



MCP19111
PMBus™ Protocol-Enabled
Point-of-Load (POL) Converter
Reference Design
User's Guide

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

- Microchip products meet the specification contained in their particular Microchip Data Sheet.
- Microchip believes that its family of products is one of the most secure families of its kind on the market today, when used in the intended manner and under normal conditions.
- There are dishonest and possibly illegal methods used to breach the code protection feature. All of these methods, to our knowledge, require using the Microchip products in a manner outside the operating specifications contained in Microchip's Data Sheets. Most likely, the person doing so is engaged in theft of intellectual property.
- Microchip is willing to work with the customer who is concerned about the integrity of their code.
- Neither Microchip nor any other semiconductor manufacturer can guarantee the security of their code. Code protection does not mean that we are guaranteeing the product as "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.

Information contained in this publication regarding device applications and the like is provided only for your convenience and may be superseded by updates. It is your responsibility to ensure that your application meets with your specifications. MICROCHIP MAKES NO REPRESENTATIONS OR WARRANTIES OF ANY KIND WHETHER EXPRESS OR IMPLIED, WRITTEN OR ORAL, STATUTORY OR OTHERWISE, RELATED TO THE INFORMATION, INCLUDING BUT NOT LIMITED TO ITS CONDITION, QUALITY, PERFORMANCE, MERCHANTABILITY OR FITNESS FOR PURPOSE. Microchip disclaims all liability arising from this information and its use. Use of Microchip devices in life support and/or safety applications is entirely at the buyer's risk, and the buyer agrees to defend, indemnify and hold harmless Microchip from any and all damages, claims, suits, or expenses resulting from such use. No licenses are conveyed, implicitly or otherwise, under any Microchip intellectual property rights unless otherwise stated.

Trademarks

The Microchip name and logo, the Microchip logo, dsPIC, FlashFlex, flexPWR, JukeBlox, KEELOQ, KEELOQ logo, Kleer, LANCheck, MediaLB, MOST, MOST logo, MPLAB, OptoLyzer, PIC, PICSTART, PIC³² logo, RightTouch, SpyNIC, SST, SST Logo, SuperFlash and UNI/O are registered trademarks of Microchip Technology Incorporated in the U.S.A. and other countries.

The Embedded Control Solutions Company and mTouch are registered trademarks of Microchip Technology Incorporated in the U.S.A.

Analog-for-the-Digital Age, BodyCom, chipKIT, chipKIT logo, CodeGuard, dsPICDEM, dsPICDEM.net, ECAN, In-Circuit Serial Programming, ICSP, Inter-Chip Connectivity, KleerNet, KleerNet logo, MiWi, MPASM, MPF, MPLAB Certified logo, MPLIB, MPLINK, MultiTRAK, NetDetach, Omniscient Code Generation, PICDEM, PICDEM.net, PICtail, RightTouch logo, REAL ICE, SQI, Serial Quad I/O, Total Endurance, TSHARC, USBCheck, VariSense, ViewSpan, WiperLock, Wireless DNA, and ZENA are trademarks of Microchip Technology Incorporated in the U.S.A. and other countries.

SQTP is a service mark of Microchip Technology Incorporated in the U.S.A.

Silicon Storage Technology is a registered trademark of Microchip Technology Inc. in other countries.

GestIC is a registered trademarks of Microchip Technology Germany II GmbH & Co. KG, a subsidiary of Microchip Technology Inc., in other countries.

All other trademarks mentioned herein are property of their respective companies.

© 2015, Microchip Technology Incorporated, Printed in the U.S.A., All Rights Reserved.

ISBN: 978-1-63277-476-7

QUALITY MANAGEMENT SYSTEM
CERTIFIED BY DNV
= ISO/TS 16949 =

Microchip received ISO/TS-16949:2009 certification for its worldwide headquarters, design and wafer fabrication facilities in Chandler and Tempe, Arizona; Gresham, Oregon and design centers in California and India. The Company's quality system processes and procedures are for its PIC® MCUs and dsPIC® DSCs, KEELOQ® code hopping devices, Serial EEPROMs, microperipherals, nonvolatile memory and analog products. In addition, Microchip's quality system for the design and manufacture of development systems is ISO 9001:2000 certified.

Object of Declaration: MCP19111 PMBus™ Protocol-Enabled POL Converter Reference Design

EU Declaration of Conformity

Manufacturer: Microchip Technology Inc.
2355 W. Chandler Blvd.
Chandler, Arizona, 85224-6199
USA

This declaration of conformity is issued by the manufacturer.

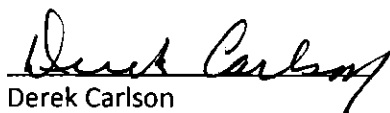
The development/evaluation tool is designed to be used for research and development in a laboratory environment. This development/evaluation tool is not a Finished Appliance, nor is it intended for incorporation into Finished Appliances that are made commercially available as single functional units to end users under EU EMC Directive 2004/108/EC and as supported by the European Commission's Guide for the EMC Directive 2004/108/EC (8th February 2010).

This development/evaluation tool complies with EU RoHS2 Directive 2011/65/EU.

This development/evaluation tool, when incorporating wireless and radio-telecom functionality, is in compliance with the essential requirement and other relevant provisions of the R&TTE Directive 1999/5/EC and the FCC rules as stated in the declaration of conformity provided in the module datasheet and the module product page available at www.microchip.com.

For information regarding the exclusive, limited warranties applicable to Microchip products, please see Microchip's standard terms and conditions of sale, which are printed on our sales documentation and available at www.microchip.com.

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


Derek Carlson
VP Development Tools

12-Sep-14
Date

NOTES:



MCP19111 PMBus™ PROTOCOL-ENABLED POL CONVERTER REFERENCE DESIGN USER'S GUIDE

Table of Contents

Preface	7
Introduction	7
Document Layout	8
Conventions Used in this Guide	9
Warranty Registration	10
Recommended Reading	10
The Microchip Web Site	10
Development Systems Customer Change Notification Service	11
Customer Support	11
MCP19111 PMBus™-Enabled POL Converter Reference Design License	11
Revision History	11
Chapter 1. Product Overview	
1.1 Introduction	13
1.2 MCP19111 Device Short Overview	13
1.3 What is the MCP19111 PMBus™ Protocol-Enabled Point-of-Load Converter Reference Design?	15
1.4 System Requirements	15
1.4.1 The Development System's Components	16
1.5 What the MCP19111 PMBus™ Protocol-Enabled Point-of-Load Converter Reference Design Kit Contains?	16
Chapter 2. Installation and Operation	
2.1 Board Features	17
2.2 Getting Started	18
2.2.1 Necessary Instruments and Tools	18
2.2.2 Setup Procedure	18
2.2.3 Board Testing	19
Chapter 3. Calibration Procedure	
3.1 Introduction	21
3.2 Voltage Calibration	22
3.3 Current Calibration with Inductor Temperature Measurement	23
Chapter 4. Typical Performance Data, Curves and Waveforms	25

Appendix A. Schematics and Layouts

A.1 Introduction	33
A.2 Board – Schematic 1	34
A.3 Board – Schematic 2	35
A.4 Board – Top Layer	36
A.5 Board – Top Copper	36
A.6 Board – Mid Layer 1	37
A.7 Board – Mid Layer 2	37
A.8 Board – Bottom Layer	38
A.9 Board – Bottom Copper	38

Appendix B. Bill of Materials (BOM)39

Appendix C. Calibration Example

C.1 Introduction	41
C.2 Configuration Requirements	42
C.2.1 Calibration	42

Worldwide Sales and Service44



MCP19111 PMBus™ PROTOCOL-ENABLED POL CONVERTER REFERENCE DESIGN USER'S GUIDE

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 web site (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 MCP19111 PMBus™ Protocol-Enabled Point-of-Load Converter Reference Design. Items discussed in this chapter include:

- [Document Layout](#)
- [Conventions Used in this Guide](#)
- [Warranty Registration](#)
- [Recommended Reading](#)
- [The Microchip Web Site](#)
- [Development Systems Customer Change Notification Service](#)
- [Customer Support](#)
- [Revision History](#)

WARNING

The present reference design is intended to be used only to prove the MCP19111 functionality and performance, solely in a laboratory environment. Microchip Technology Inc. assumes no liability for any damage resulting from using the present reference design in other purposes.

DOCUMENT LAYOUT

This document describes how to use the MCP19111 PMBus™ Protocol-Enabled Point-of-Load Converter Reference Design as a development tool to emulate and debug firmware on a target board, as well as how to program devices. The document is organized as follows:

- **Chapter 1. “Product Overview”** – Important information about the MCP19111 PMBus™ Protocol-Enabled Point-of-Load Converter Reference Design.
- **Chapter 2. “Installation and Operation”** – Includes instructions on how to get started using the MCP19111 PMBus™ Protocol-Enabled Point-of-Load Converter Reference Design.
- **Chapter 3. “Calibration Procedure”** – Includes instructions on the calibration procedure of the MCP19111 PMBus™ Protocol-Enabled Point-of-Load Converter Reference Design.
- **Chapter 4. “Typical Performance Data, Curves and Waveforms”** – Includes typical performance graphs of data, curves and waveforms.
- **Appendix A. “Schematics and Layouts”** – Shows the schematic and layout diagrams for the MCP19111 PMBus™ Protocol-Enabled Point-of-Load Converter Reference Design.
- **Appendix B. “Bill of Materials (BOM)”** – Lists the parts used to build the MCP19111 PMBus™ Protocol-Enabled Point-of-Load Converter Reference Design.
- **Appendix C. “Calibration Example”** – Gives an example of a calibration procedure for the MCP19111 PMBus™ Protocol-Enabled Point-of-Load Converter Reference Design.

CONVENTIONS USED IN THIS GUIDE

This manual uses the following documentation conventions:

DOCUMENTATION CONVENTIONS

Description	Represents	Examples
Arial font:		
Italic characters	Referenced books	<i>MPLAB[®] IDE User's Guide</i>
	Emphasized text	...is the <i>only</i> 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><i>File>Save</i></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	<i>file.o</i> , where <i>file</i> can be any valid filename
Square brackets []	Optional arguments	mcc18 [options] <i>file</i> [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) { ... }

WARRANTY REGISTRATION

Please complete the enclosed Warranty Registration Card and mail it promptly. Sending in the Warranty Registration Card entitles users to receive new product updates. Interim software releases are available at the Microchip web site.

RECOMMENDED READING

This user's guide describes how to use MCP19111 PMBus™ Protocol-Enabled Point-of-Load Converter Reference Design. Other useful documents are listed below. The following Microchip documents are available and recommended as supplemental reference resources.

MCP19110/11 Data Sheet (DS20002331)

This data sheet describes the operation and features of the MCP19110/11 digitally-enhanced power analog controller with integrated synchronous driver.

PMBus™ Monitoring Graphical User Interface User's Guide (DS50002380)

This user's guide describes how to use the PMBus Monitoring Graphical User Interface (GUI).

TB3139, MCP19111 PMBus™ Firmware Technical Brief (DS90003139)

This technical brief describes how to use the MCP19111 PMBus firmware.

THE MICROCHIP WEB SITE

Microchip provides online support via our web site at www.microchip.com. This web site is used as a means to make files and information easily available to customers. Accessible by using your favorite Internet browser, the web site 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

DEVELOPMENT SYSTEMS CUSTOMER CHANGE NOTIFICATION SERVICE

Microchip's customer notification service helps keep customers current on Microchip products. Subscribers will receive e-mail notification whenever there are changes, updates, revisions or errata related to a specified product family or development tool of interest.

To register, access the Microchip web site at www.microchip.com, click on Customer Change Notification and follow the registration instructions.

The Development Systems product group categories are:

- **Compilers** – The latest information on Microchip C compilers, assemblers, linkers and other language tools. These include all MPLAB® C compilers; all MPLAB assemblers (including MPASM™ Assembler); all MPLAB linkers (including MPLINK™ Object Linker); and all MPLAB librarians (including MPLIB™ Object Librarian).
- **Emulators** – The latest information on Microchip in-circuit emulators. This includes the MPLAB REAL ICE™ and MPLAB ICE 2000 In-Circuit Emulators.
- **In-Circuit Debuggers** – The latest information on the Microchip in-circuit debuggers. This includes MPLAB ICD 3 In-Circuit debugger and PICKit™ 3 Debug Express.
- **MPLAB® IDE** – The latest information on Microchip MPLAB IDE, the Windows® Integrated Development Environment for development systems tools. This list is focused on the MPLAB IDE, MPLAB IDE Project Manager, MPLAB Editor and MPLAB SIM Simulator, as well as general editing and debugging features.
- **Programmers** – The latest information on Microchip programmers. These include production programmers, such as MPLAB REAL ICE In-Circuit Emulator, MPLAB ICD 3 In-Circuit Debugger and MPLAB PM3 Device Programmer.

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 web site at:

<http://www.microchip.com/support>

MCP19111 PMBUS-ENABLED POL CONVERTER REFERENCE DESIGN LICENSE

Copyright © 2015 Microchip Technology Inc. All rights reserved.

1. **License Grant.** Microchip licenses to you the right to use this reference design and all related documentation ("Reference Design Materials") for purposes of developing your application using Microchip products. You may not re-distribute Reference Design Materials to any third parties.
2. **Warranty Disclaimer.** Reference Design Materials are provided for your convenience only and may be superseded by updates. These materials will not be deemed to modify Microchip's standard warranty for its products. It is your responsibility to: (1) ensure that the Reference Design Materials, and your use thereof, meet your requirements; and (2) test your application.

REFERENCE DESIGN MATERIALS ARE PROVIDED “AS IS” WITHOUT WARRANTY OF ANY KIND, EITHER EXPRESS OR IMPLIED, INCLUDING WITHOUT LIMITATION, ANY WARRANTY OF MERCHANTABILITY, TITLE, NON-INFRINGEMENT AND FITNESS FOR A PARTICULAR PURPOSE.

3. Limit on Liability. IN NO EVENT WILL MICROCHIP BE LIABLE OR OBLIGATED UNDER CONTRACT, NEGLIGENCE, STRICT LIABILITY, CONTRIBUTION, BREACH OF WARRANTY, OR OTHER LEGAL EQUITABLE THEORY ANY DIRECT OR INDIRECT DAMAGES OR EXPENSES INCLUDING BUT NOT LIMITED TO ANY INCIDENTAL, SPECIAL, OR CONSEQUENTIAL DAMAGES, LOST PROFITS OR LOST DATA, COST OF PROCUREMENT OF SUBSTITUTE GOODS, TECHNOLOGY, SERVICES, ANY CLAIMS BY THIRD PARTIES (INCLUDING BUT NOT LIMITED TO ANY DEFENSE THEREOF), OR OTHER SIMILAR COSTS. MICROCHIP DISCLAIMS ALL LIABILITY ARISING FROM THIS INFORMATION AND ITS USE. USE OF MICROCHIP DEVICES IN LIFE SUPPORT AND/OR SAFETY APPLICATIONS IS ENTIRELY AT THE BUYER'S RISK, AND THE BUYER AGREES TO DEFEND, INDEMNIFY AND HOLD HARMLESS MICROCHIP FROM ANY AND ALL DAMAGES, CLAIMS, SUITS, OR EXPENSES RESULTING FROM SUCH USE.

TO THE FULLEST EXTENT PERMITTED BY LAW, MICROCHIP'S LIABILITY IS CAPPED AT THE AMOUNT YOU PAID DIRECTLY TO MICROCHIP FOR THESE REFERENCE DESIGN MATERIALS.

4. Governing Law. THIS LICENSE WILL BE GOVERNED BY AND CONSTRUCTED UNDER THE LAWS OF THE STATE OF ARIZONA AND THE UNITED STATES WITHOUT REGARD TO CONFLICTS OF LAWS PROVISIONS. Licensee agrees that any disputes arising out of or related to this License, Software or Reference Design Materials will be brought in the courts of State of Arizona. The parties agree to waive their rights to a jury trial in actions relating to this License.

