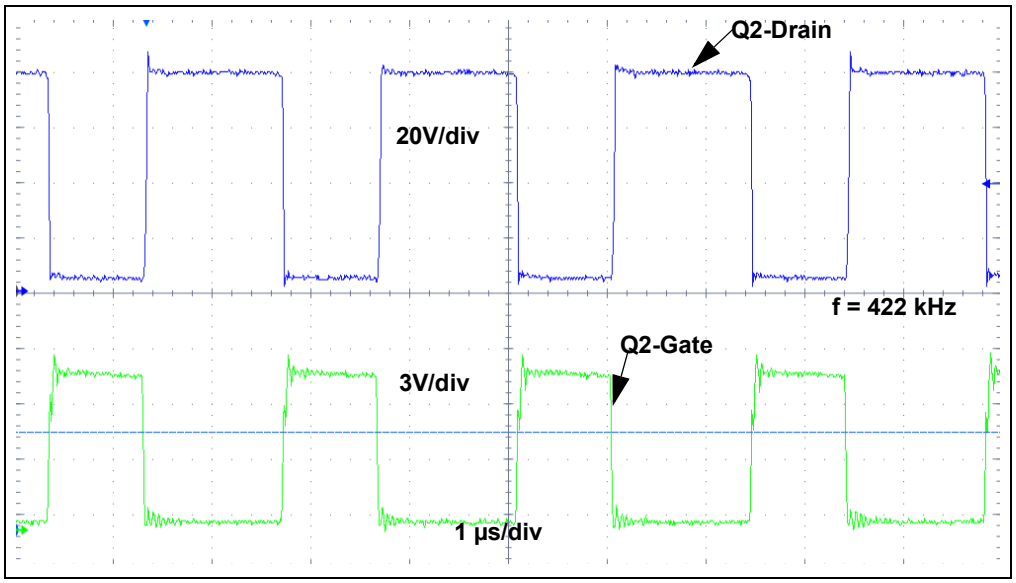


FIGURE C-2: *Switching Edges, Q2 Gate and Drain Voltage.*

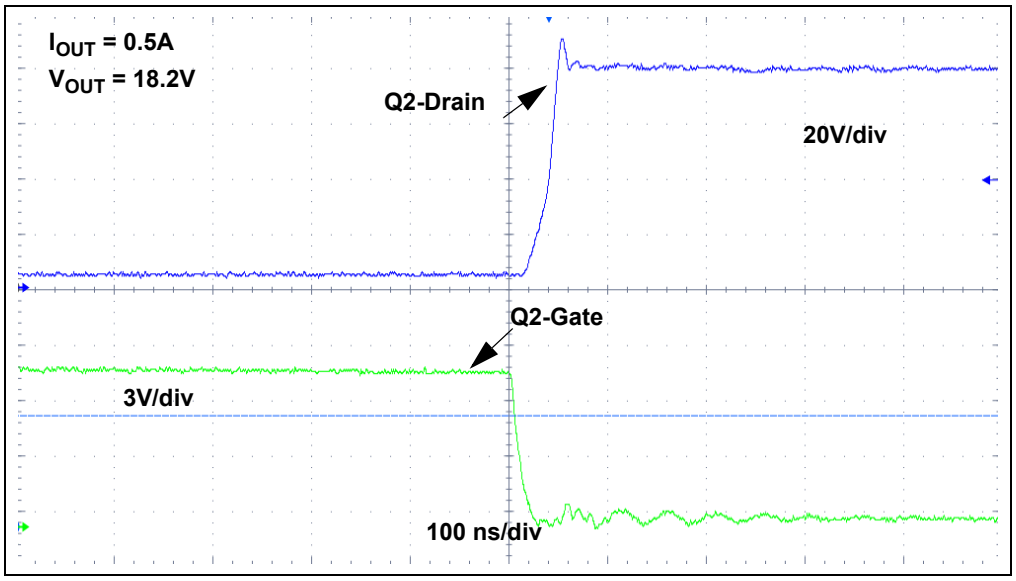


FIGURE C-3: *Switching Edges, Q2 Gate and Drain Voltage.*

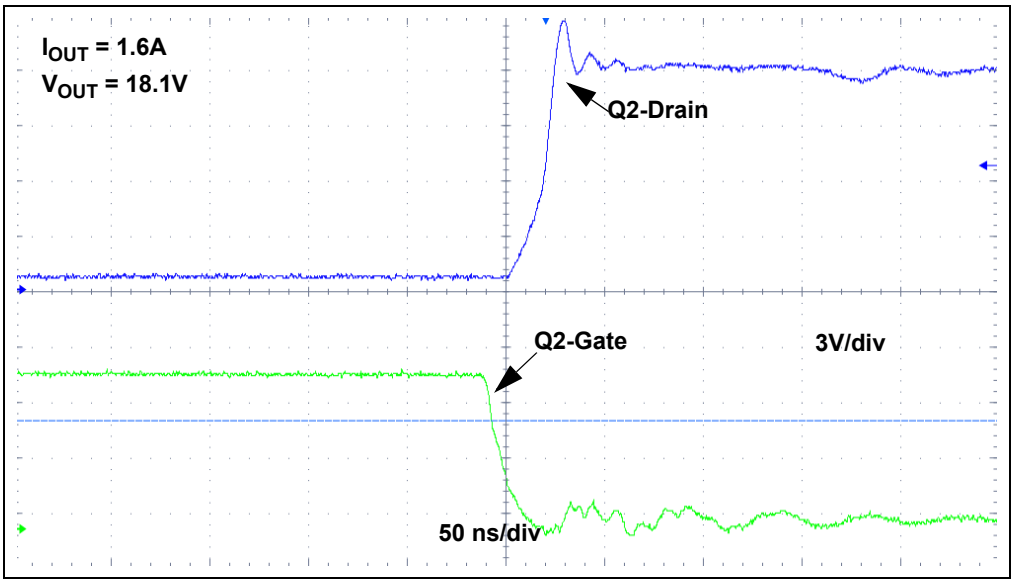


