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

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12-Sep-14
Date

NOTES:

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

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

Preface

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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

<table>
<tr><th>Description</th><th>Represents</th><th>Examples</th></tr>
<tr><td colspan="3">Arial font:</td></tr>
<tr><td rowspan="2">Italic characters</td><td>Referenced books</td><td>MPLAB® IDE User's Guide</td></tr>
<tr><td>Emphasized text</td><td>...is the only compiler...</td></tr>
<tr><td rowspan="3">Initial caps</td><td>A window</td><td>the Output window</td></tr>
<tr><td>A dialog</td><td>the Settings dialog</td></tr>
<tr><td>A menu selection</td><td>select Enable Programmer</td></tr>
<tr><td>Quotes</td><td>A field name in a window or dialog</td><td>"Save project before build"</td></tr>
<tr><td>Underlined, italic text with right angle bracket</td><td>A menu path</td><td><u>File>Save</u></td></tr>
<tr><td rowspan="2">Bold characters</td><td>A dialog button</td><td>Click OK</td></tr>
<tr><td>A tab</td><td>Click the Power tab</td></tr>
<tr><td>N'Rnnnn</td><td>A number in verilog format, where N is the total number of digits, R is the radix and n is a digit.</td><td>4'b0010, 2'hF1</td></tr>
<tr><td>Text in angle brackets < ></td><td>A key on the keyboard</td><td>Press <Enter>, <F1></td></tr>
<tr><td colspan="3">Courier New font:</td></tr>
<tr><td rowspan="7">Plain Courier New</td><td>Sample source code</td><td><code>#define START</code></td></tr>
<tr><td>Filenames</td><td><code>autoexec.bat</code></td></tr>
<tr><td>File paths</td><td><code>c:\mcc18\h</code></td></tr>
<tr><td>Keywords</td><td><code>_asm, _endasm, static</code></td></tr>
<tr><td>Command-line options</td><td><code>-Opa+, -Opa-</code></td></tr>
<tr><td>Bit values</td><td><code>0, 1</code></td></tr>
<tr><td>Constants</td><td><code>0xFF, 'A'</code></td></tr>
<tr><td>Italic Courier New</td><td>A variable argument</td><td><code>file.o</code>, where <code>file</code> can be any valid filename</td></tr>
<tr><td>Square brackets [ ]</td><td>Optional arguments</td><td><code>mcc18 [options] file [options]</code></td></tr>
<tr><td>Curly brackets and pipe character: { | }</td><td>Choice of mutually exclusive arguments; an OR selection</td><td><code>errorlevel {0|1}</code></td></tr>
<tr><td rowspan="2">Ellipses...</td><td>Replaces repeated text</td><td><code>var_name [, var_name...]</code></td></tr>
<tr><td>Represents code supplied by user</td><td><code>void main (void)
{ ...
}</code></td></tr>
</table>

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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.

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- **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.

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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:

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REVISION HISTORY

Revision A (June 2015)

This is the initial release of this document.

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 I^2C™ 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.

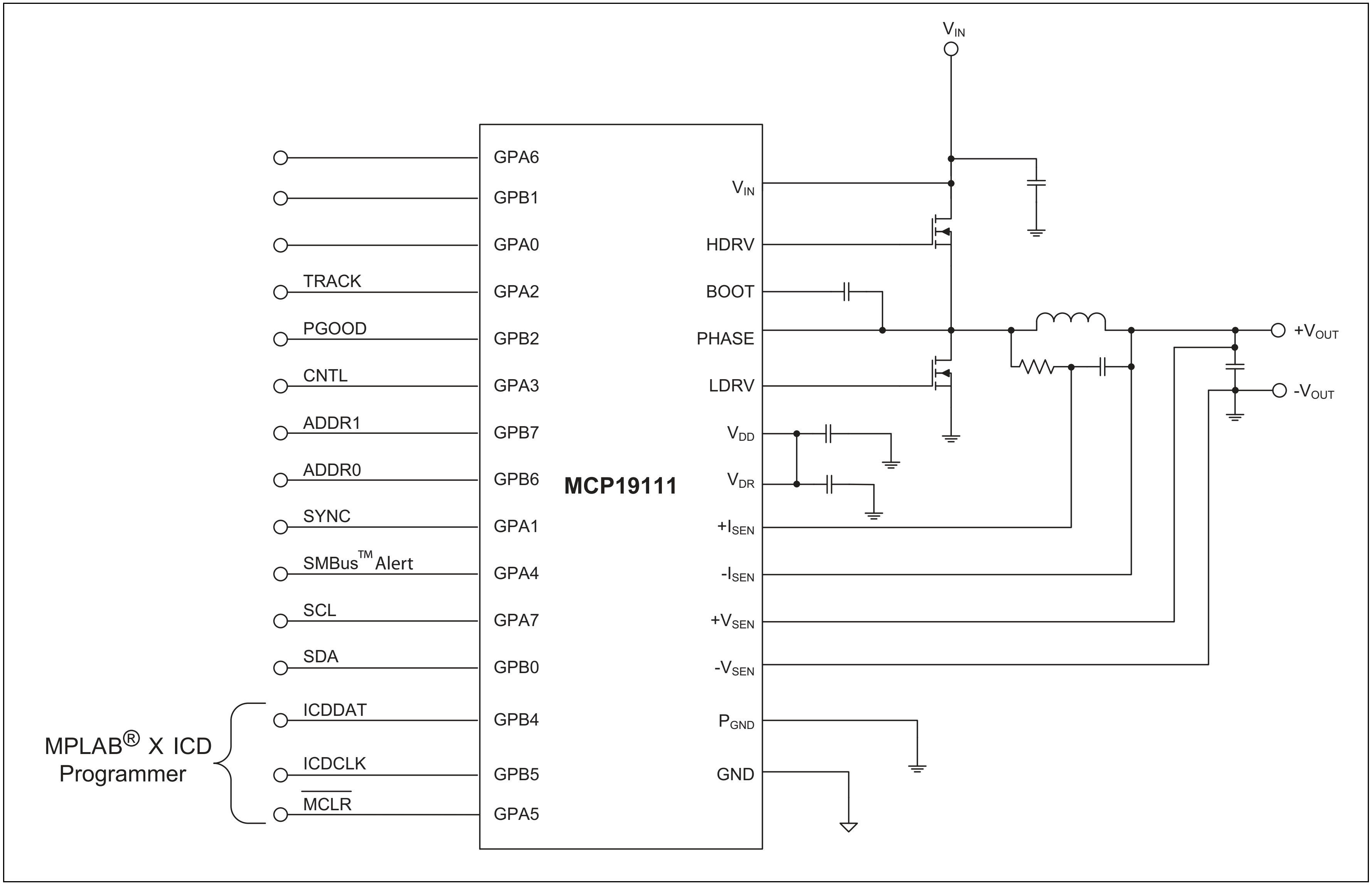


FIGURE 1-1: *MCP19111 Typical Application.*

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 I^2C 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 I^2C 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

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 I^2C 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/I^{2}C 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"**.