REVISION HISTORY

Revision A (June 2015)

This is the initial release of this document.



MCP19111 PMBus™ PROTOCOL-ENABLED POL CONVERTER REFERENCE DESIGN USER'S GUIDE

Chapter 1. Product Overview

NOTICE TO CUSTOMERS

The present reference design is intended to be used only to prove the MCP19111 functionality and performance, solely in laboratory environment. Microchip Technology Inc. assumes no liability for any damage resulting from using the present reference design in other purposes.

1.1 INTRODUCTION

This chapter provides an overview of the MCP19111 PMBus™ Protocol-Enabled Point-of-Load Converter Reference Design and covers the following topics:

- [MCP19111 Device Short Overview](#)
- [What is the MCP19111 PMBus™ Protocol-Enabled Point-of-Load Converter Reference Design?](#)
- [What the MCP19111 PMBus™ Protocol-Enabled Point-of-Load Converter Reference Design Kit Contains?](#)

CAUTION

All the functionalities described in this document are specific to the original firmware loaded in the MCP19111. Once the user software is loaded, the PMBus communication and board settings become the user's responsibility.

1.2 MCP19111 DEVICE SHORT OVERVIEW

The MCP19111 device is a highly integrated, mixed signal, Analog Pulse-Width Modulation (PWM) Current mode controller with an integrated microcontroller core for synchronous DC/DC step-down applications. Since the MCP19111 uses traditional analog control circuitry to regulate the output of the DC/DC converter, the integration of the PIC® microcontroller mid-range core is used to provide complete customization of the device operating parameters, start-up and shutdown profiles, protection levels and Fault handling procedures.

The MCP19111 is designed to efficiently operate from a single, 4.5V to 32V supply. It features integrated synchronous drivers, a bootstrap device, internal linear regulator and 4000 words of nonvolatile memory, all in a space-saving, 28-pin 5 mm x 5 mm QFN package.

PMBus™ or I²C™ can be used by a host to communicate with, or modify the operation of, the MCP19111. A subset of the commands contained in the “PMBus™ Power System Management Protocol Specification, Revision 1.1” are supported by the ARD00609 board.

An internal 5V rail provides power to the PIC MCU and is also present on the V_{DD} pin.

It is recommended that a 1 µF capacitor be placed between V_{DD} and P_{GND}. The V_{DD} pin may also be directly connected to the V_{DR} pin or connected through a low-pass RC filter. The V_{DR} pin provides power to the internal synchronous driver.

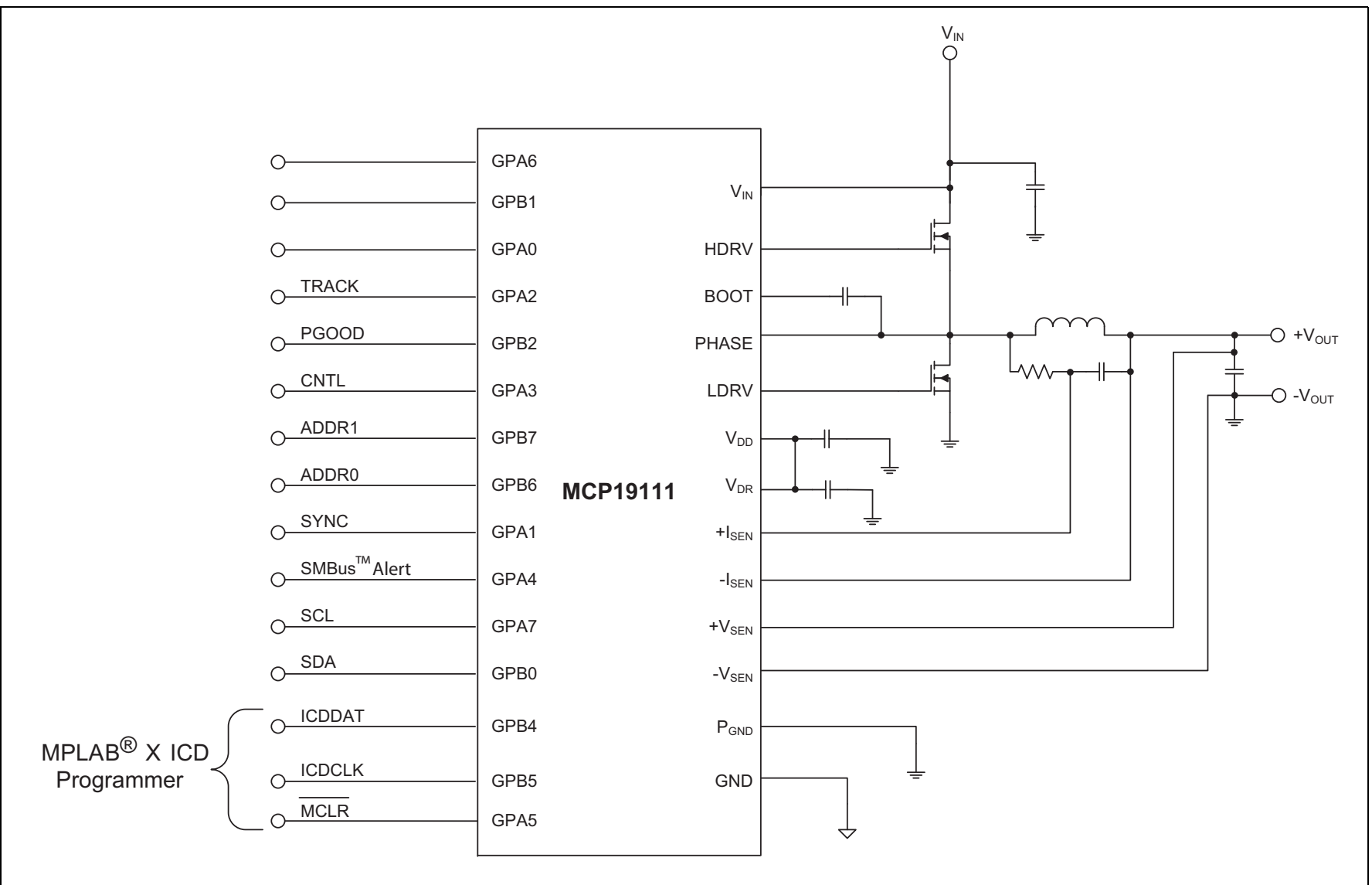


FIGURE 1-1: MCP19111 Typical Application.

1.3 WHAT IS THE MCP19111 PMBus™ PROTOCOL-ENABLED POINT-OF-LOAD CONVERTER REFERENCE DESIGN?

The MCP19111 PMBus™ Protocol-Enabled Point-of-Load Converter Reference Design demonstrates how the MCP19111 device operates in a synchronous buck topology over a wide input voltage and load range. Nearly all operational and control system parameters are programmable by utilizing the integrated PIC microcontroller.

For precise measurements of the output current, a precision op amp (MCP6061) and an inductor temperature sensor (MCP9700) are provided. The output current may be measured and calibrated using an internal or external op amp. The temperature compensation may be performed by temperature measurement or by second order polynomial approximation.

The PMBus Monitoring Graphical User Interface (GUI) can be used to program the functioning parameters and to check the operational status. To simplify the connection, a USB to PMBus converter is implemented on board, allowing a standard interface to any Windows® computer.

Alternatively, the user can program the MCP19111 using self-developed firmware (see [Section 1.4.1 “The Development System’s Components”](#)), tailoring it to the application.

The evaluation board contains headers for In-Circuit Serial Programming™ (ICSP™) as well as I²C and mini-USB communication, pull-up and pull-down resistor pads and test point pads on each GPIO pin, and a push button for system development. The MCP19111 PMBus™ Protocol-Enabled Point-of-Load Converter Reference Design is also intended to demonstrate an optimized Printed Circuit Board (PCB) layout that minimizes parasitics, while increasing efficiency and power density.

Proper PCB layout is critical to achieve optimum MCP19111 operation, as well as power train efficiency and noise minimization.

1.4 SYSTEM REQUIREMENTS

To operate the board, the following tools are required:

- Microsoft® .NET Framework 4.5 or higher
- PMBus Monitoring Graphical User Interface: This graphical user interface allows monitoring and changing input and output parameters for any device that has an incorporated PMBus™ protocol. For installation, operation and other system requirements, see the “PMBus™ Monitoring Graphical User Interface User’s Guide” (DS50002380).

WARNING

Any changes in the Settings tab from the Developer menu may result in system instability and/or permanent damage of the board, and is the user’s sole responsibility to take the necessary precautions.

1.4.1 The Development System's Components

To redevelop the board firmware, the following may be required:

- MCP19111 MPLAB® X IDE Graphical User Interface Plug-In: This graphical user interface simplifies the configuration of the MCP19111. It is user-installed and resides within the MPLAB X IDE. The “MCP19110/11/18/19 – Buck Power Supply Graphical User Interface User's Guide” (DS50002113) describes the plug-in installation procedure, as well as how to use it.
- MPLAB® X Integrated Development Environment (IDE): This is a complete software development environment that links the software and hardware development. This is a free tool, available from Microchip, that supports device configuration, advanced programming, as well as debug support. The GUI resides inside the MPLAB X IDE.
- MPLAB® XC8 Compiler: The firmware described above is coded in C and thus requires a C compiler. C compilers are available for free from Microchip's web site.
- Configuration tools:
 - PICkit™ Serial Analyzer: This communication tool may be used to configure the evaluation board. The PICkit Serial Analyzer is recommended and is available for purchase on microchipDIRECT.
 - PICkit 3 In-Circuit Debugger/Programmer: A programming tool is required to reprogram the evaluation board. The PICkit 3 or MPLAB ICD 3 is recommended and they are available for purchase on microchipDIRECT.
 - Any other user-preferred I²C connection for further board development.

To resume the original functionality of the ARD00609, the user can download the 00609_RevA1 . hex file from Microchip's web site and upload it in the MCP19111 using a PICkit 3 In-Circuit Debugger/Programmer.

1.5 WHAT THE MCP19111 PMBus™ PROTOCOL-ENABLED POINT-OF-LOAD CONVERTER REFERENCE DESIGN KIT CONTAINS?

This MCP19111 PMBus™ Protocol-Enabled Point-of-Load Converter Reference Design kit includes the following items:

- MCP19111 PMBus™ Protocol-Enabled Point-of-Load Converter Reference Design board (ARD00609)
- Important Information Sheet



MCP19111 PMBus™ PROTOCOL-ENABLED POL CONVERTER REFERENCE DESIGN USER'S GUIDE

Chapter 2. Installation and Operation

2.1 BOARD FEATURES

The MCP19111 PMBus™ Protocol-Enabled Point-of-Load Converter Reference Design was developed to provide a compact, low-cost and highly efficient step-down conversion for low-to-medium output currents.

The key features of this board include:

- Input Voltage Range: 8V to 14V
- Output Voltage: 1.2V (can be adjusted by software from 0.1 to 3.6V)
- Maximum Output Current: 20A
- 88% Typical Efficiency at 1.2V/15A output and 12V input
- 500 kHz Switching Frequency (can be software adjusted from 100 kHz to 1.6 MHz)
- On-Board High-Performance Power MOSFET Transistors
- Overcurrent and Overtemperature Protection
- Status Report (including errors, input voltage, output voltage and current) via the PMBus Communication Protocol
- Precision Op Amp for Accurate Output Current Measurement
- Inductor Temperature Sensor
- Calibration of Output Voltage
- Calibration of Output Voltage and Output Current Measurements (via PMBus)
- Undervoltage Lockout (UVLO) with Programmable (via software) Thresholds
- Output Overvoltage, Undervoltage and Overcurrent Lockout, Programmable via Software
- For Advanced Users (use with caution): Control Loop Parameters and MOSFET's Switching Dead Time can also be Adjusted by Software.

2.2 GETTING STARTED

The MCP19111 PMBus™ Protocol-Enabled Point-of-Load Converter Reference Design is fully assembled and tested to evaluate and demonstrate the MCP19111 capabilities.

2.2.1 Necessary Instruments and Tools

- Adjustable DC Power Supply with 0V-15V/5 ADC Range Output Capability
- Electronic Load with at least 25A Current Capability and Load Stepping Capability
- Digital Oscilloscope with a Minimum Bandwidth of 50 MHz
- Digital Voltmeter/Ammeter
- Optionally, a Network Analyzer/Bode Plot Analyzer for Control Loop Analyzing
- PC with PMBMonitor GUI Pre-Installed
- USB-A to mini-USB Cable
- Wires for Connections, Capable to Sustain High Currents:
 - 5A for the connection between the adjustable DC power supply and board
 - 20A for the connection between the board and the electronic load

2.2.2 Setup Procedure

To power-up the MCP19111 PMBus™ Protocol-Enabled Point-of-Load Converter Reference Design, the following steps must be completed:

1. Connect the electronic load to the J2 connector of the demo board; the Positive (+) and Negative (–) connector pins are marked on the board silkscreen.
2. Connect the adjustable DC power supply to the J1 connector of the demo board; the Positive (+) and Negative (–) connector pins are marked on the board silkscreen.
3. Supply 12V from the adjustable power source.
4. Connect the test board to a PC with the PMBMonitor GUI pre-installed via a USB-A to mini-USB cable (J3 connector).
5. After powering up, press the push button, BT1, to turn on the output voltage. Alternatively, the output may be turned on from the PMBMonitor GUI **ON** button (under *Status>Operation Panel*).
6. The board is factory set to deliver 1.2V at 20A maximum, with the loop adjusted for optimum performance and current measurement performed via the auxiliary op amp. If different settings are desired, changes may be performed in several ways:
 - Via the PMBus to USB on-board interface – refer to the “PMBus™ Monitoring Graphical User Interface User’s Guide” (DS50002380) for details.
 - Via PMBus – the user must connect a PMBus master via the I²C interface of the board, connector J1.
 - By user-developed software that may be loaded into the MCP19111 J2 connector using PICKit™ 3 or another suitable programming tool.

2.2.3 Board Testing

The typical testing setup is depicted in [Figure 2-1](#). [Table 2-1](#) shows all the available test points on the board. [Table 2-2](#) describes the ICP/I²C communication pins' function. PROG on the J2 connector is used with the PICKit 3 in-circuit programmer/debugger.

The user can connect various instruments at the listed test points to evaluate the parameters of the converter. The typical performance data, curves and waveforms are presented in [Chapter 4. "Typical Performance Data, Curves and Waveforms"](#).