FIGURE C-4: *Switching Edges, Q2 Gate and Drain Voltage.*

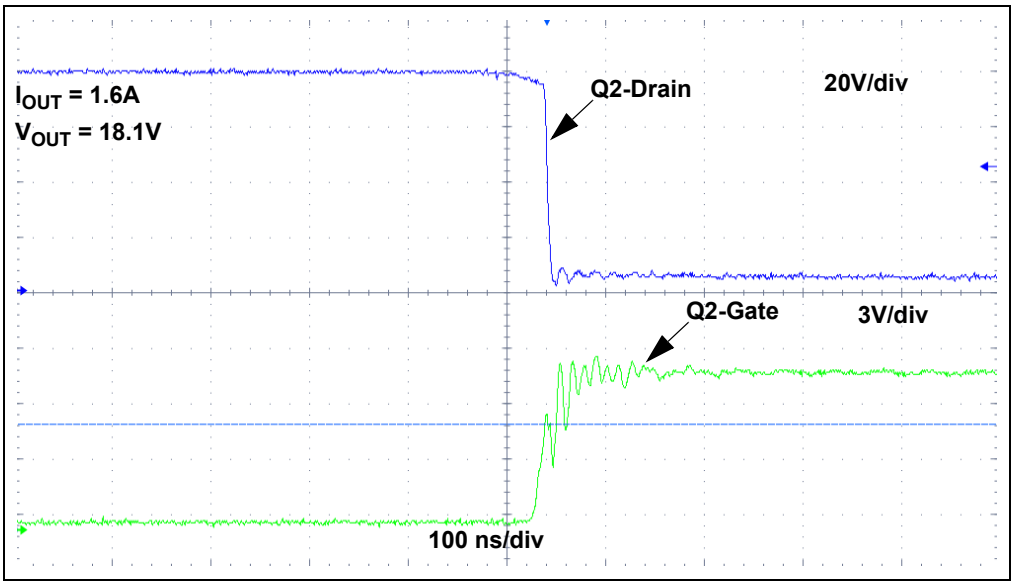


FIGURE C-5: *Switching Edges, Q2 Gate and Drain Voltage.*

C.2.1 Bode Plot

Resistive Load 12.8Ω, 1.4A, P_{OUT} = 25W

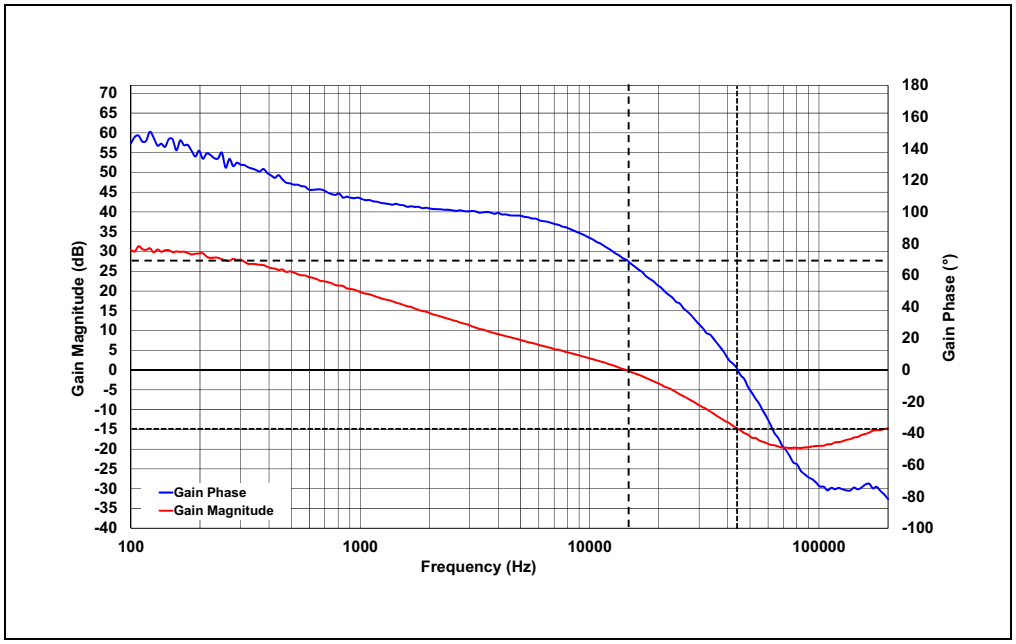