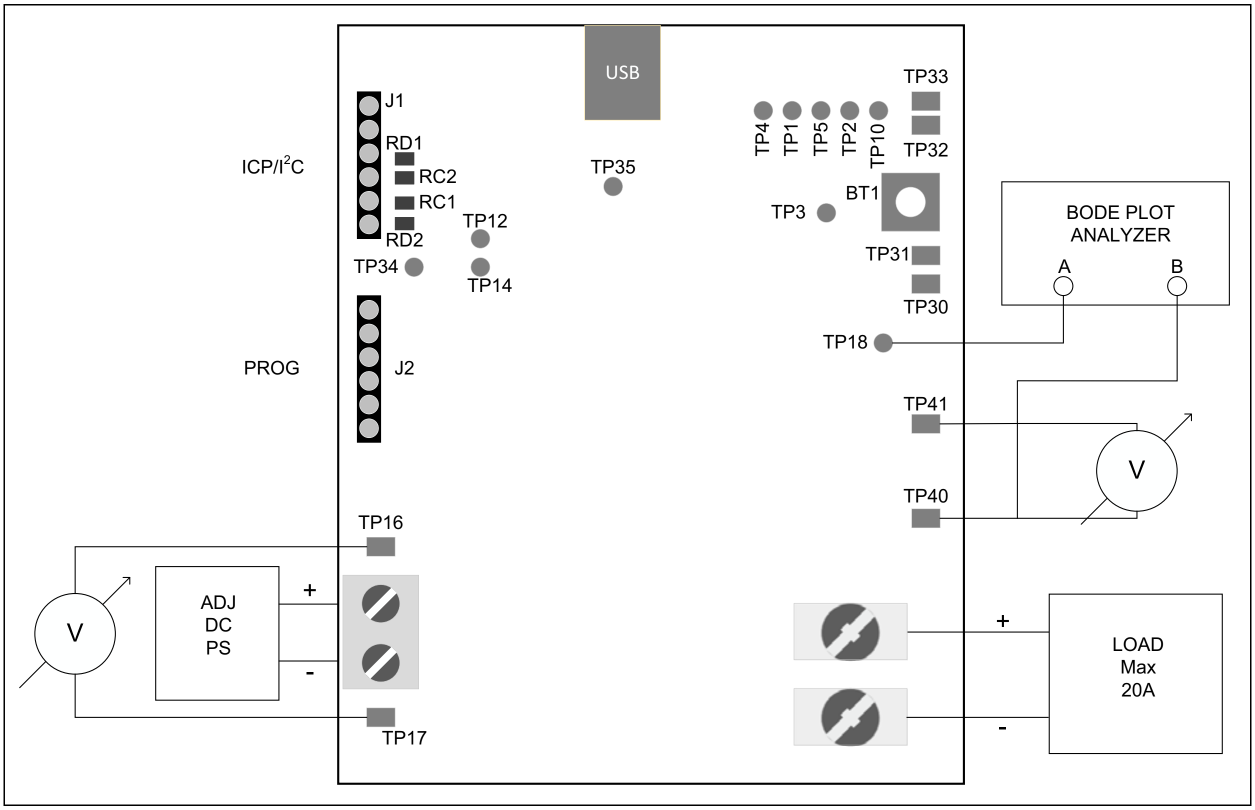


FIGURE 2-1: *Typical Test Setup.*

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/I^{2}C™ 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 I^{2}C bus; normally, the user should not simultaneously connect the USB and the ICP/I^{2}C 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).

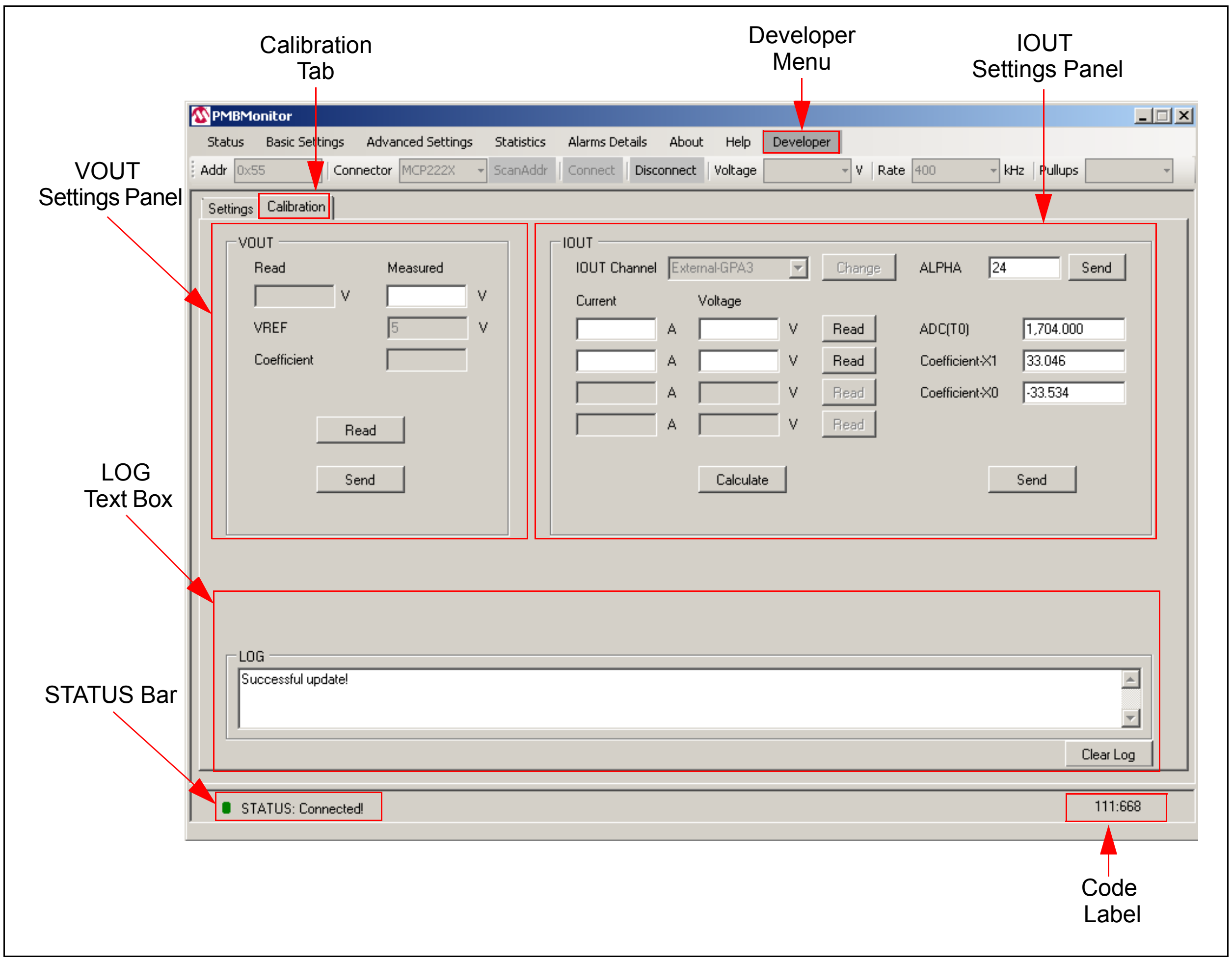


FIGURE 3-1: PMBMonitor GUI – Calibration Tab.

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.

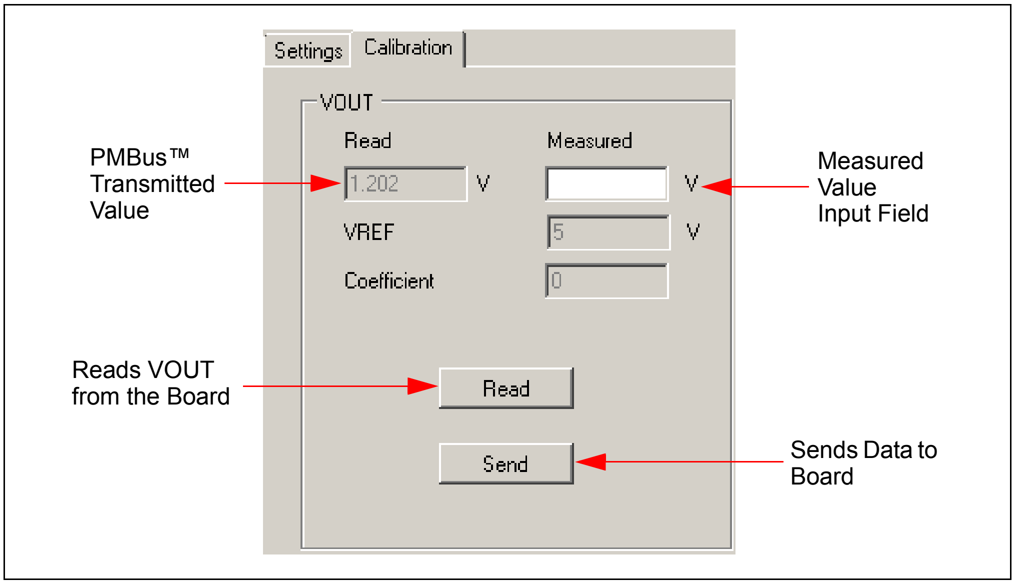


FIGURE 3-2: VOUT Settings Panel Description.