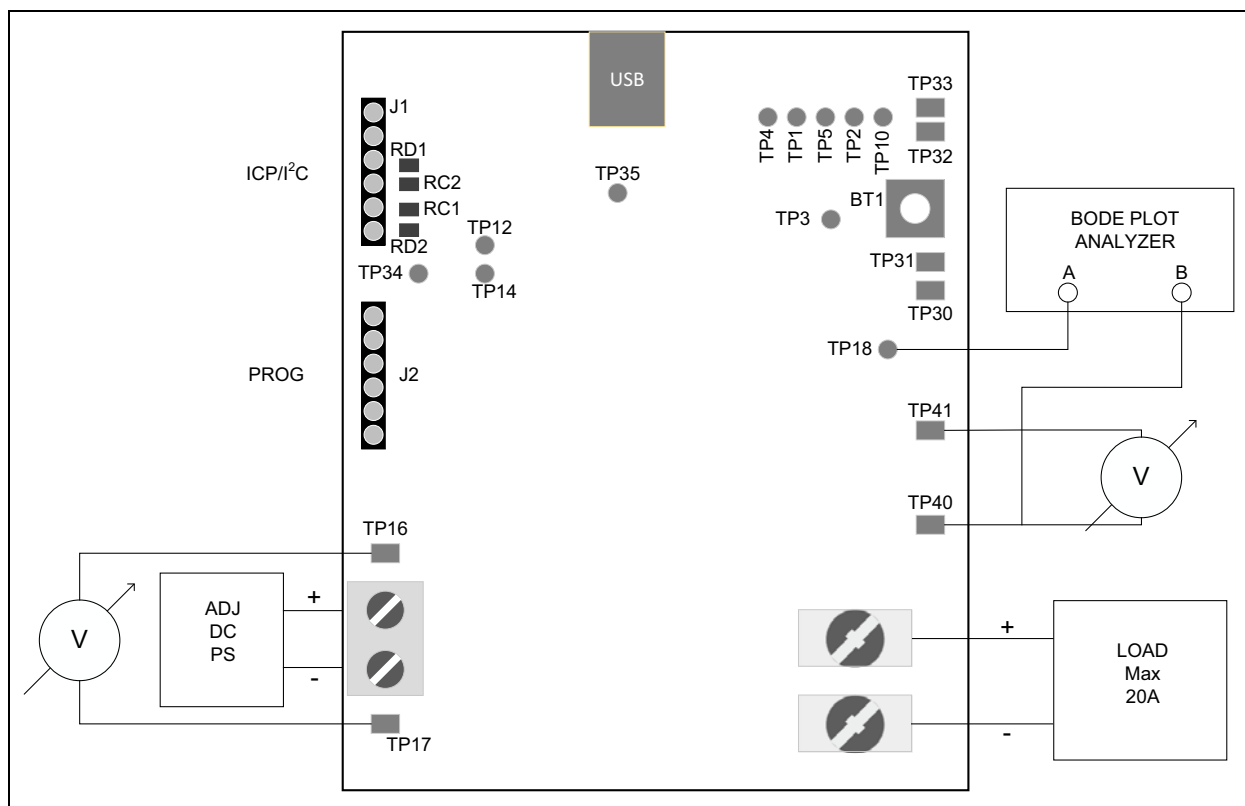


FIGURE 2-1: Typical Test Setup.

TABLE 2-1: TEST POINT DESCRIPTION

Test Point	Name	Description
TP1	GPA0	Connects to GPA0 or Analog Test Output (Note 1)
TP2	GPB1	Connects to GPB1 (Note 1)
TP3	GPB7	By Default, used as Power-on Signal (connected to BT1) (Note 1)
TP4	GPA1	Connects to GPA1 (Note 1)
TP5	GPB2	By Default, used for Inductor Temperature Measurement (Note 1)
TP10	GPB6	Connects to GPB6 (Note 1)
TP12	GPB0/SDA	Connects to GPB0/SDA (Note 1)
TP14	GPA7/SCL	Connects to GPA7/SCL (Note 1)
TP16	V _{IN}	Input Voltage
TP17, TP41	GND	Power GND
TP18	CH A	Injection Point for Loop Measurement
TP30, TP31, TP32, TP33, TP34, TP35	SGND	Signal GND
TP35	GPA3	By Default, used as External Current Measurement Input (Note 1)
TP40	V _{OUT}	Output Voltage and Channel B Injection Point for Loop Measurement

Note 1: For a detailed description of the port pin functions, see the “MCP19110/11 Data Sheet”.

TABLE 2-2: ICP/I²C™ COMMUNICATION CONNECTOR J1 PINS

Pin Number	Description
1	Do not connect
2	Do not connect
3	GND
4	SCL
5	SDA
6	GND

Note: Communication over the USB interface uses the same I²C bus; normally, the user should not simultaneously connect the USB and the ICP/I²C interfaces.

Chapter 3. Calibration Procedure

3.1 INTRODUCTION

In order to increase the accuracy of the output voltage setting, output voltage measurement and output current reading, a calibration procedure must be performed.

It is recommended to use the Microchip dedicated PMBMonitor GUI that can be downloaded from the board's web page, as it performs all needed computations and greatly simplifies the procedures.

For more information on the mathematical basis and implementation of the calibration procedures, refer to the [Appendix C. "Calibration Example"](#).

Figure 3-1 shows the PMBMonitor GUI Interface **Calibration** tab. It also identifies the main panels used in the calibration procedures described in this chapter.

For more information on the Installation and Operation of the PMBMonitor GUI, refer to the "PMBus™ Monitoring Graphical User Interface User's Guide" (DS50002380).

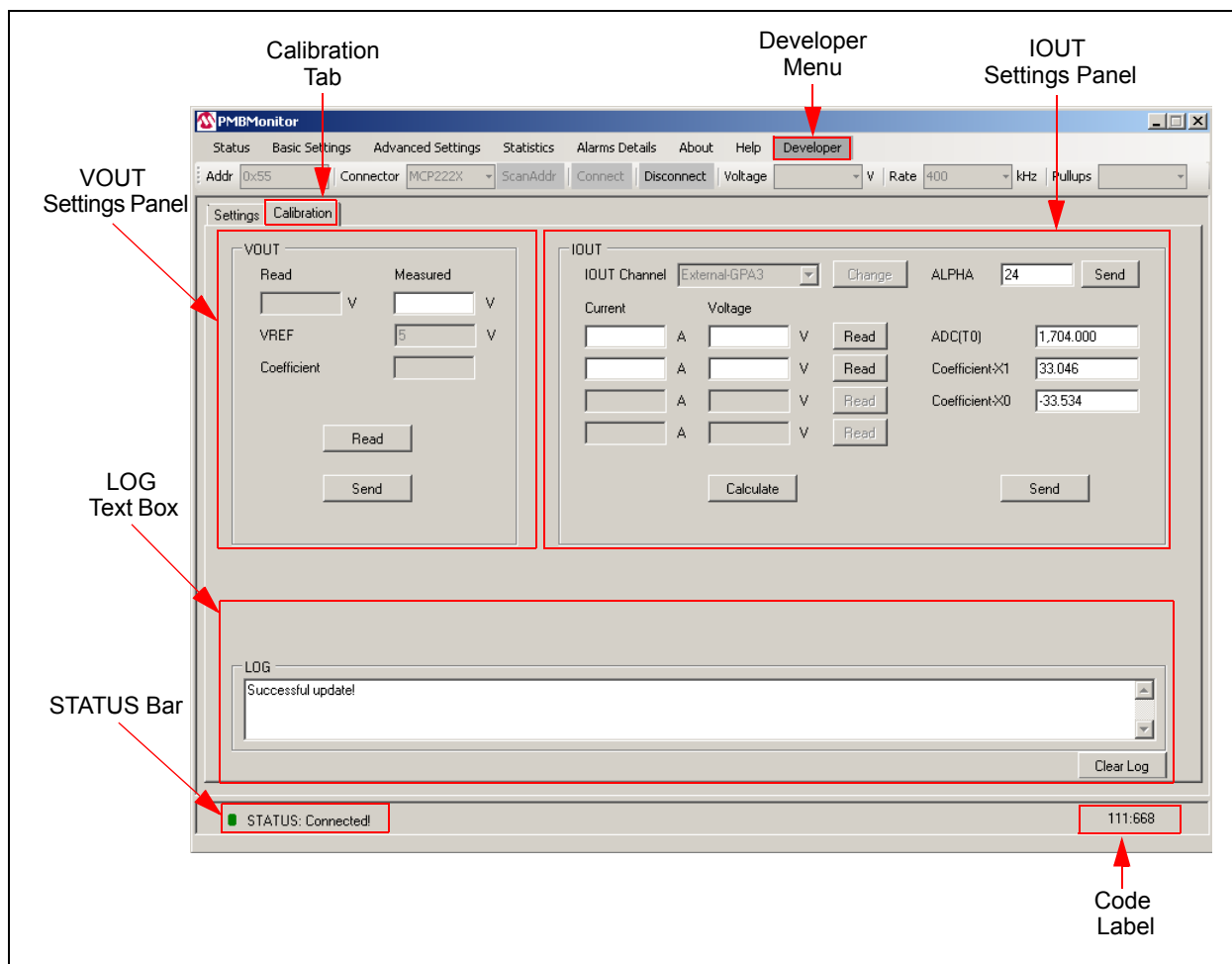


FIGURE 3-1: PMBMonitor GUI – Calibration Tab.

3.2 VOLTAGE CALIBRATION

Follow these steps to perform the voltage calibration procedure:

1. Select Developer from the PMBMonitor GUI main menu, then choose the **Calibration** tab.
2. In the VOUT Settings Panel, press the **Read** button.

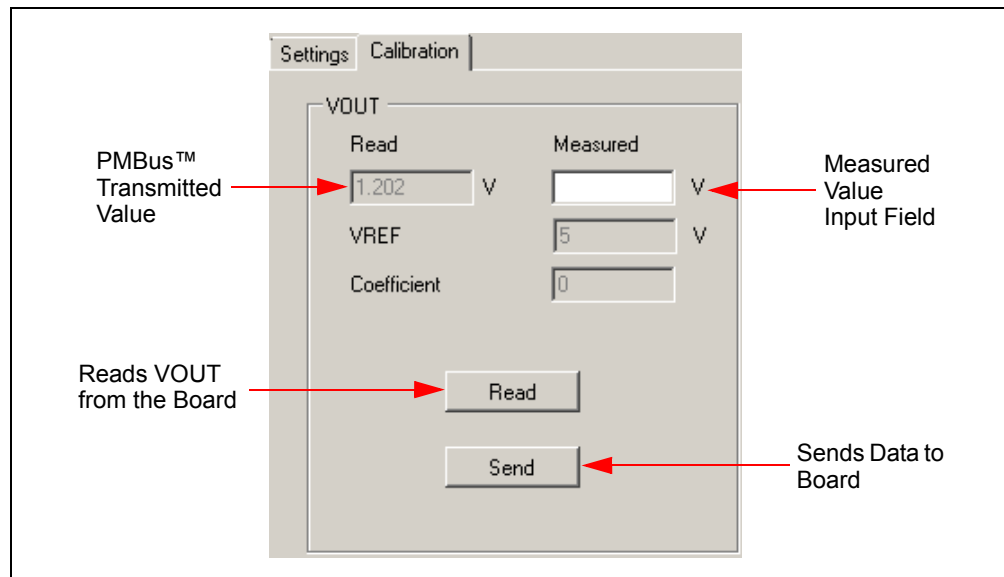


FIGURE 3-2: VOUT Settings Panel Description.

3. On the board, measure with an accurate voltmeter the output voltage between the TP41 and TP40 test points.
4. Input the value obtained in Step 3 in the “Measured” field, then press the **Send** button to update the data on the board.
5. Verify that both the output voltage (measured with the voltmeter) and the PMBMonitor transmitted value that appears on the screen are correct.
6. Go to the Status menu, and in the Operation Panel, press the **StoreALL** button to keep the actual value after power-off.

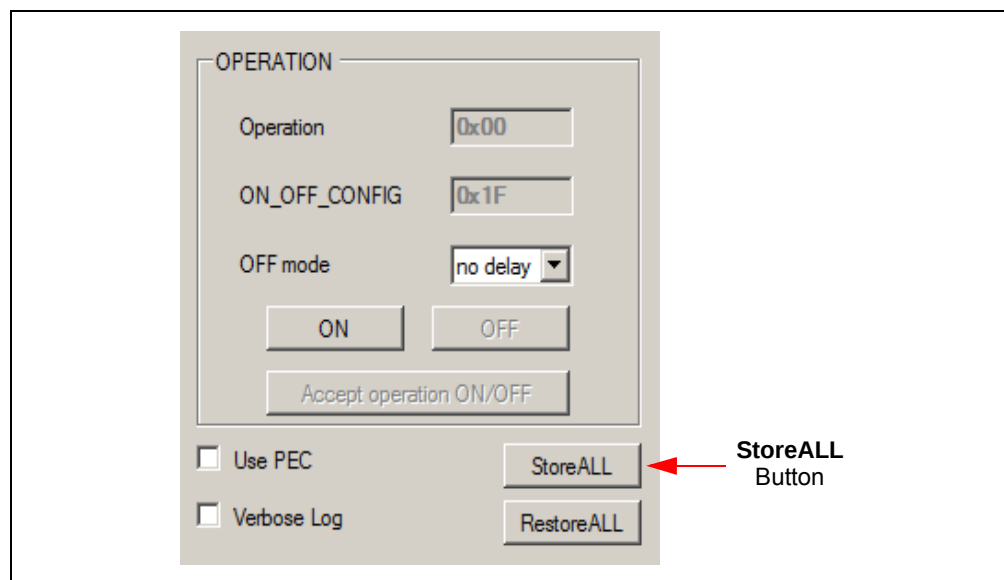


FIGURE 3-3: Status Menu – Operation Panel.

3.3 CURRENT CALIBRATION WITH INDUCTOR TEMPERATURE MEASUREMENT

1. Select Developer from the PMBMonitor GUI main menu, then choose the **Calibration** tab.
2. Choose a low test current (except zero, for example, 1A) and write the value in the first “Current” field in the IOUT Settings Panel. Set this current on the external load as accurate as possible. Press the corresponding **Read** button. A value will appear in the corresponding “Voltage” field.

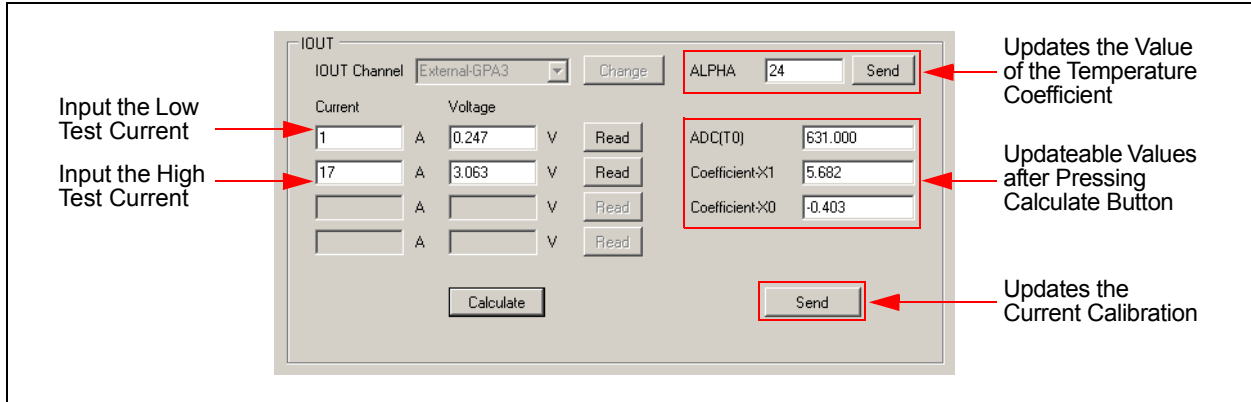


FIGURE 3-4: IOUT Settings Panel.

3. Choose a high test current (at best, the highest load current, for example, 17A), write the value in the second “Current” field and set this output current on the external load. Press the corresponding **Read** button. Write down the value that appears in the second “Voltage” field.
4. Press the **Calculate** button. The values in the “ADC(T0)”, “Coefficient-X1” and “Coefficient-X0” fields may update once the calculations are done.
5. Press **Send** from the bottom of the IOUT Settings Panel.

WARNING

Keep constant board temperature around ambient during Steps 2 to 5; therefore, all these measurements should be done as fast as possible and/or provide adequate cooling.

Steps 6-12 are used to calibrate the temperature coefficient. **Note that these steps apply only when a different inductor and/or layout is used.**

6. Write down the T0 value from the “ADC(T0)” field.
7. Maintain the high-current output and allow the board to heat up (70-80°C is the optimum).
8. Press the high-current corresponding **Read** button and the **Calculate** button to update the values. Remember the updated value of the second voltage.
9. Compute the difference between the high-current voltage obtained in Step 8 and the one written down (see Step 3).
10. Compute the difference between the T0 value updated on Step 8 and the one written down (see Step 6).
11. Compute α as the voltage difference, divided by the last second voltage value, divided again by the T0 difference (see example in [Equation C-5](#)) ($\alpha = \text{Step 9}:\text{Step 8}:\text{Step 10}$). Multiply the α value by 16384; write the rounded to next integer value of the result in the “ALPHA” field and press the corresponding **Send** button at the right.
12. Go to the Status menu, and in the Operation Panel, press the **StoreALL** button to preserve the actual value after power-off.