FIGURE C-6: *Gain Magnitude and Gain Phase vs. Frequency for 48V Input. Gain Margin, GM = 14.9 dB, Phase Margin, PM = 69.6°.*

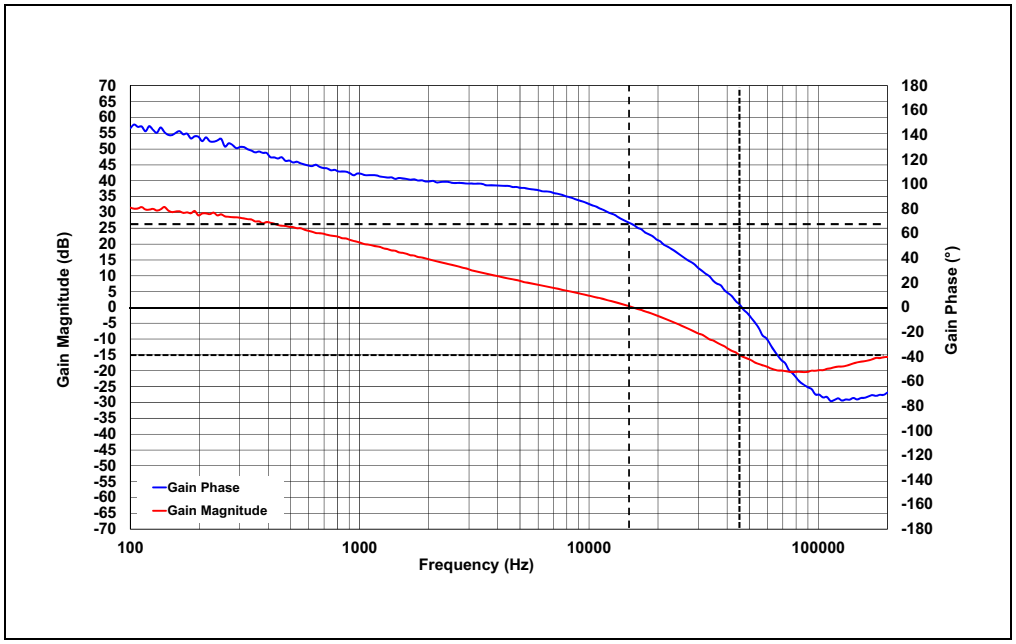


FIGURE C-7: *Gain Magnitude and Gain Phase vs. Frequency for 60V Input. Gain Margin, GM = 15.5 dB, Phase Margin, PM = 67.5°.*