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.

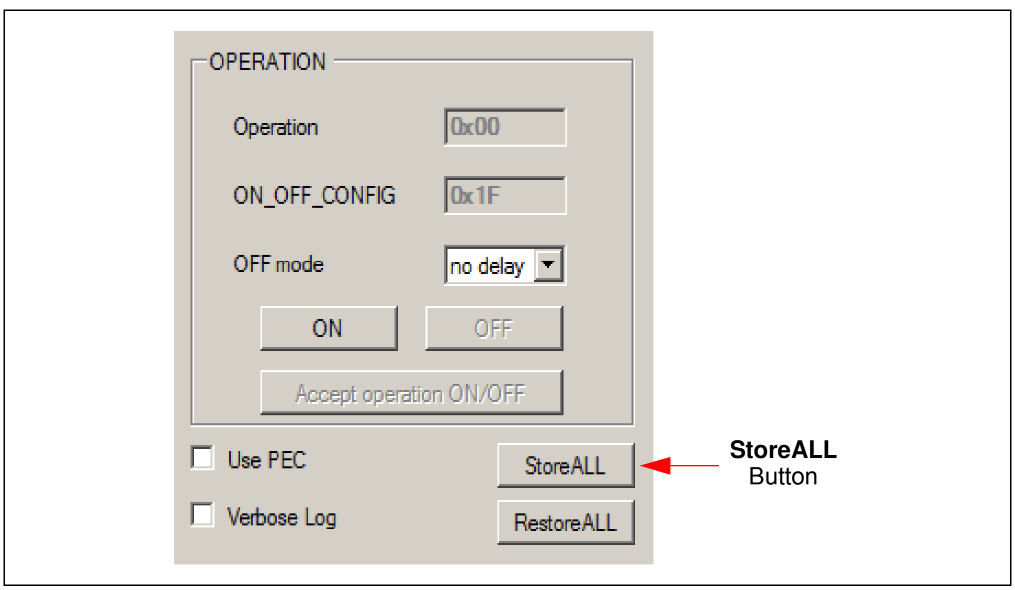


FIGURE 3-3: Status Menu – Operation Panel.

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.

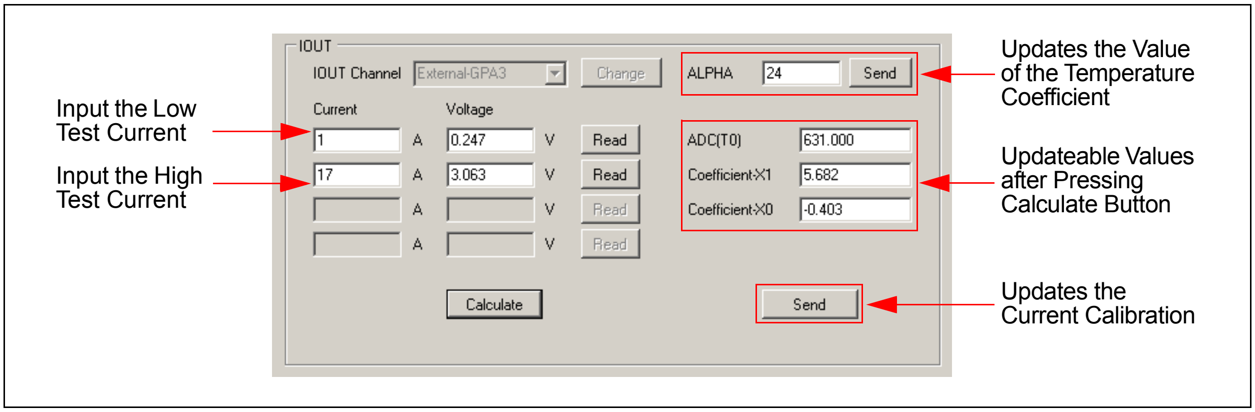


FIGURE 3-4: *IOUT Settings Panel.*

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) (α = Step 9:Step 8: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	—