Chapter 4. Typical Performance Data, Curves and Waveforms

This chapter shows examples of the parameters used for converter and performance curves, and waveforms.

TABLE 4-1: CONVERTER PARAMETERS

Parameter	Value	Comments
Input Voltage Range (V)	8-14	—
Output Voltage (V)	1.2	±2.5% Tolerance
Maximum Output Current (A)	20	Steady-State Output Current
Output Voltage Ripple (mV)	<30	$V_{IN} = 12V$, $I_{OUT} = 20A$
Input Voltage Ripple (mV)	<400	$V_{IN} = 12V$, $I_{OUT} = 20A$
Output Voltage Overshoot during Step Load (mV)	<30	Step Load 5A to 15A
Switching Frequency (kHz)	Typical 570 kHz	—

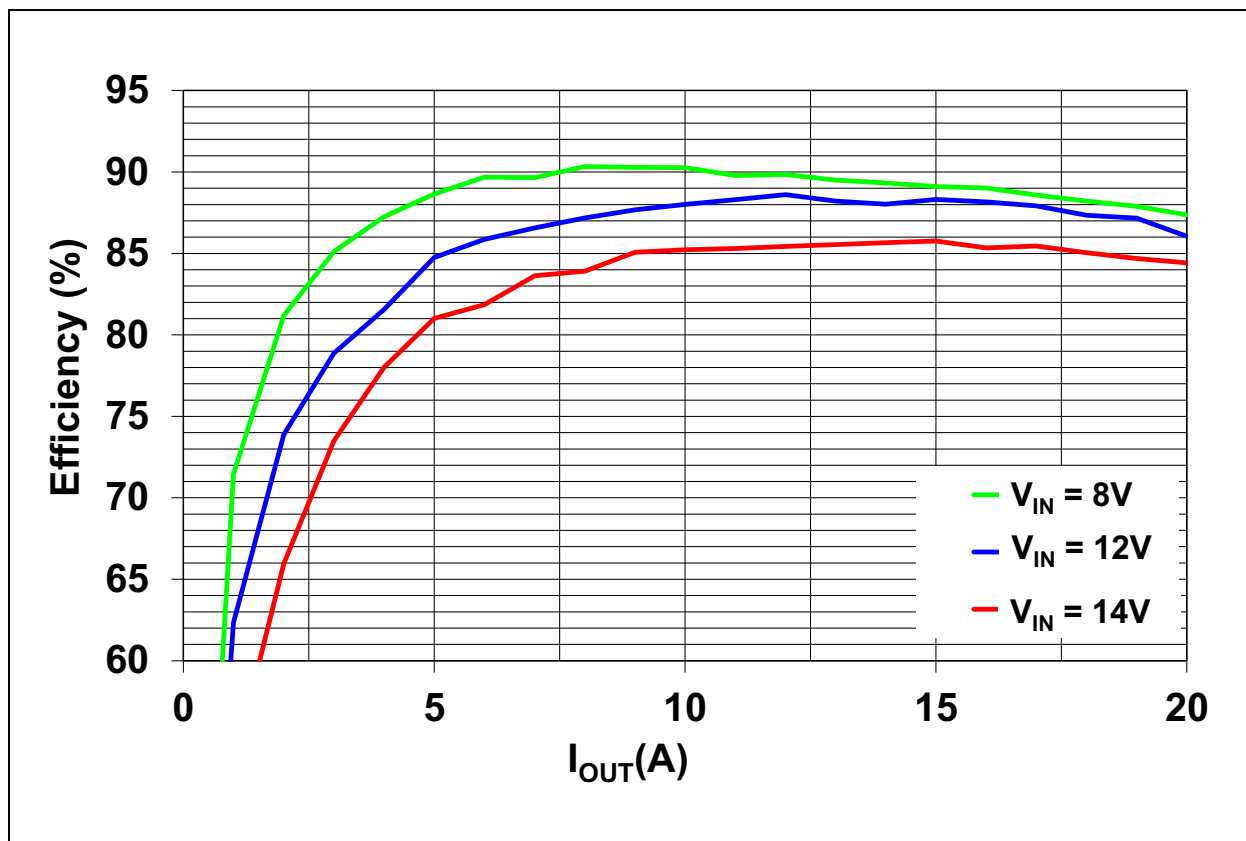


FIGURE 4-1: Efficiency.

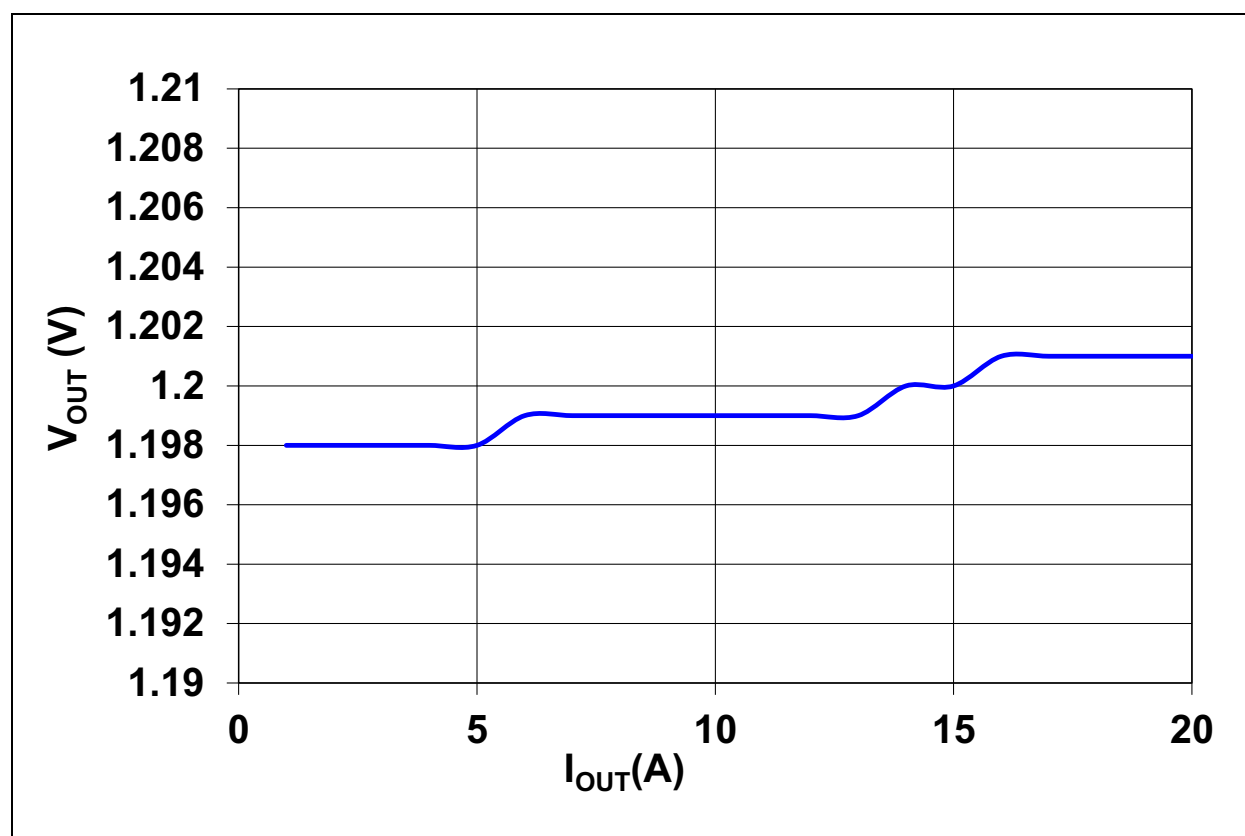


FIGURE 4-2: Load Regulation ($V_{IN} = 12V$).

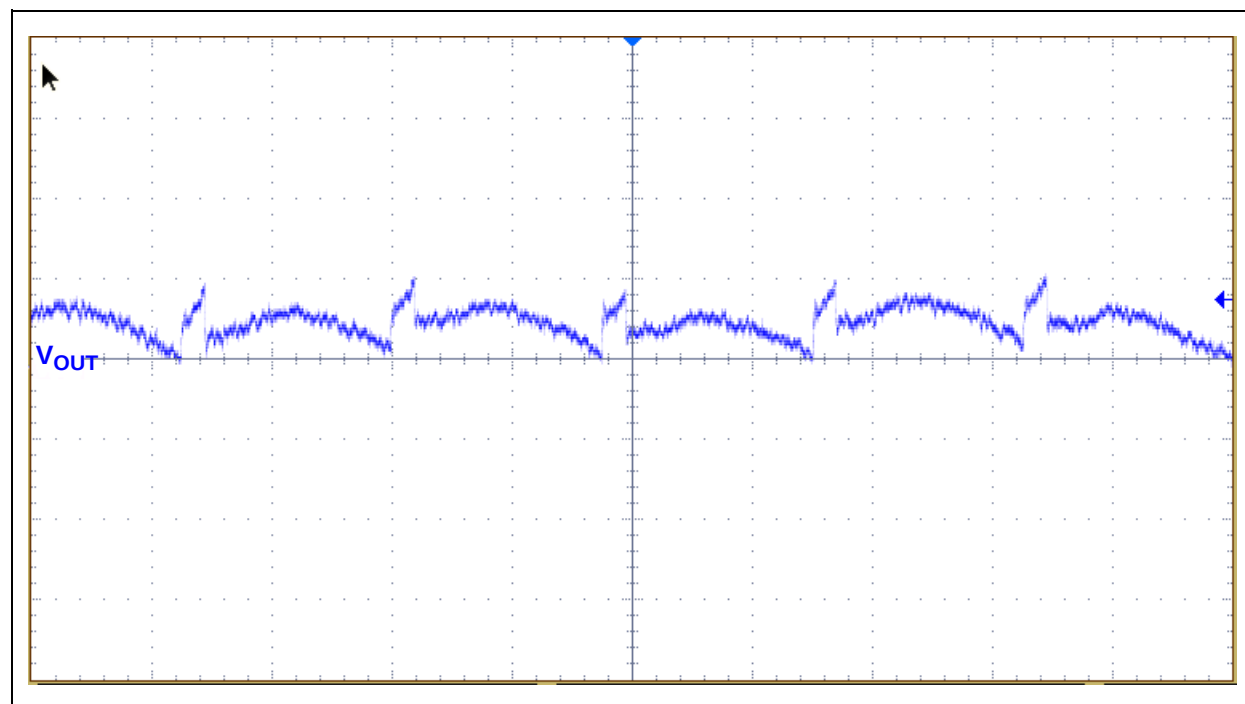


FIGURE 4-3: Output Voltage Ripple/Noise ($V_{IN} = 12V$, $I_{OUT} = 10A$, $BW = 20\text{ MHz}$).

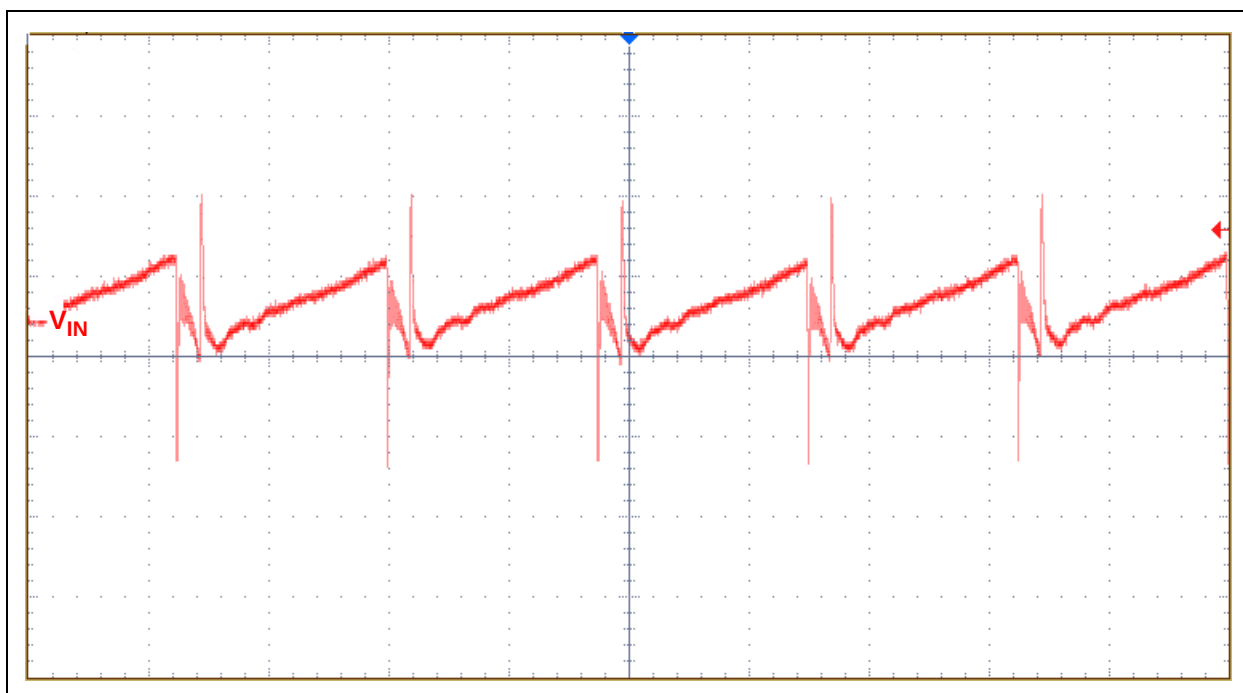


FIGURE 4-4: Input Voltage Ripple/Noise ($V_{IN} = 12V$, $I_{OUT} = 10A$, $BW = 20\text{ MHz}$).

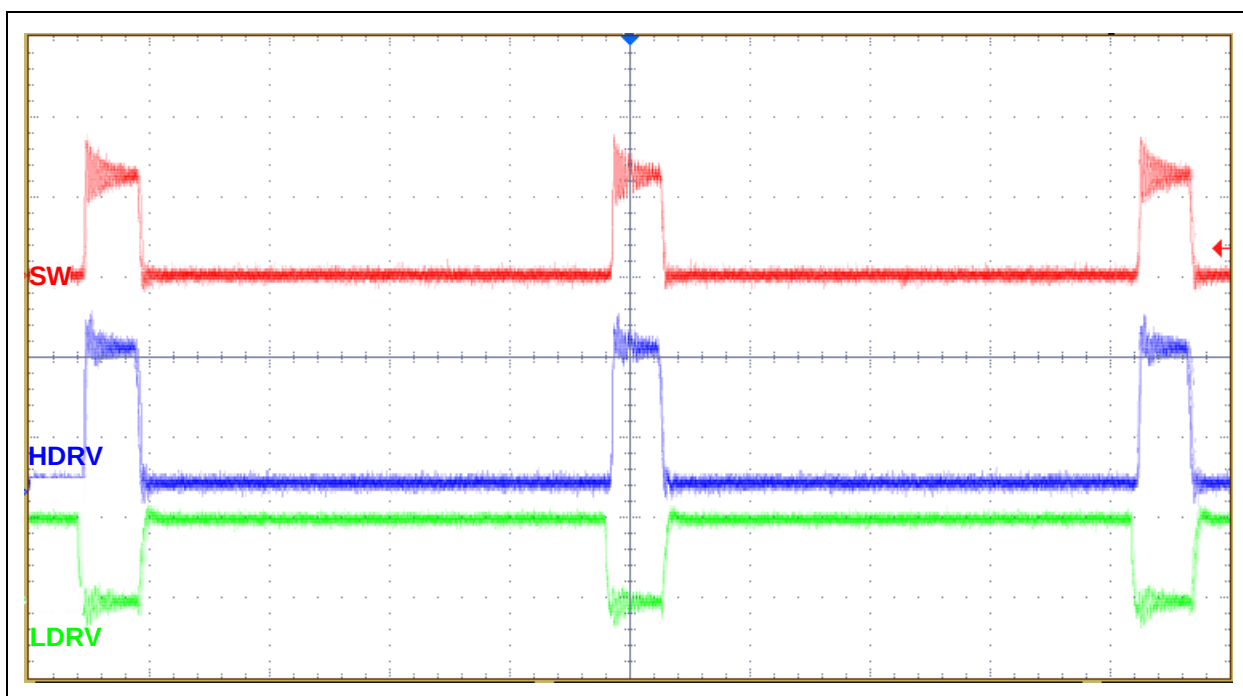


FIGURE 4-5: SW, LDRV and HDRV Signals ($V_{IN} = 12V$, $I_{OUT} = 15A$, $BW = 300\text{ MHz}$).