C.3 BOARD SET TYPICAL MEASUREMENTS

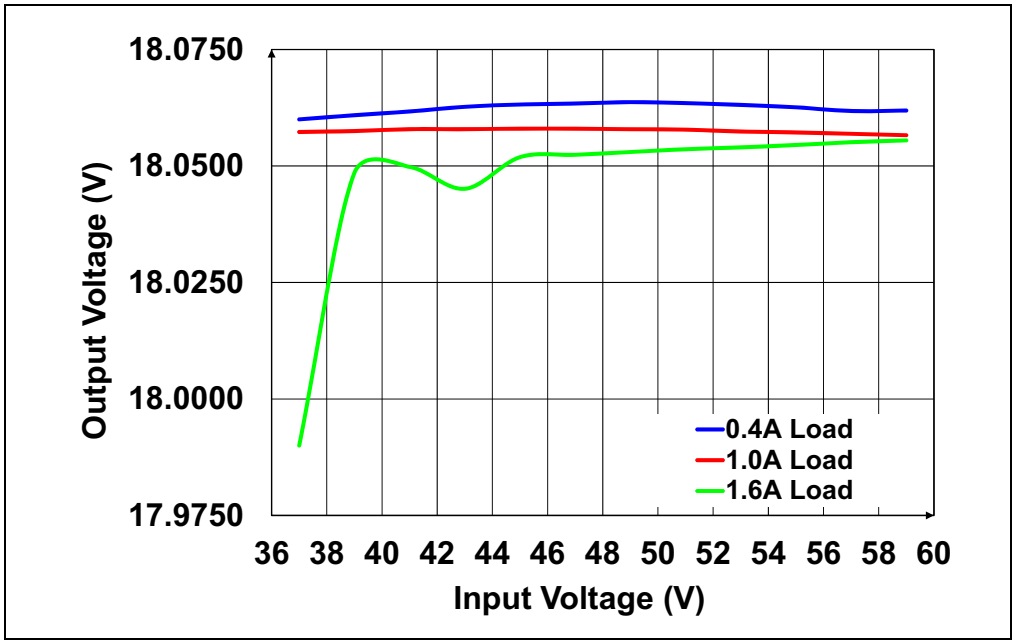


FIGURE C-8: *Line Regulation - Output Voltage vs. Input Voltage.*

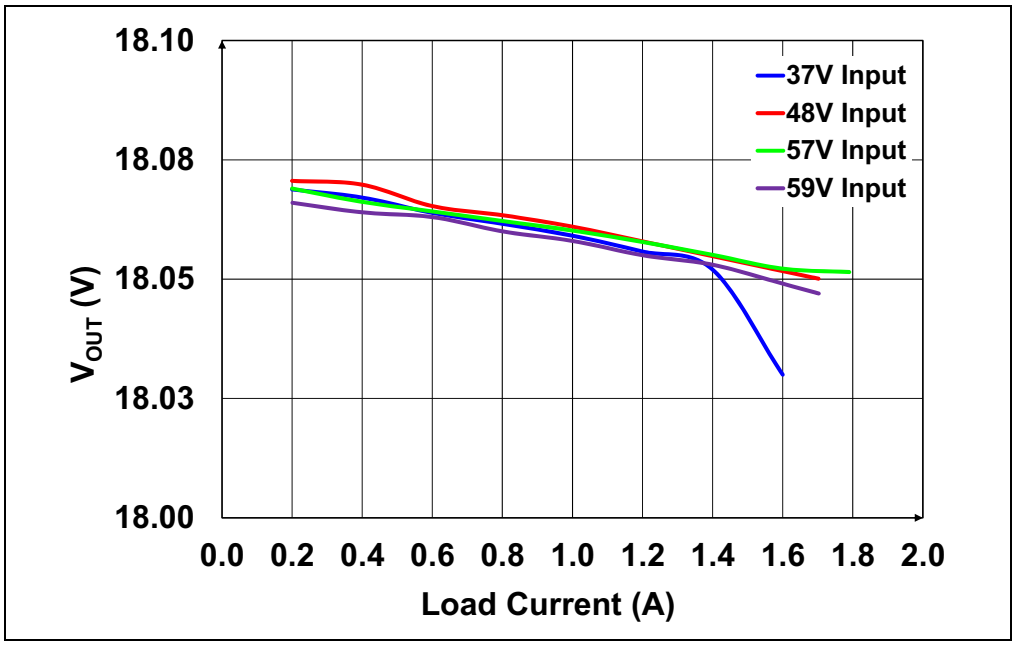


FIGURE C-9: *Load Regulation - Output Voltage vs. Output Current.*