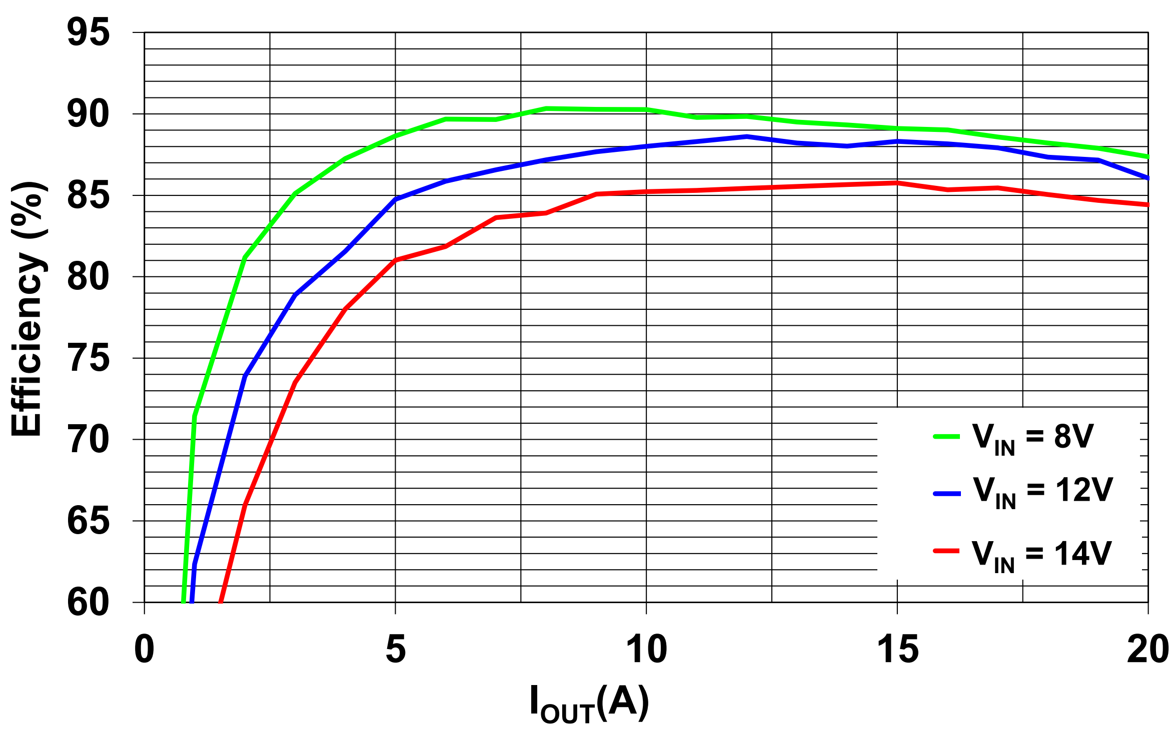


FIGURE 4-1: *Efficiency.*

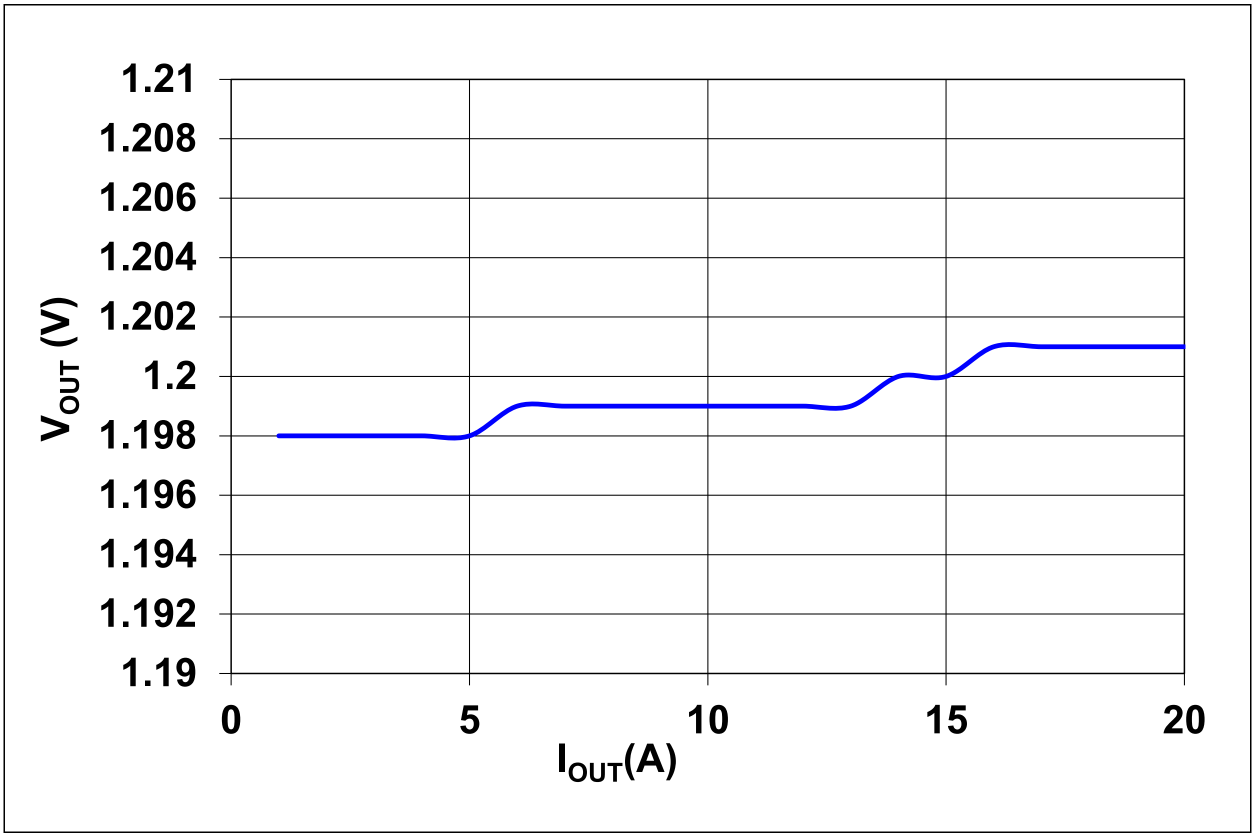


FIGURE 4-2: *Load Regulation (V_{IN} = 12V).*

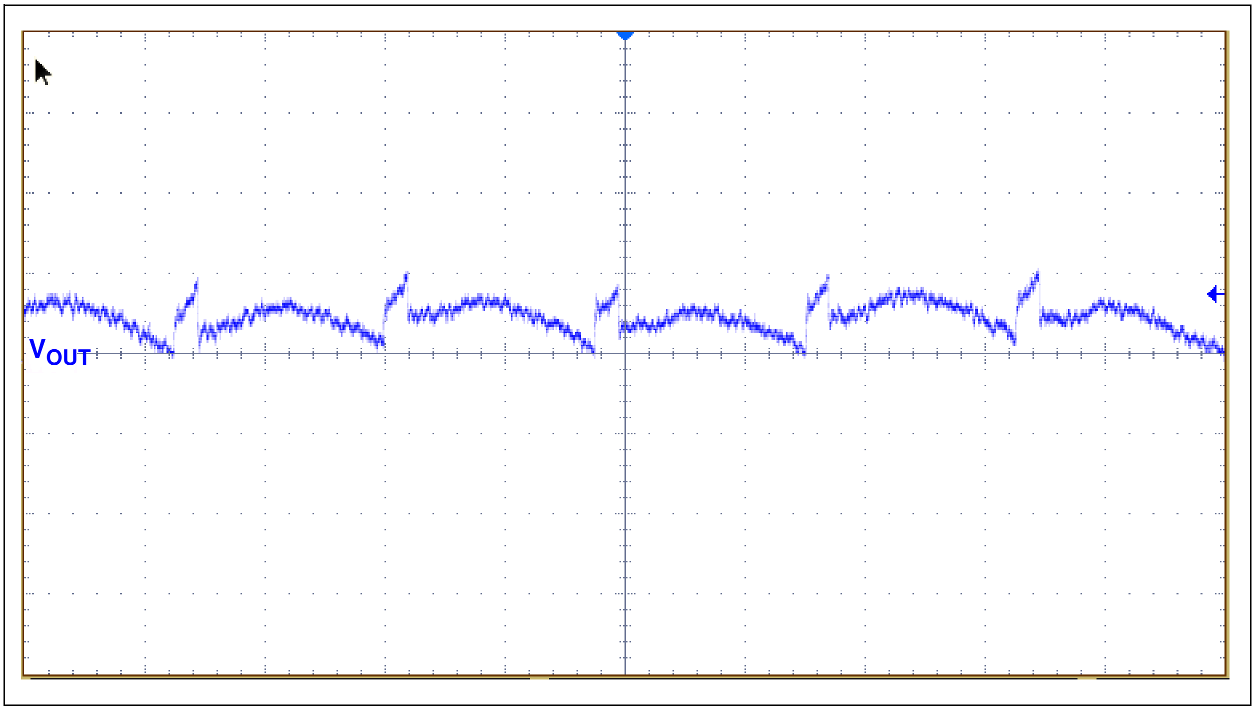


FIGURE 4-3: *Output Voltage Ripple/Noise (V_{IN} = 12V, I_{OUT} = 10A, BW = 20 MHz).*

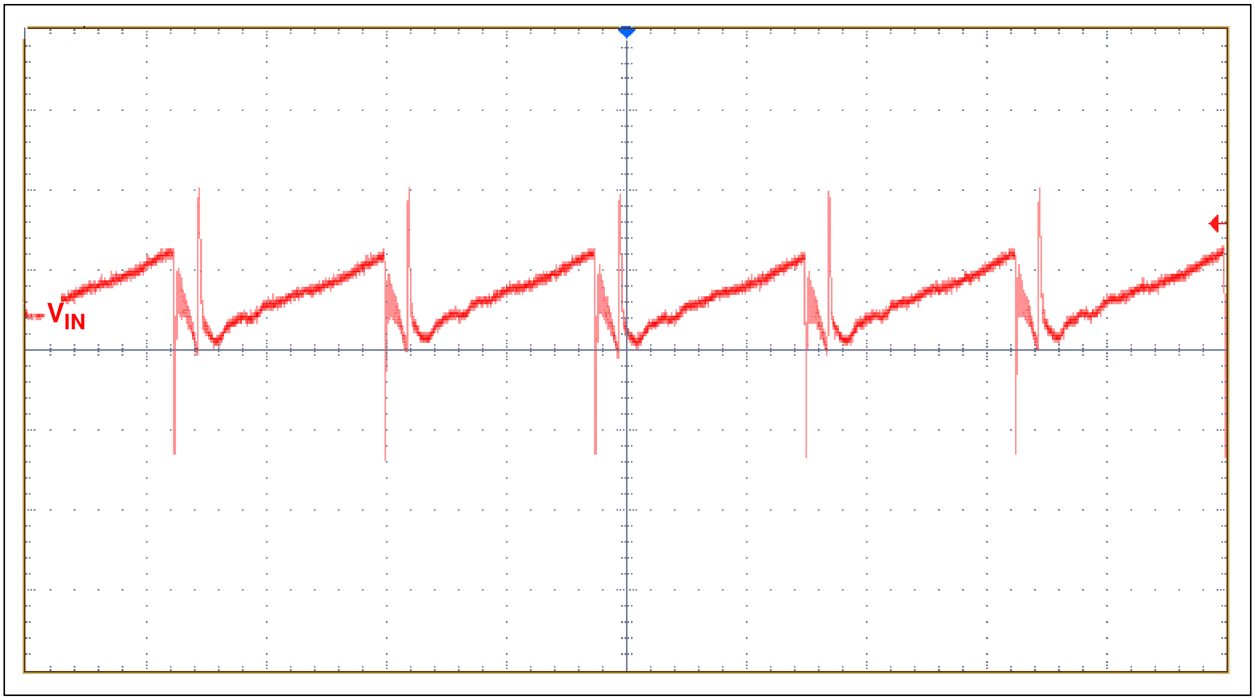


FIGURE 4-4: *Input Voltage Ripple/Noise (V_{IN} = 12V, I_{OUT} = 10A, BW = 20 MHz).*