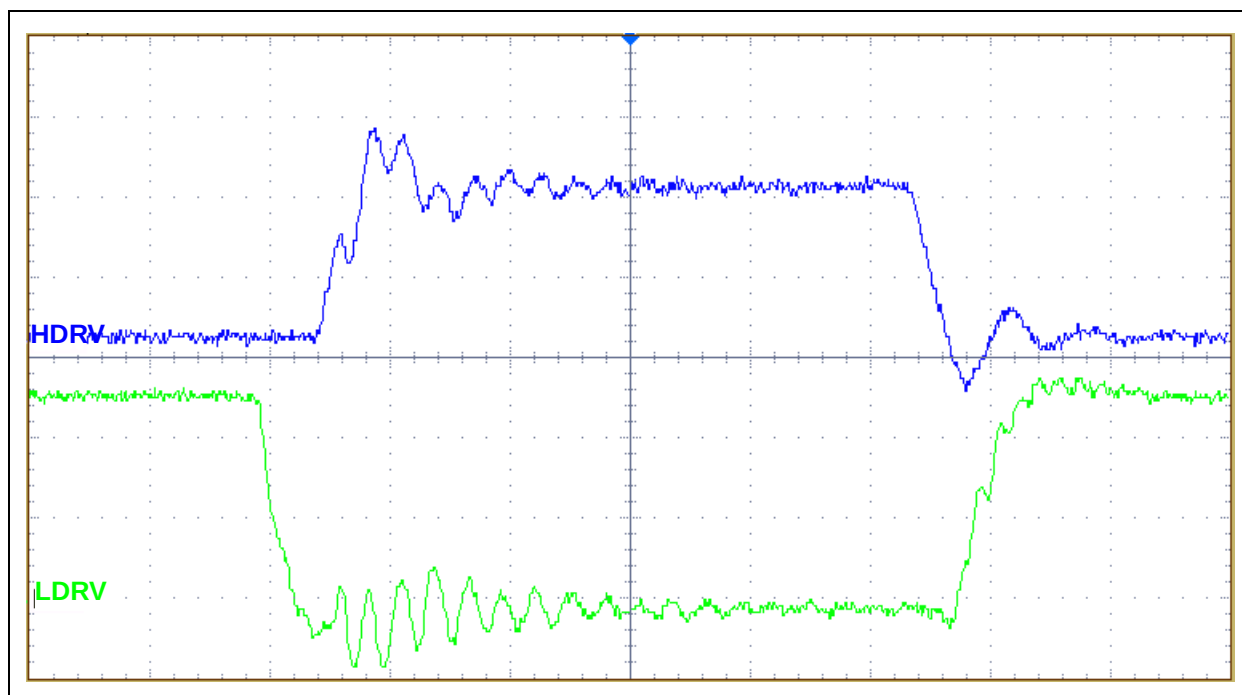


FIGURE 4-6: LDRV and HDRV Signals ($V_{IN} = 12V$, $I_{OUT} = 15A$, $BW = 300\text{ MHz}$).

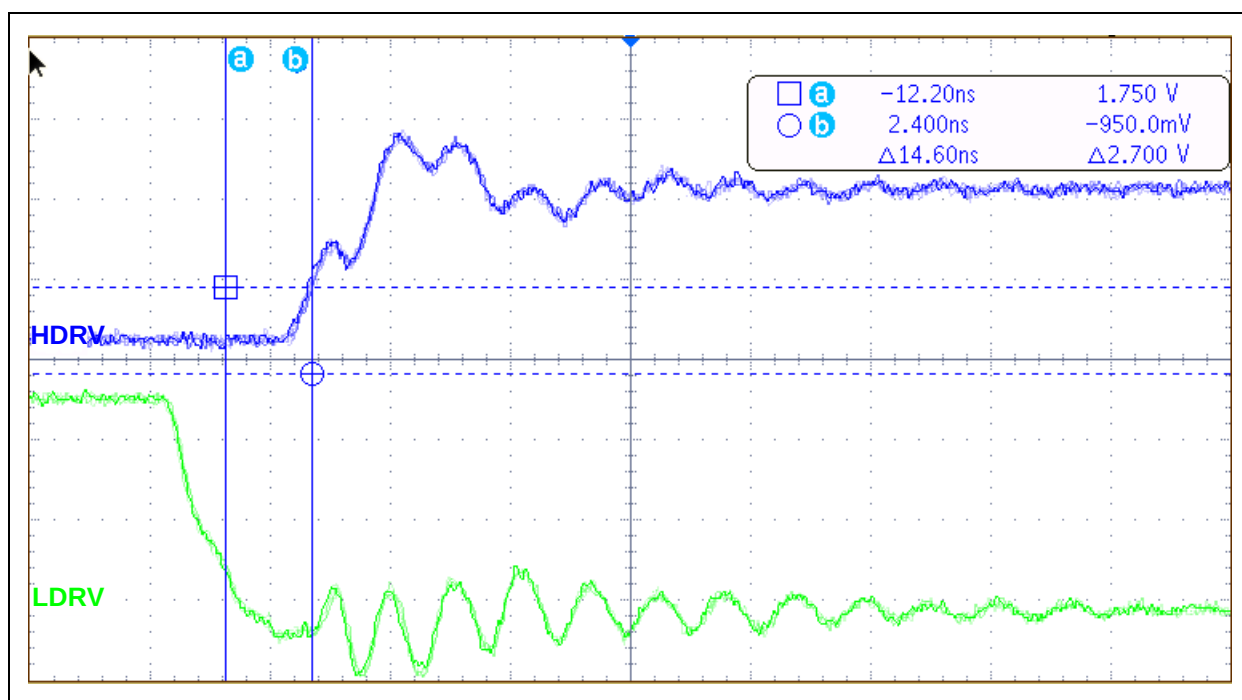


FIGURE 4-7: Dead-Time Rise ($V_{IN} = 12V$, $I_{OUT} = 15A$, $BW = 300\text{ MHz}$).

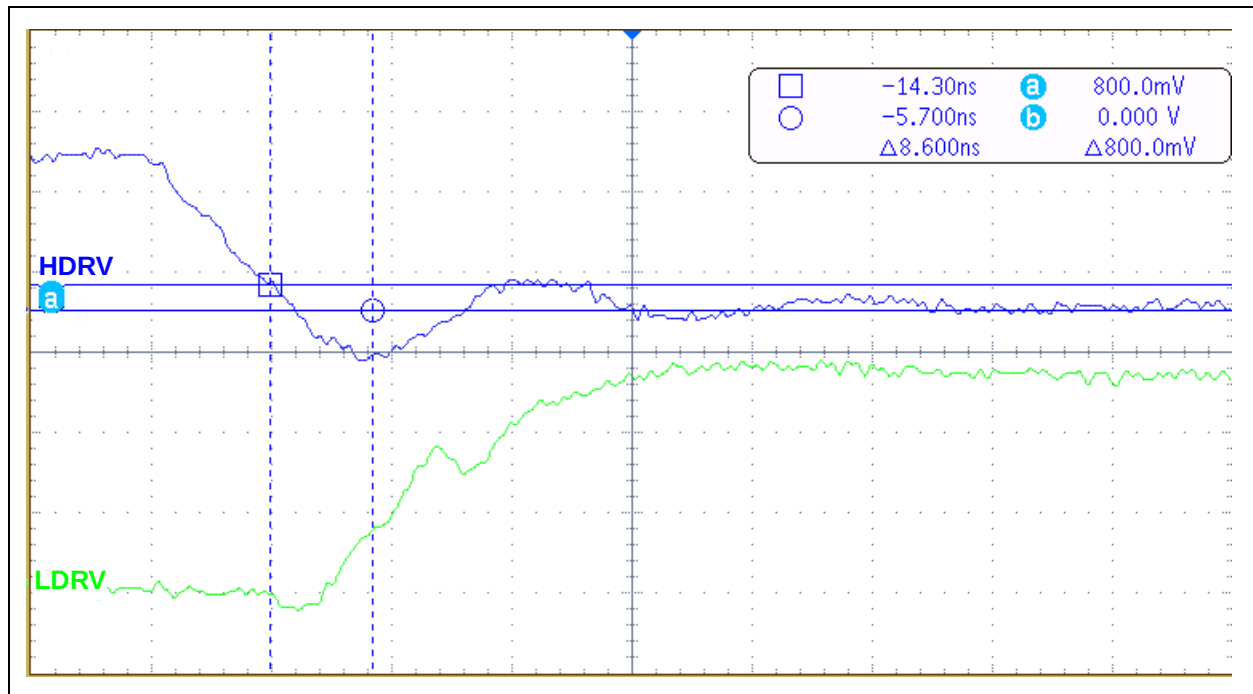


FIGURE 4-8: Dead-Time Fall ($V_{IN} = 12V$, $I_{OUT} = 15A$, $BW = 300\text{ MHz}$).

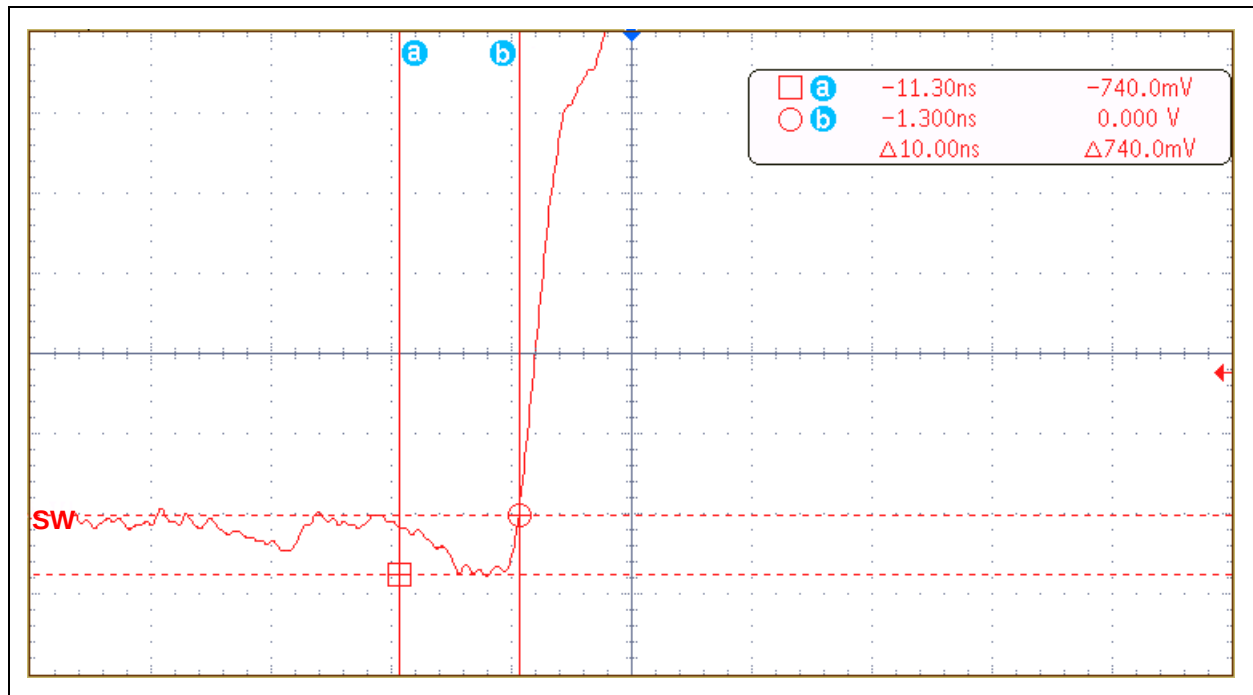


FIGURE 4-9: The Body Diode Conduction Time ($V_{IN} = 12V$, $I_{OUT} = 15A$, $BW = 300\text{ MHz}$).

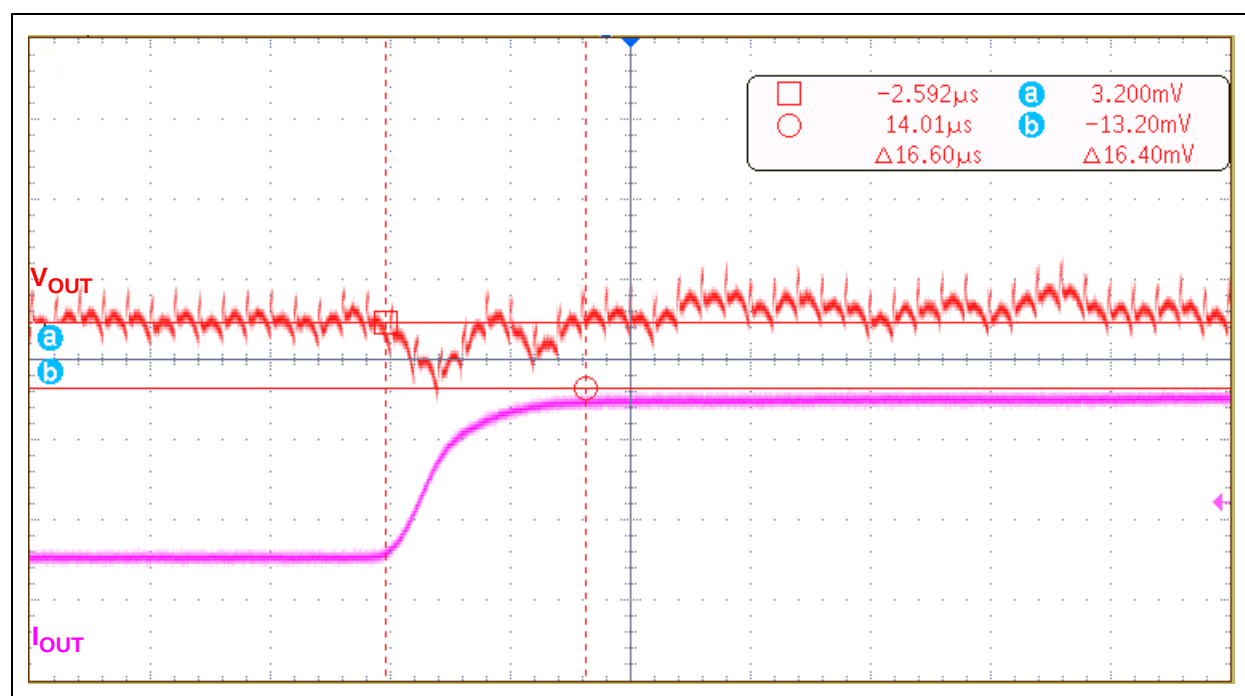


FIGURE 4-10: Step Load Rising Current ($V_{IN} = 12V$).