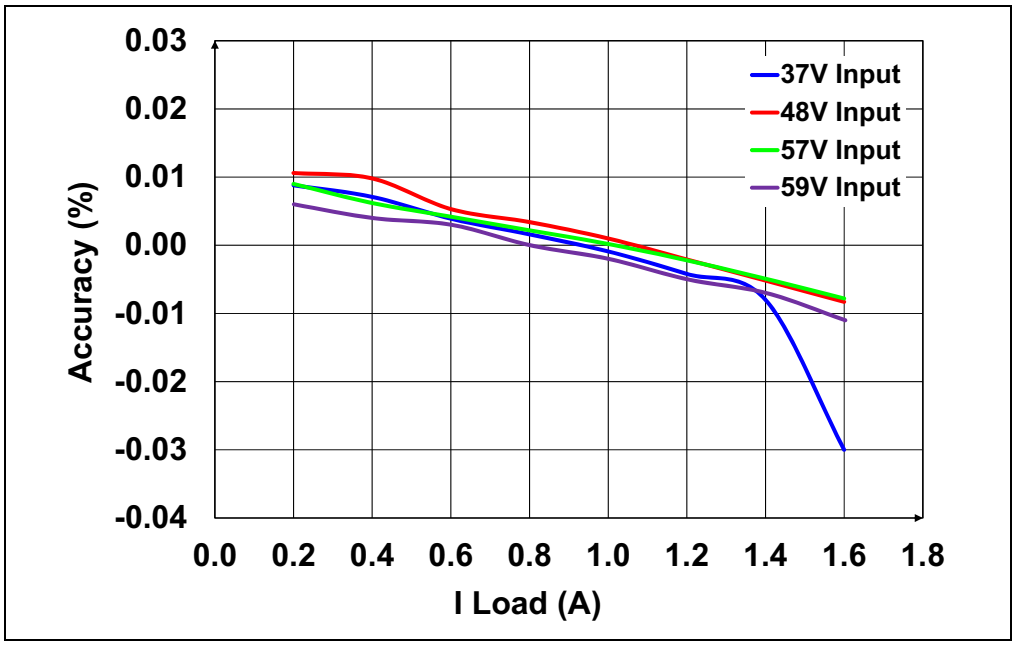


FIGURE C-10: *Output Voltage Accuracy - V_{OUT} Accuracy vs. Output Current.*

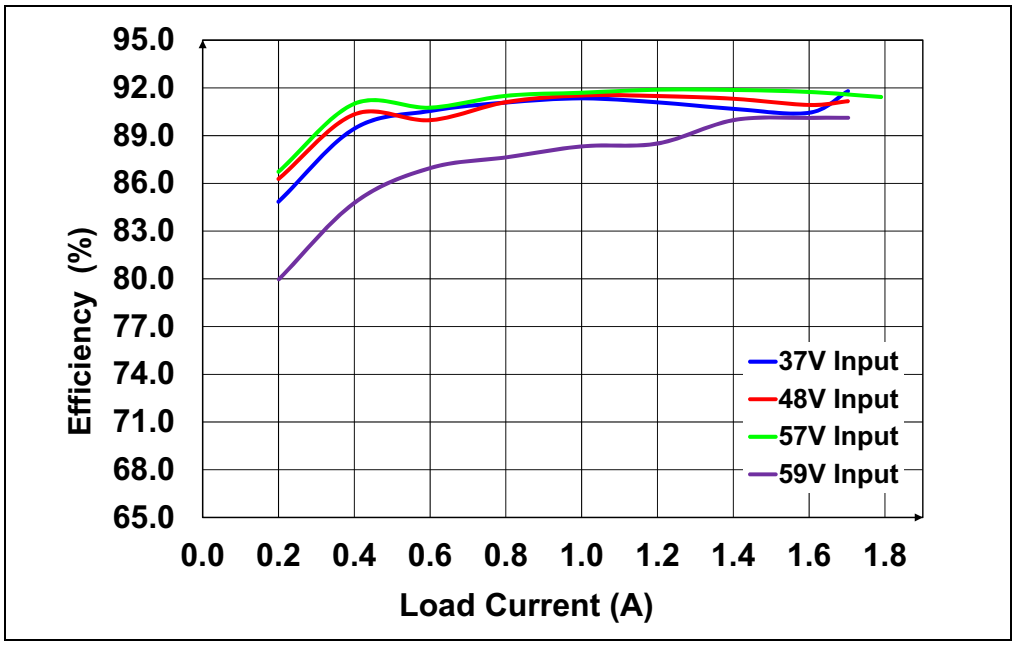


FIGURE C-11: *Efficiency vs. Load Current at Different Input Voltages.*

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