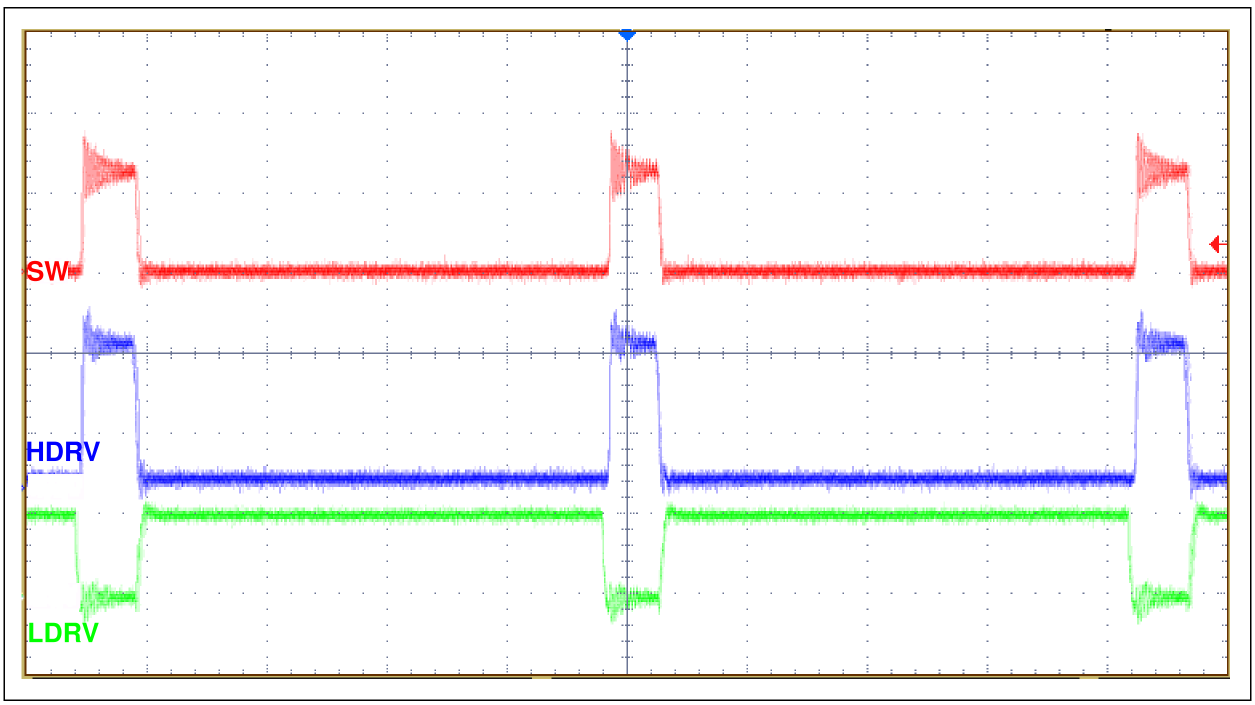


FIGURE 4-5: *SW, LDRV and HDRV Signals (V_{IN} = 12V, I_{OUT} = 15A, BW = 300 MHz).*