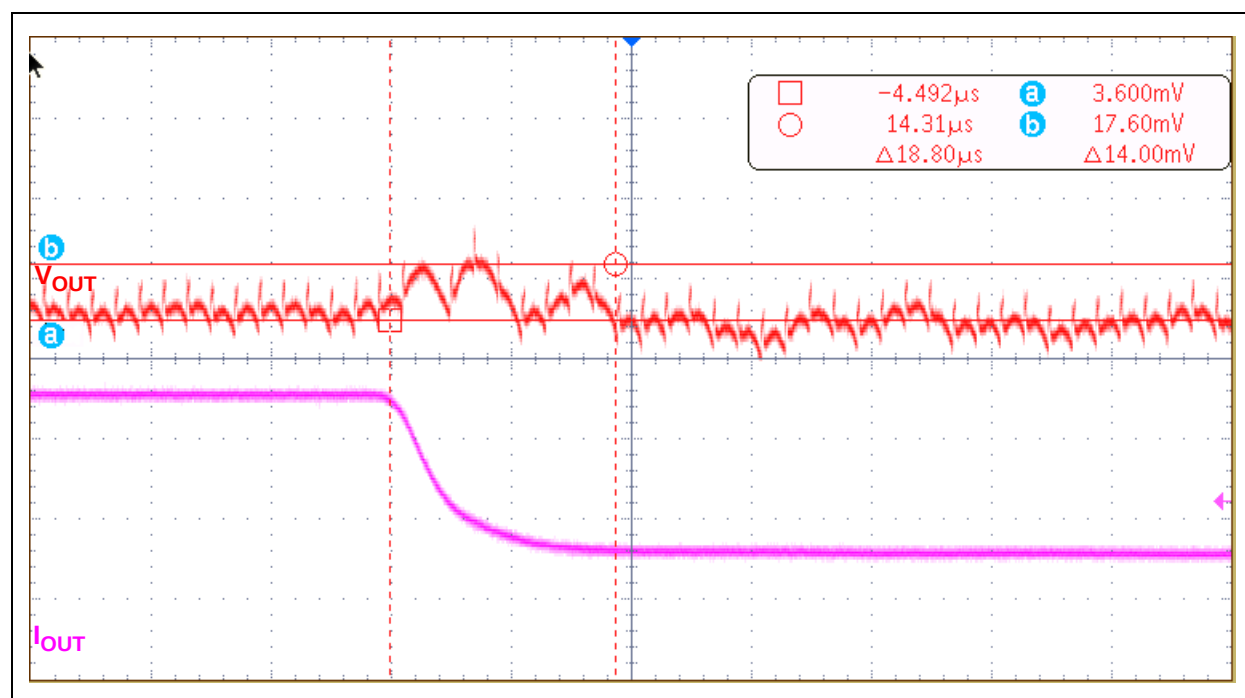


FIGURE 4-11: Step Load Falling Current ($V_{IN} = 12V$).

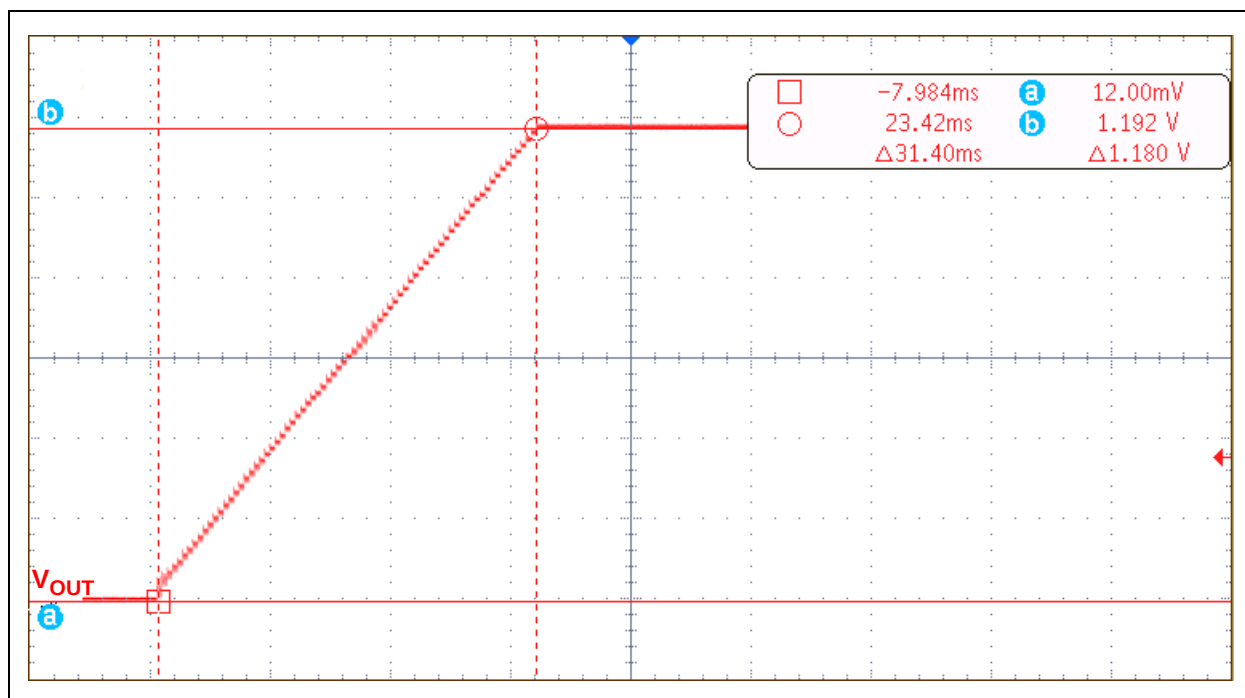


FIGURE 4-12: Soft Start.

NOTES:



MCP19111 PMBus™ PROTOCOL-ENABLED POL CONVERTER REFERENCE DESIGN USER'S GUIDE

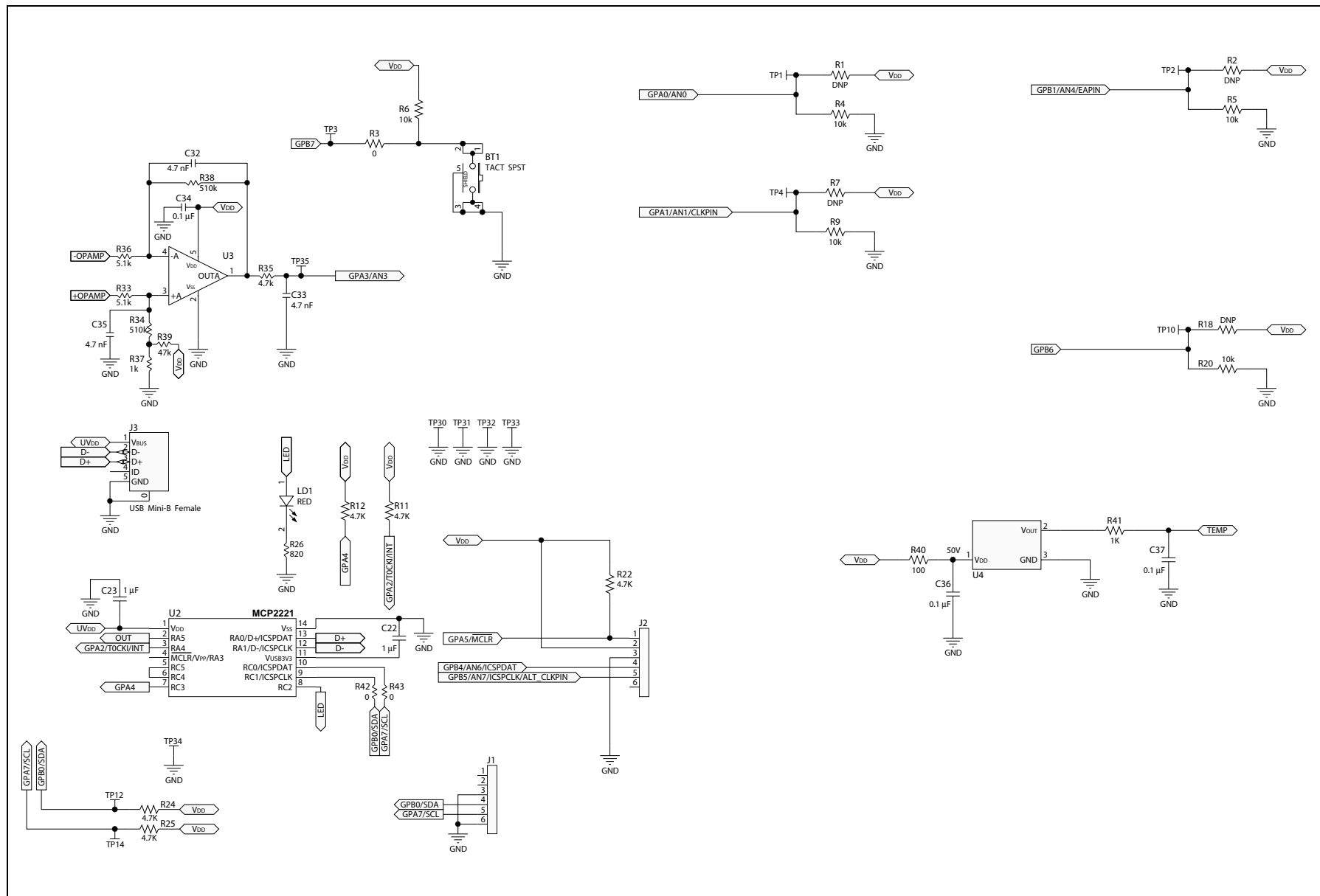
Appendix A. Schematics and Layouts

A.1 INTRODUCTION

This appendix contains the following schematics and layouts for the MCP19111 PMBus™ Protocol-Enabled Point-of-Load Converter Reference Design:

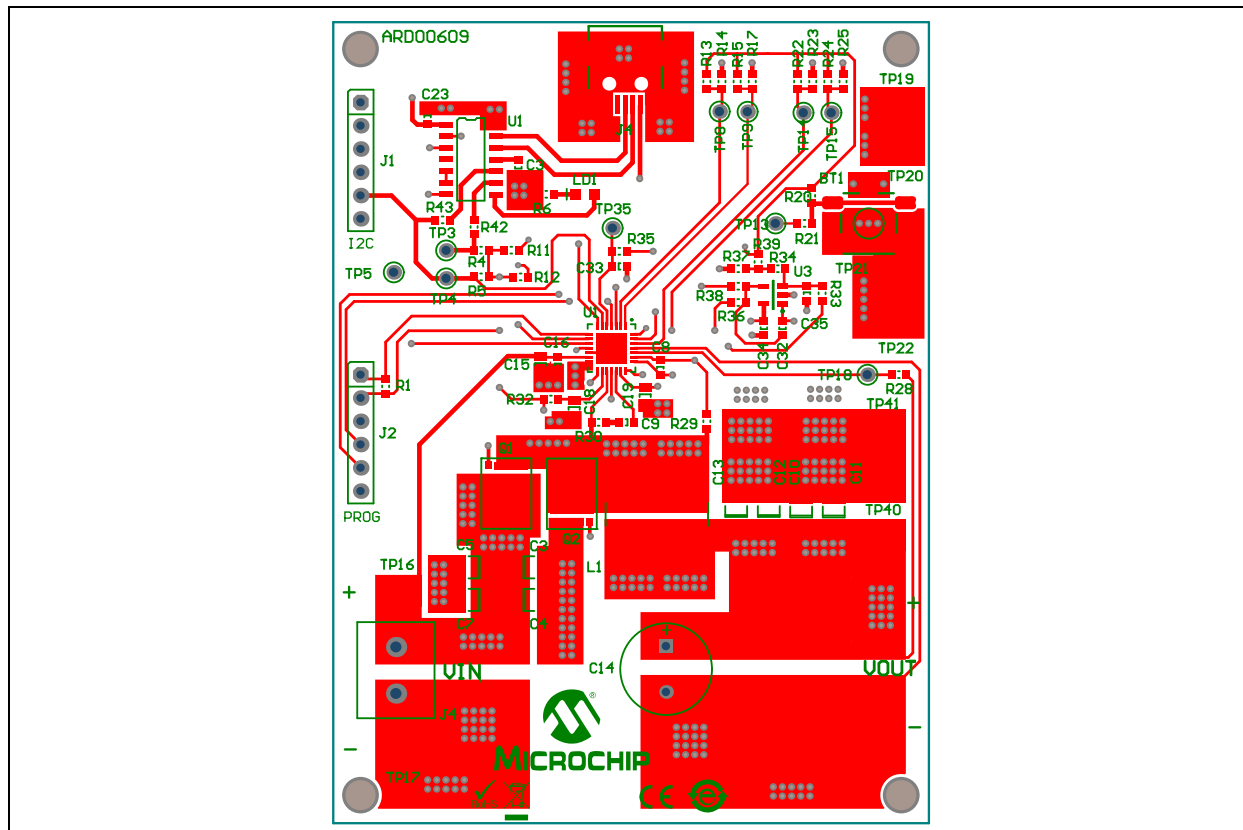
- [Board – Schematic 1](#)
- [Board – Schematic 2](#)
- [Board – Top Layer](#)
- [Board – Top Copper](#)
- [Board – Mid Layer 1](#)
- [Board – Mid Layer 2](#)
- [Board – Bottom Layer](#)
- [Board – Bottom Copper](#)

© 2015 Microchip Technology Inc.