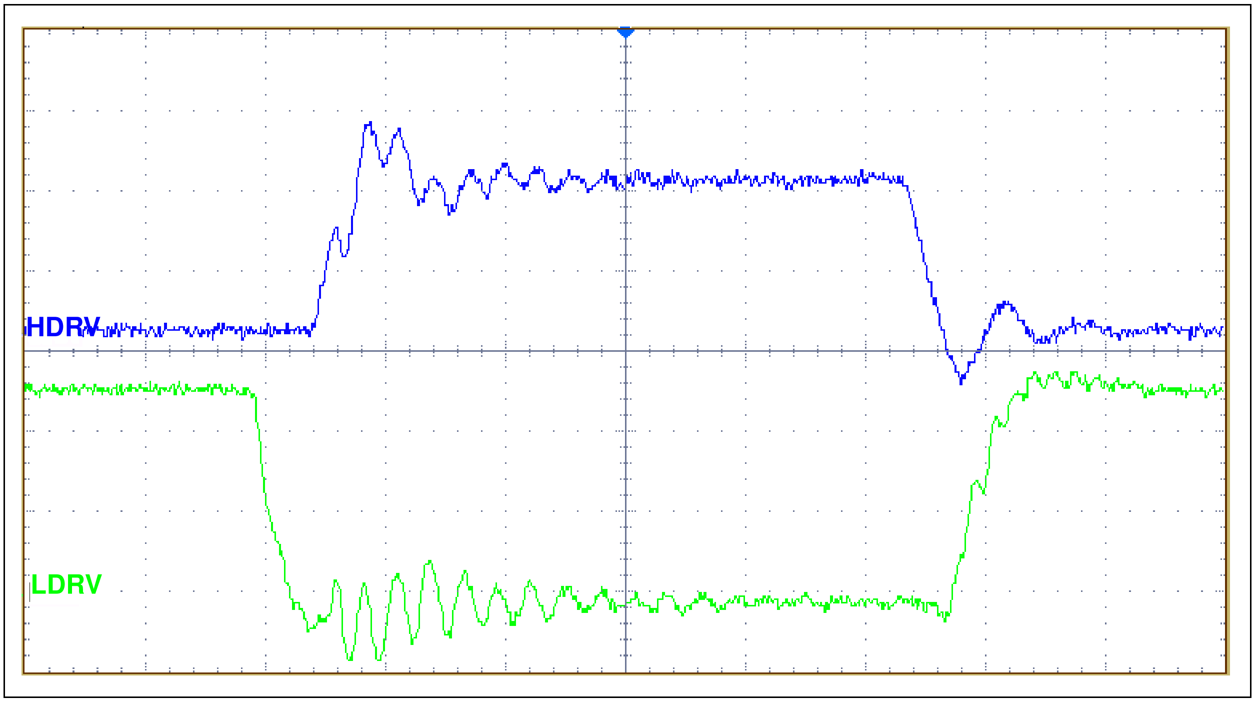


FIGURE 4-6: *LDRV and HDRV Signals (V_{IN} = 12V, I_{OUT} = 15A, BW = 300 MHz).*

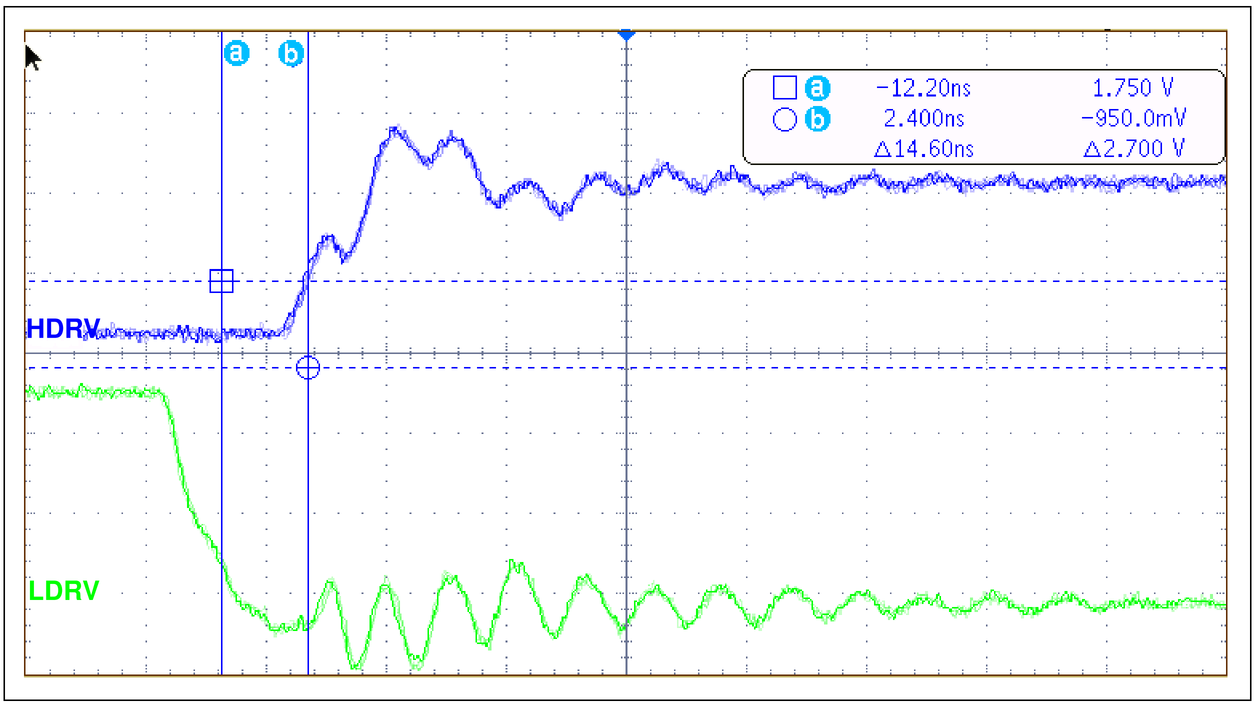


FIGURE 4-7: *Dead-Time Rise (V_{IN} = 12V, I_{OUT} = 15A, BW = 300 MHz).*

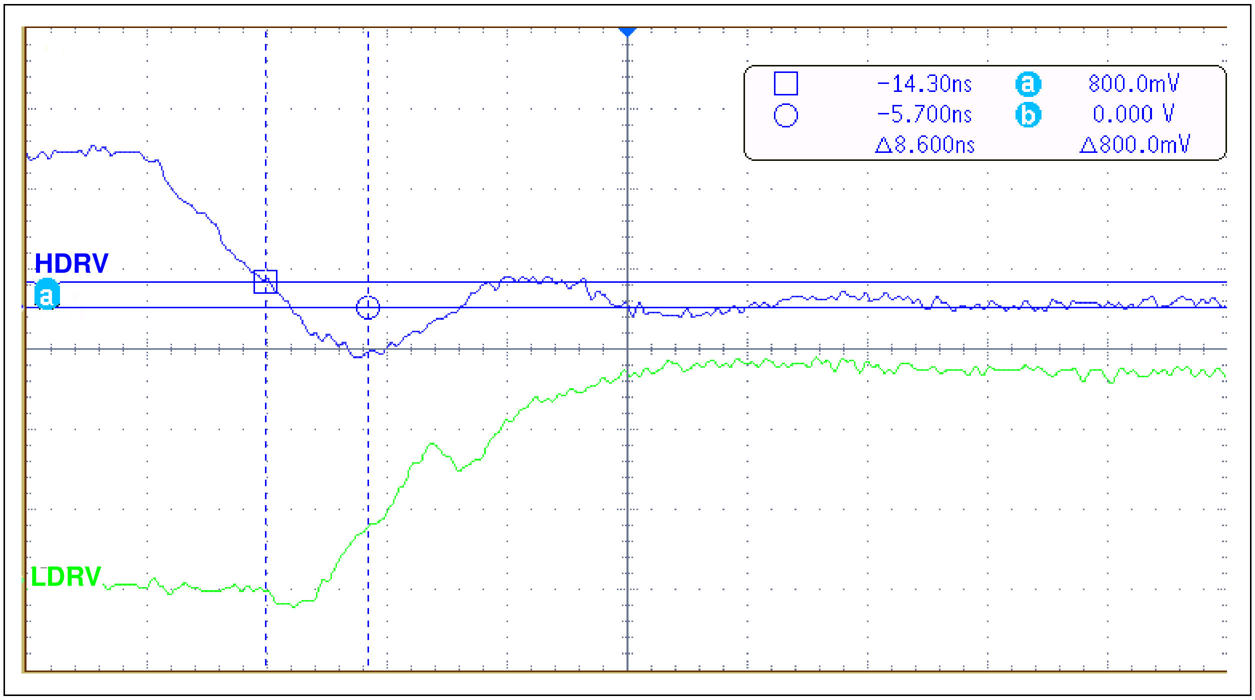


FIGURE 4-8: *Dead-Time Fall (V_{IN} = 12V, I_{OUT} = 15A, BW = 300 MHz).*

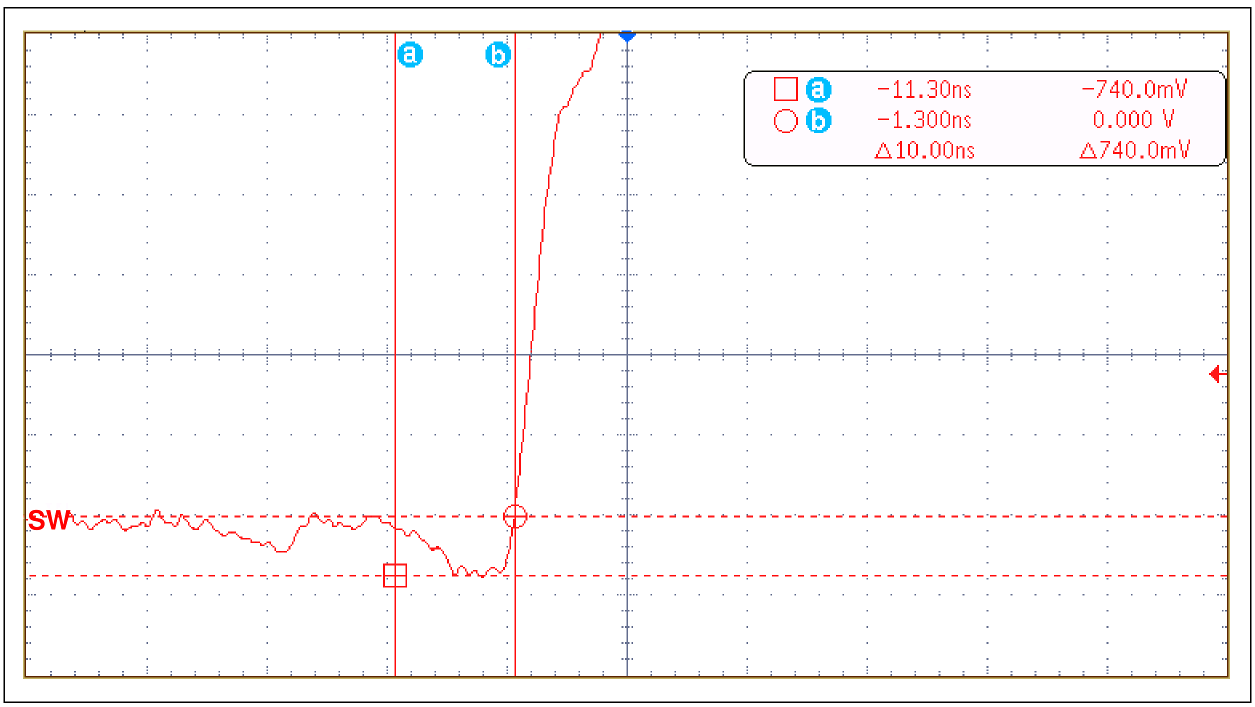


FIGURE 4-9: *The Body Diode Conduction Time (V_{IN} = 12V, I_{OUT} = 15A, BW = 300 MHz).*