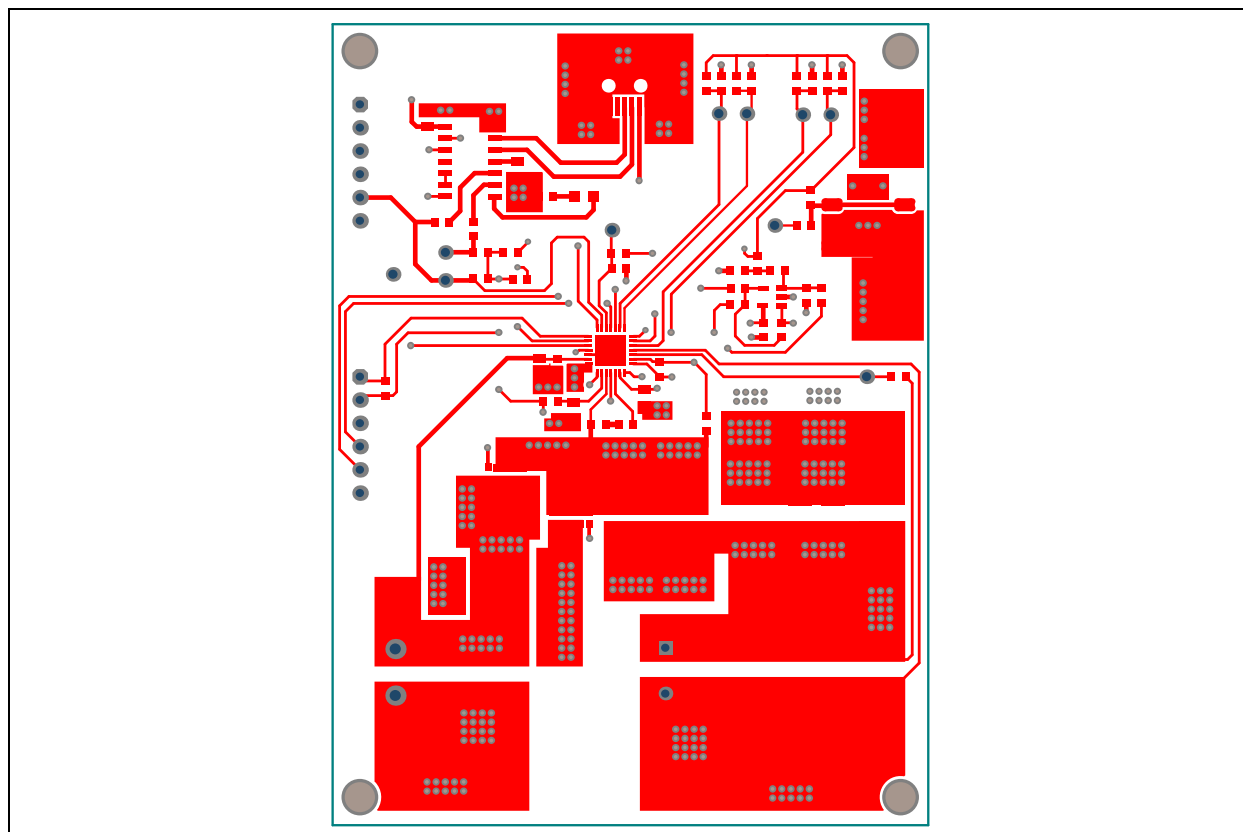


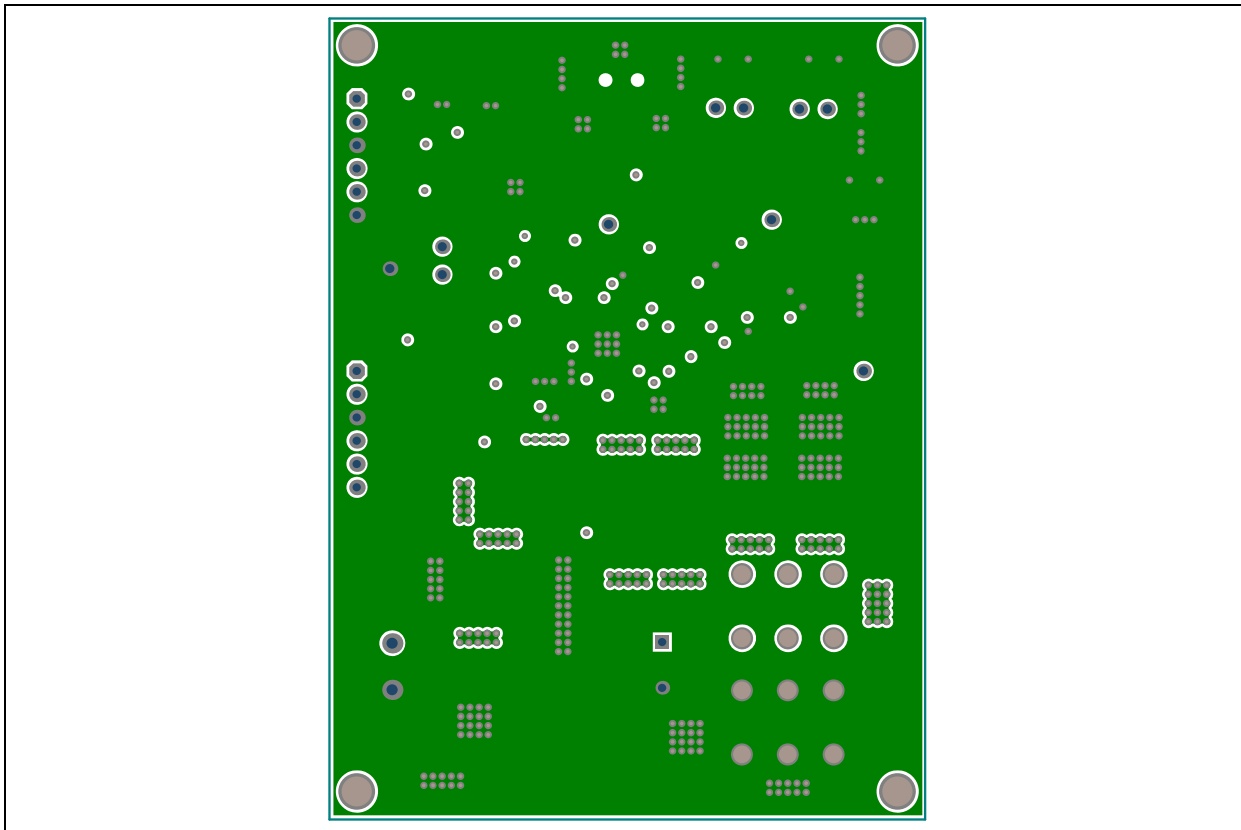
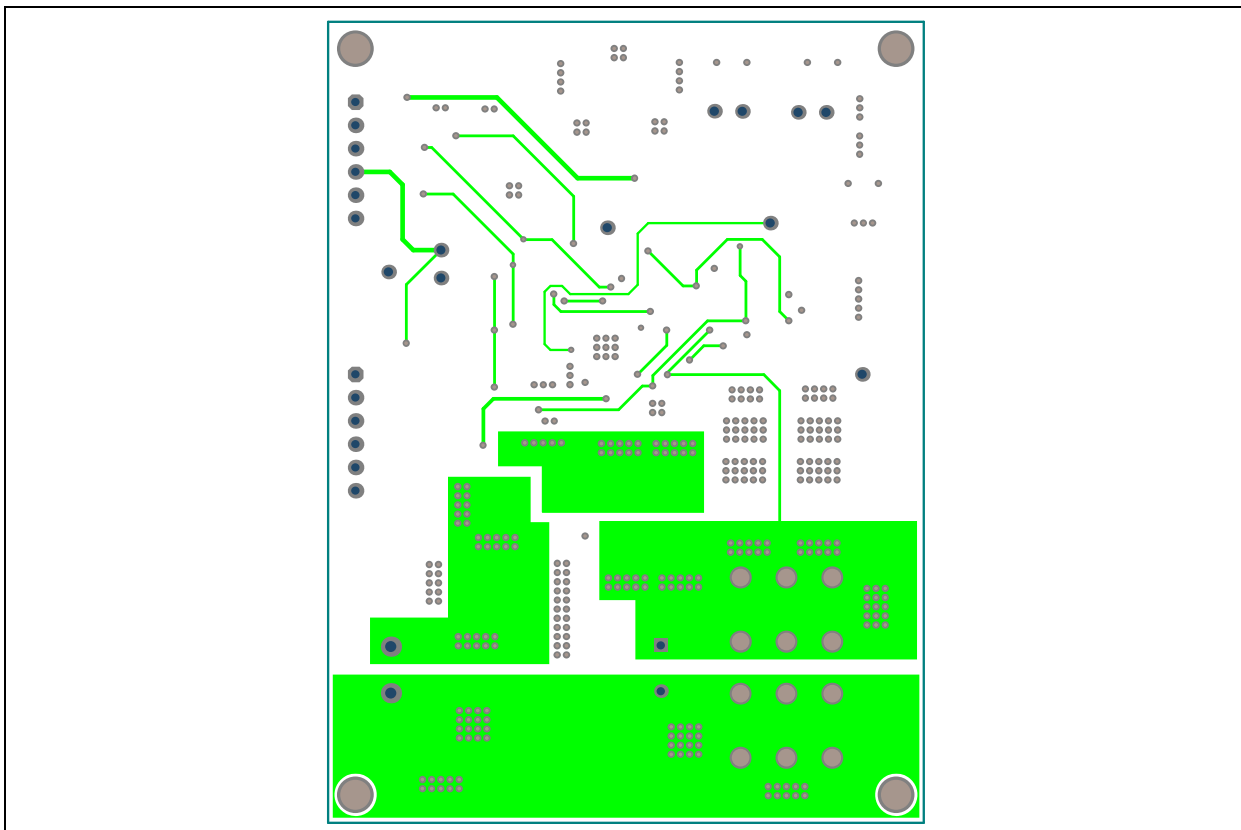
[illegible]

A.4 BOARD – TOP LAYER

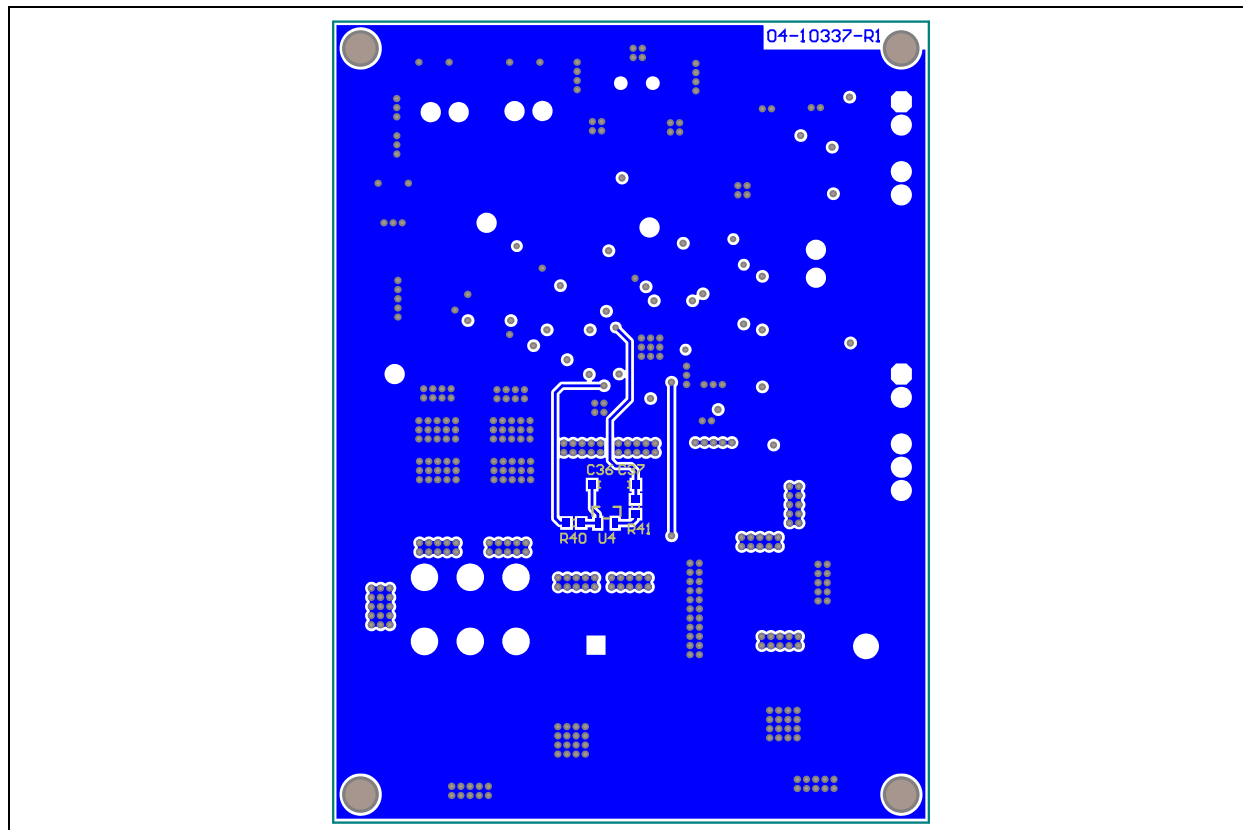


A.5 BOARD – TOP COPPER

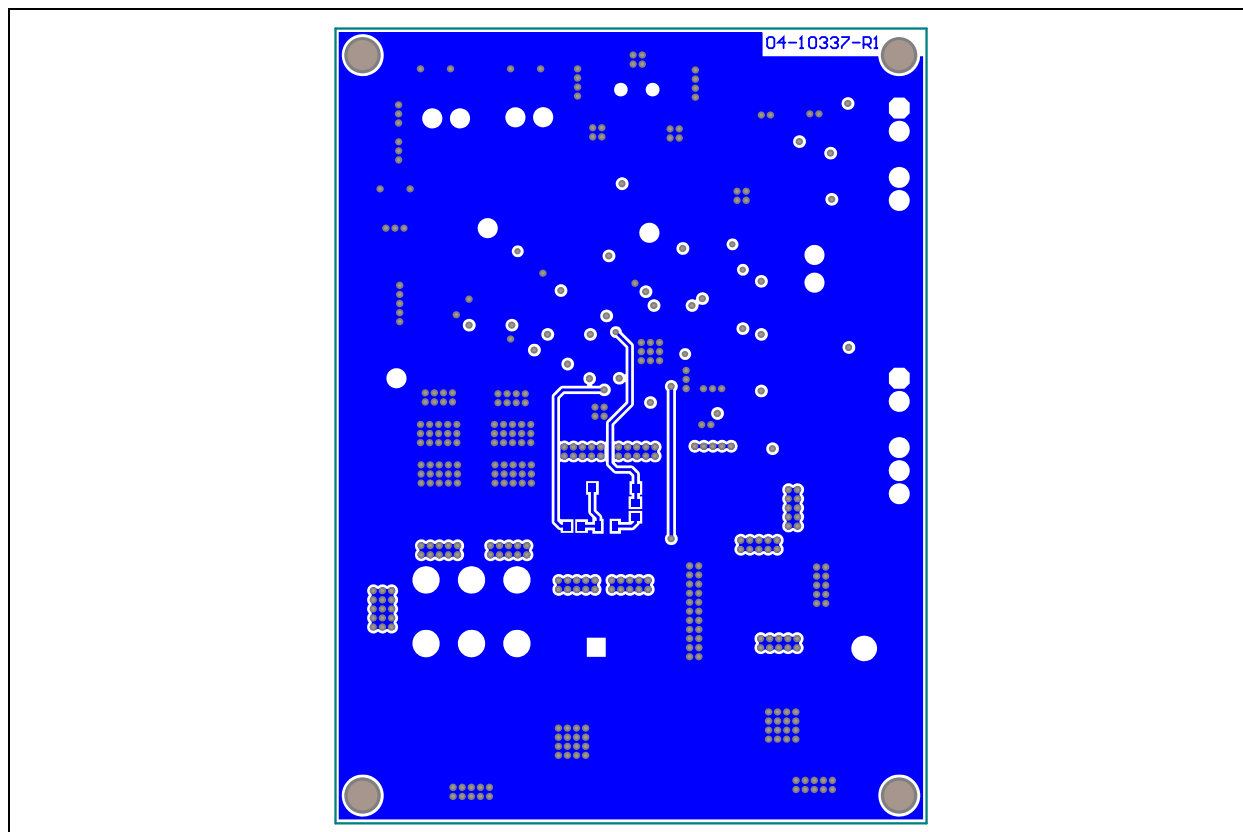


A.6 BOARD – MID LAYER 1**A.7 BOARD – MID LAYER 2**

A.8 BOARD – BOTTOM LAYER



A.9 BOARD – BOTTOM COPPER





MCP19111 PMBus™ PROTOCOL-ENABLED POL CONVERTER REFERENCE DESIGN USER'S GUIDE

Appendix B. Bill of Materials (BOM)

TABLE B-1: BILL OF MATERIALS (BOM)

Qty	Reference	Description	Manufacturer	Part Number
1	BT1	Switch TACT, SPST, 24V, 50 mA, B3S-1100, SMD	OMRON Corporation	B3S-1100
4	C3, C4, C5, C7	Cap. Ceramic, 10 μ F, 25V, 20%, X5R, SMD, 1210	Panasonic® – ECG	ECJ-4YB1E106M
2	C8, C9	Cap. Ceramic, 0.47 μ F, 10V, 10%, X5R, 0603	TDK Corporation	C1608X5R1A474K080AA
4	C10, C11, C12, C13	Cap. Ceramic, 100 μ F, 6.3V, 20%, X5R, 1210	Murata Electronics®	GRM32ER60J107ME20L
1	C14	Cap. Alum., 1000 μ F, 6.3V, 20%, Radial	Nichicon Corporation	RL80J102MDN1KX
1	C19	Cap. Ceramic, 2.2 μ F, 10V, 20%, X5R, 0805	TDK Corporation	C2012X5R1A225M085AA
4	C15, C18, C22, C23	Cap. Ceramic, 1 μ F, 16V, 10%, X7R, 0805	TDK Corporation	C2012X7R1C105K125AA
4	C16, C34, C36, C37	Cap. Ceramic, 0.1 μ F, 25V, 10%, X7R, 0603	TDK Corporation	C1608X7R1E104K080AA
3	C32, C33, C35	Cap. Ceramic, 4700 pF, 25V, 5%, C0G, 0603	TDK Corporation	C1608C0G1E472J080AA
2	J1, J2	Conn. Header, .100, Single, STR, 6 Pos	Sullins Connector Solutions	PEC06SAAN
1	J3	Conn., USB Mini-B Female, SMD, R/A	Hirose Electric Co., Ltd.	UX60-MB-5ST
1	J4	Terminal Block, 5.08 mm, 2 Pos, PCB	On-Shore Technology, Inc.	EDZ250/2
1	L1	Fixed IND, 470 nH, 26A, 0.72 m Ω	Würth Elektronik	7443320047
1	LD1	LED CHIPLED, 633 nm, Red, 0805, SMD	OSRAM Opto Semiconductors GmbH.	LS R976-NR-1
1	PCB	Printed Circuit Board – MCP19111 PMBus™ Protocol-Enabled Point-of-Load Converter Reference Design	Microchip Technology Inc.	04-10337
1	Q1	High-Speed N-Channel Power MOSFET	Microchip Technology Inc.	MCP87050T-U/MF
1	Q2	High-Speed N-Channel Power MOSFET	Microchip Technology Inc.	MCP87018T-U/MF
4	R1, R2, R7, R18	DO NOT POPULATE	—	—
4	R3, R30, R42, R43	Res., SMD, 0.0 Ω , Jumper, 1/10W	Vishay/Dale	CRCW06030000Z0EA
5	R4, R5, R6, R9, R20	Res., SMD, 10 k Ω , 5%, 1/10W, 0603	Yageo Corporation	RC0603JR-0710KP
6	R11, R12, R22, R24, R25, R35	Res., SMD, 4.7 k Ω , 5%, 1/10W, 0603	Yageo Corporation	RC0603JR-074K7P
1	R26	Res., SMD, 820 Ω , 5%, 1/10W, 0603	ROHM Semiconductor	MCR03ERTJ821
1	R28	Res., SMD, 51 Ω , 1%, 1/10W, 0603	ROHM Semiconductor	MCR03ERTF51R0
1	R29	Res., SMD, 220 Ω , 1%, 1/10W, 0603	ROHM Semiconductor	MCR03ERTF2200

MCP19111 PMBus™ Protocol-Enabled POL Converter Reference Design

TABLE B-1: BILL OF MATERIALS (BOM)

Qty	Reference	Description	Manufacturer	Part Number
1	R32	Res., SMD, 10Ω, 1%, 1/10W, 0603	ROHM Semiconductor	MCR03ERTF10R0
2	R33, R36	Res., SMD, 5.1 kΩ, 1%, 1/10W, 0603	ROHM Semiconductor	MCR03ERTF5101
2	R34, R38	Res., SMD, 510 kΩ, 1%, 1/10W, 0603	ROHM Semiconductor	MCR03ERTF5103
2	R37, R41	Res., SMD, 1 kΩ, 1%, 1/10W, 0603	ROHM Semiconductor	MCR03ERTF1001
1	R39	Res., SMD, 47 kΩ, 1%, 1/10W, 0603	ROHM Semiconductor	MCR03ERTF4702
1	R40	Res., SMD, 100Ω, 1%, 1/10W, 0603	ROHM Semiconductor	MCR03ERTF1000
2	TP19, T20	Terminal Screw PC Heavy Duty	Keystone Electronics Corp.	8197
4	TP16, TP17, TP40, TP41	PC Test Point Compact SMT	Keystone Electronics Corp.	5016
6	TP19, TP20, TP30, TP31, TP32, TP33	Test Point PC Multi-Purpose BLK	Keystone Electronics Corp.	5011
1	U1	Digitally Enhanced Power Analog Controller with Integrated Synchronous Driver	Microchip Technology Inc.	MCP19111-E/MQ
1	U2	USB 2.0 to I ² C™/UART Protocol Converter with GPIO	Microchip Technology Inc.	MCP2221- I/SL
1	U3	MCHP Analog Op Amp, 1-Ch, 1 MHz, MCP6001T-I/OT, SOT-23-5	Microchip Technology Inc.	MCP6001T-I/OT
1	U4	Low-Power Linear Active Thermistor™ ICs	Microchip Technology Inc.	MCP9700AT-E/OT

Appendix C. Calibration Example

C.1 INTRODUCTION

Current measurements on the MCP19111 PMBus™ Protocol-Enabled Point-of-Load Converter Reference Design are done by differentially sensing a voltage drop on the inductor. This voltage drop is proportional to the current and the copper resistance of the inductor wire.

Since the board output current limit is very high, there is also significant thermal dissipation and the inductor will heat up. This modifies the copper wire DC resistance, and consequently, the voltage drop on the inductor, making the current readings higher than the real value.

The following fundamental equation describes the variation of electrical resistance versus temperature:

EQUATION C-1:

$$R(T) = R(T_0) \times [1 + \alpha \times (T - T_0)]$$

Where:

- R = Inductor DC Resistance
- T_0 = Reference Temperature
- T = Ambient Temperature
- α = Temperature Coefficient

The current sense amplifier has an offset specifically used to preserve output linearity. The readings taken from the amplifier output will have the following form:

EQUATION C-2:

$$V = I \times R + C$$

Where:

- I = Load current set on the electronic load
- R = Inductor DC resistance
- C = Amplifier offset

For convenience, it is considered that the amplifier offset does not vary with temperature.

The purpose is to compensate the value of the inductor voltage drop with temperature, so that, in the end, the value for the same current is obtained at room temperature. To properly measure the inductor temperature, an MCP9700 temperature sensor has been placed in close contact with the inductor.

Based on [Equation C-1](#), the value of the copper resistance is approximated at room temperature (T_0).

EQUATION C-3:

$$I \times R(T_0) = I \times R(1 - \alpha \times \Delta T)$$

$$V(T_0) - C = (V - C)(1 - \alpha \times \Delta T)$$

If lower than 100 mV, the amplifier offset may also be ignored in the calculation of the temperature coefficient with no significant change in the final result.

C.2 CONFIGURATION REQUIREMENTS

To properly calibrate the board current reading, the user needs the following tools:

- 12V power supply
- PMBMonitor GUI running on a PC connected to the board via USB
- 20A capable electronic load

C.2.1 Calibration

To calibrate the MCP19111 PMBus™ Protocol-Enabled Point-of-Load Converter Reference Design, proceed to the following steps:

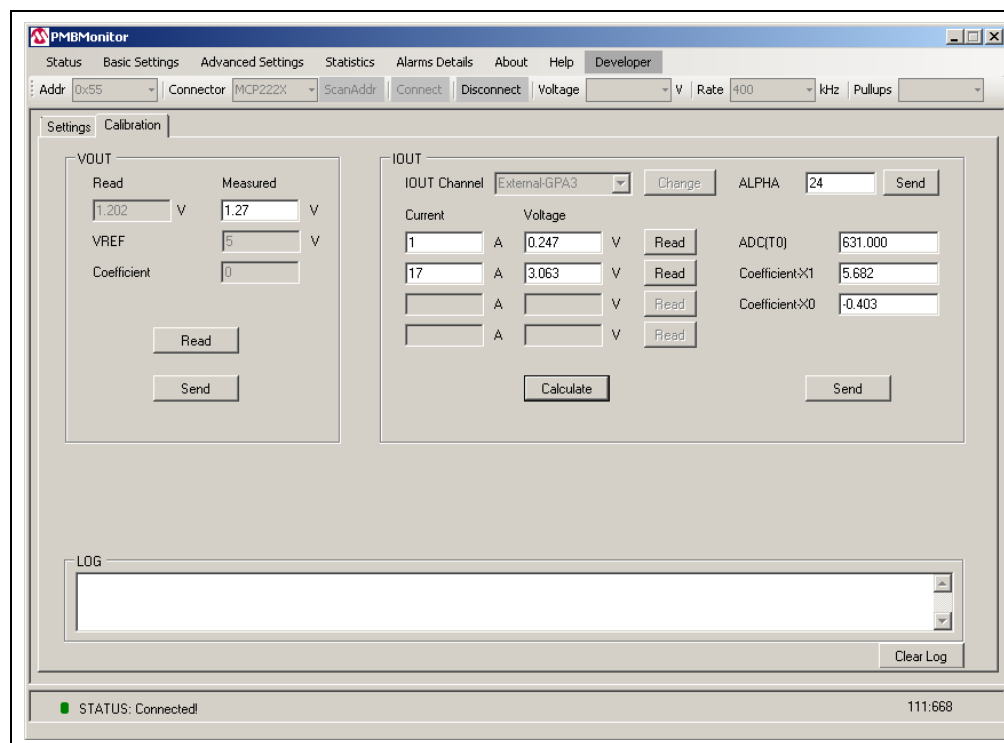


FIGURE C-1: MCP19111 Calibration Values Example.

1. Connect the PC with the GUI installed to the board and power-up the board. Go to the Developer menu in the GUI and select the **Calibration** tab.
2. Set the low test current to 1A and write the value in the first “Current” field, in the IOUT Settings Panel. Set this current on the external load as accurate as possible. Press the corresponding **Read** button. In this calibration example, a voltage of 0.247V is obtained in the corresponding “Voltage” field.
3. Set the high test current to 17A, write the value in the second “Current” field and set this output current on the external load. Press the corresponding **Read** button. In this calibration example, the result is 3.063V. Write down the result.
4. Press the **Calculate** button to update values. Write down the “ADC(T0)” value. This value will later be used to compensate all current readings. **The “ADC(T0)” value and the second voltage value must be read simultaneously.**

For this example, the measurement was taken at +27°C, resulting in a reading of 770 mV or 631 ADC units (4x10-bit samples summed together).

WARNING

Keep constant board temperature around ambient during Steps 2 to 4 to obtain accurate values. Use an external cooling device on the board to prevent heating while drawing 17A.

5. Press **Send** from the bottom of the IOUT Settings Panel. The coefficients are used in a first-order polynomial to calculate the output current based on the readings from the current amplifier. These coefficients are calculated using the amplifier offset and the inductor resistance at room temperature.
Before the next steps, stop the external cooling device and make sure the board heats up to around 70-80°C. Cover it up, if necessary. Ideally, a forced temperature enclosure should be used, but this can also be done on a laboratory bench.
6. Press the **Read** button on the 17A row and write down the result. For this example, the reading is 3.516V. Write this down.
7. Press the **Calculate** button again and write down the “ADC(T0)” value. For the calibration example, the final temperature is +70°C, resulting in a temperature reading of 1200 mV or 983 ADC units. This is the “T” value later used in the calculations.
8. Start the calculations. Even if the values are shown as 12-bit (4x10-bit) results, the internal calculations only use 10-bit values for temperature and voltage. Using a different resolution will affect the α calculation.

Do the following calculations:

- Divide the temperature ADC results by 4.
- Round the results to the nearest integer if necessary.

For calculating the voltage ADC units, use a 5V reference.

Two temperature points and two voltages are required to calculate the temperature coefficient:

EXAMPLE C-1:

27°C → 0.770V → 631 ADC (12-bit) → 158 ADC (10-bit)
 70°C → 1.200V → 931 ADC (12-bit) → 246 ADC (10-bit)
 $\Delta T = 246 \text{ ADC} - 156 \text{ ADC} = 88 \text{ ADC}$
 17A @ 27°C → $V(T_0) = 3.063$
 17A @ 70°C → $V(T) = 3.516\text{V}$

Use the simplest form of the equation:

EQUATION C-4:

$$\begin{aligned}
 V(T_0) &= V(T) \times (1 - \alpha \times \Delta T) \\
 3.063 &= 3.516 \times (1 - 88 \times \alpha) \\
 \alpha &= 0.001464
 \end{aligned}$$

Since all calculations are done using integer arithmetic, the temperature coefficient is scaled internally by 2^{14} or 16384.

EQUATION C-5:

$$ALPHA = 0.001464 \times 16384 = 23.98$$

9. In the “ALPHA” field from the IOUT Settings Panel, write the rounded value (24) and press the associated **Send** button.
10. Go to the Status menu and press the **StoreALL** button to save all of the calibration values. The calibration is now finished and the board should indicate the correct load current at any operating temperature.

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

Cleveland
Independence, OH
Tel: 216-447-0464
Fax: 216-447-0643

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

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

New York, NY
Tel: 631-435-6000

San Jose, CA
Tel: 408-735-9110

Canada - Toronto
Tel: 905-673-0699
Fax: 905-673-6509

ASIA/PACIFIC

Asia Pacific Office
Suites 3707-14, 37th Floor
Tower 6, The Gateway
Harbour City, Kowloon

Hong Kong
Tel: 852-2943-5100
Fax: 852-2401-3431

Australia - Sydney
Tel: 61-2-9868-6733
Fax: 61-2-9868-6755

China - Beijing
Tel: 86-10-8569-7000
Fax: 86-10-8528-2104

China - Chengdu
Tel: 86-28-8665-5511
Fax: 86-28-8665-7889

China - Chongqing
Tel: 86-23-8980-9588
Fax: 86-23-8980-9500

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

China - Hangzhou
Tel: 86-571-8792-8115
Fax: 86-571-8792-8116

China - Hong Kong SAR
Tel: 852-2943-5100
Fax: 852-2401-3431

China - Nanjing
Tel: 86-25-8473-2460
Fax: 86-25-8473-2470

China - Qingdao
Tel: 86-532-8502-7355
Fax: 86-532-8502-7205

China - Shanghai
Tel: 86-21-5407-5533
Fax: 86-21-5407-5066

China - Shenyang
Tel: 86-24-2334-2829
Fax: 86-24-2334-2393

China - Shenzhen
Tel: 86-755-8864-2200
Fax: 86-755-8203-1760

China - Wuhan
Tel: 86-27-5980-5300
Fax: 86-27-5980-5118

China - Xian
Tel: 86-29-8833-7252
Fax: 86-29-8833-7256

ASIA/PACIFIC

China - Xiamen
Tel: 86-592-2388138
Fax: 86-592-2388130

China - Zhuhai
Tel: 86-756-3210040
Fax: 86-756-3210049

India - Bangalore
Tel: 91-80-3090-4444
Fax: 91-80-3090-4123

India - New Delhi
Tel: 91-11-4160-8631
Fax: 91-11-4160-8632

India - Pune
Tel: 91-20-3019-1500

Japan - Osaka
Tel: 81-6-6152-7160
Fax: 81-6-6152-9310

Japan - Tokyo
Tel: 81-3-6880-3770
Fax: 81-3-6880-3771

Korea - Daegu
Tel: 82-53-744-4301
Fax: 82-53-744-4302

Korea - Seoul
Tel: 82-2-554-7200
Fax: 82-2-558-5932 or
82-2-558-5934

Malaysia - Kuala Lumpur
Tel: 60-3-6201-9857
Fax: 60-3-6201-9859

Malaysia - Penang
Tel: 60-4-227-8870
Fax: 60-4-227-4068

Philippines - Manila
Tel: 63-2-634-9065
Fax: 63-2-634-9069

Singapore
Tel: 65-6334-8870
Fax: 65-6334-8850

Taiwan - Hsin Chu
Tel: 886-3-5778-366
Fax: 886-3-5770-955

Taiwan - Kaohsiung
Tel: 886-7-213-7828

Taiwan - Taipei
Tel: 886-2-2508-8600
Fax: 886-2-2508-0102

Thailand - Bangkok
Tel: 66-2-694-1351
Fax: 66-2-694-1350

EUROPE

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

Denmark - Copenhagen
Tel: 45-4450-2828
Fax: 45-4485-2829

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

Germany - Dusseldorf
Tel: 49-2129-3766400

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

Germany - Pforzheim
Tel: 49-7231-424750

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

Italy - Venice
Tel: 39-049-7625286

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

Poland - Warsaw
Tel: 48-22-3325737

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

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

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