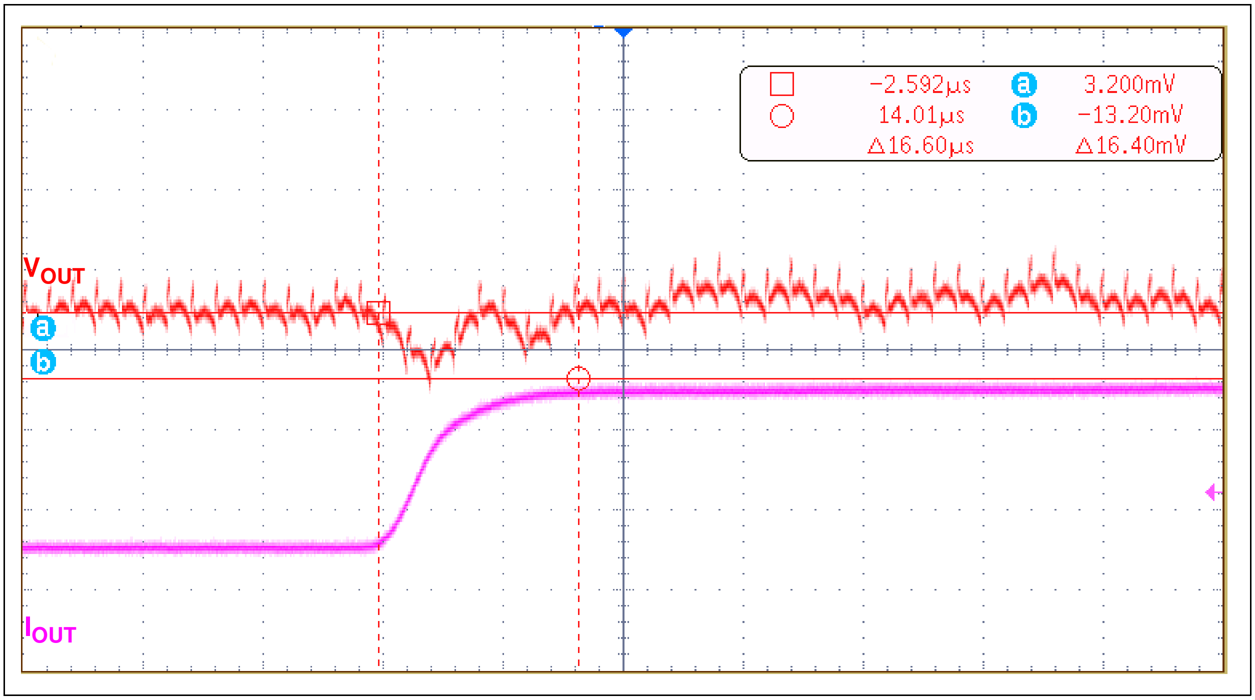


FIGURE 4-10: *Step Load Rising Current (V_{IN} = 12V).*

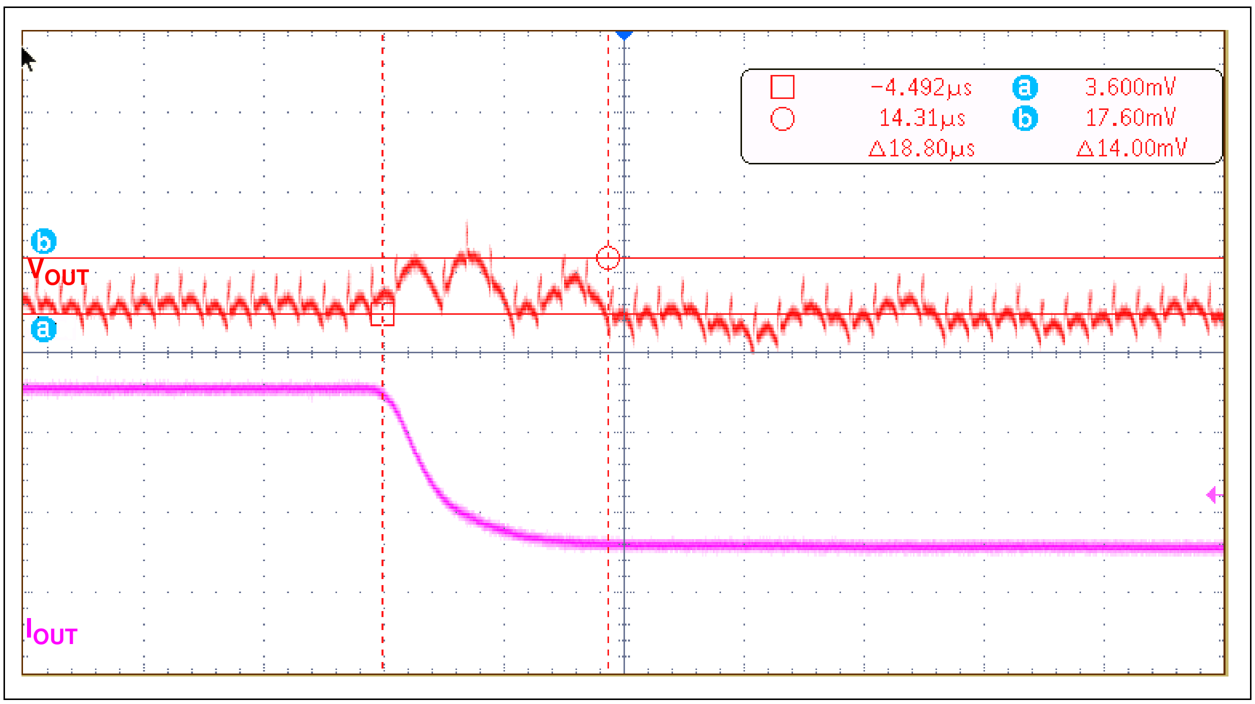


FIGURE 4-11: *Step Load Falling Current (V_{IN} = 12V).*

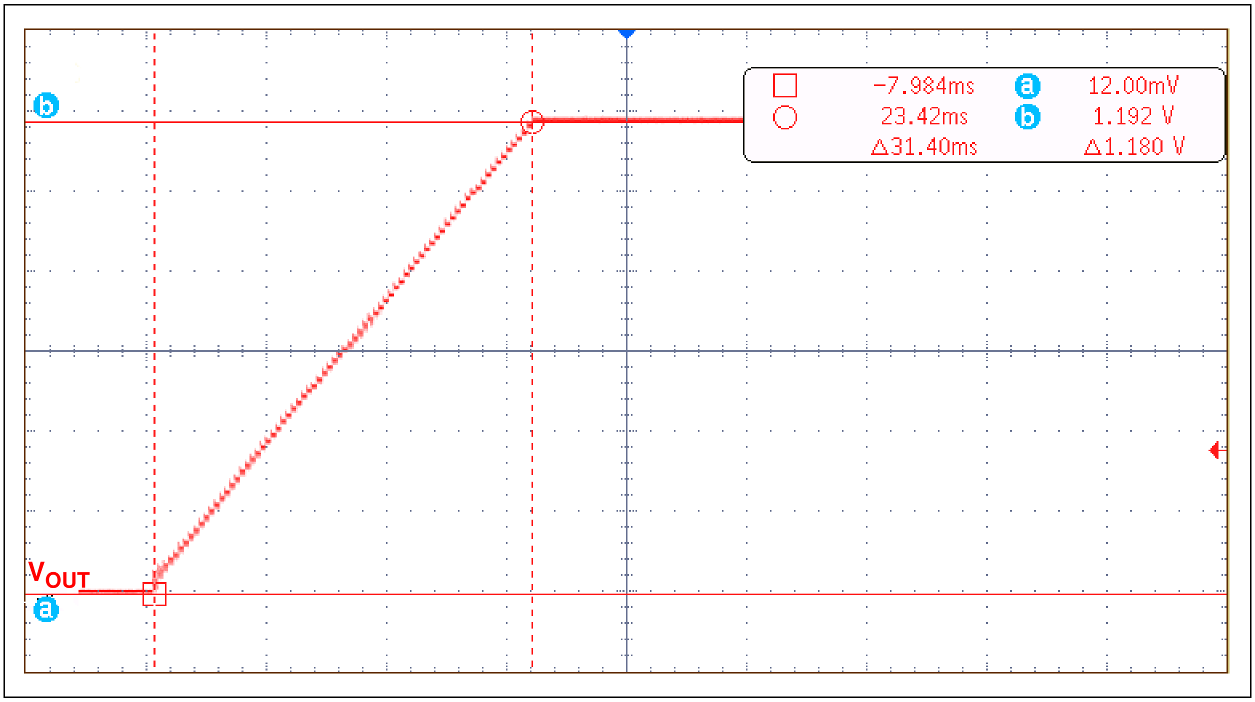


FIGURE 4-12: *Soft Start.*

NOTES:

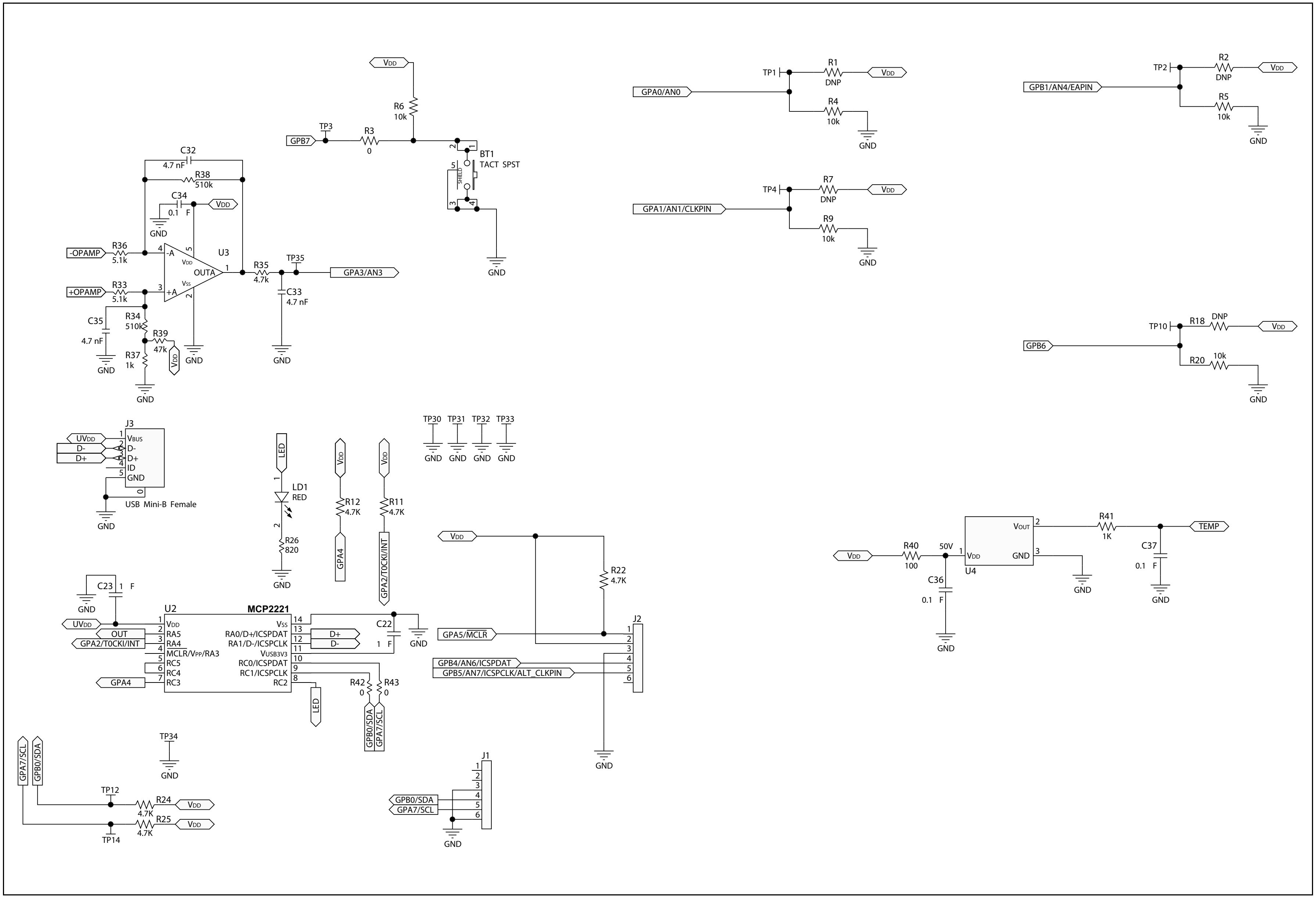
Appendix A. Schematics and Layouts

A.1 INTRODUCTION

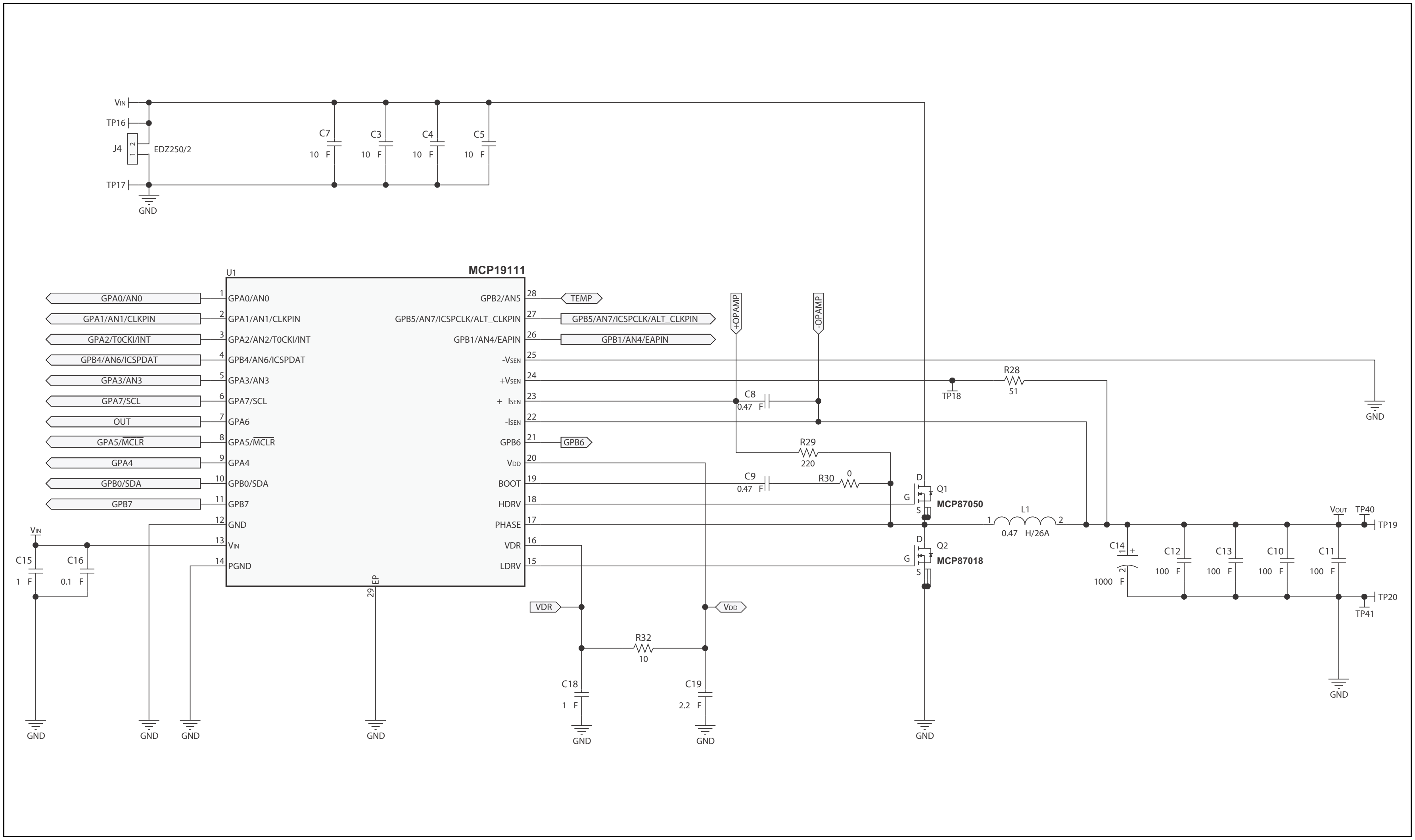
This appendix contains the following schematics and layouts for the MCP19111 PMBus™ Protocol-Enabled Point-of-Load Converter Reference Design:

- 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

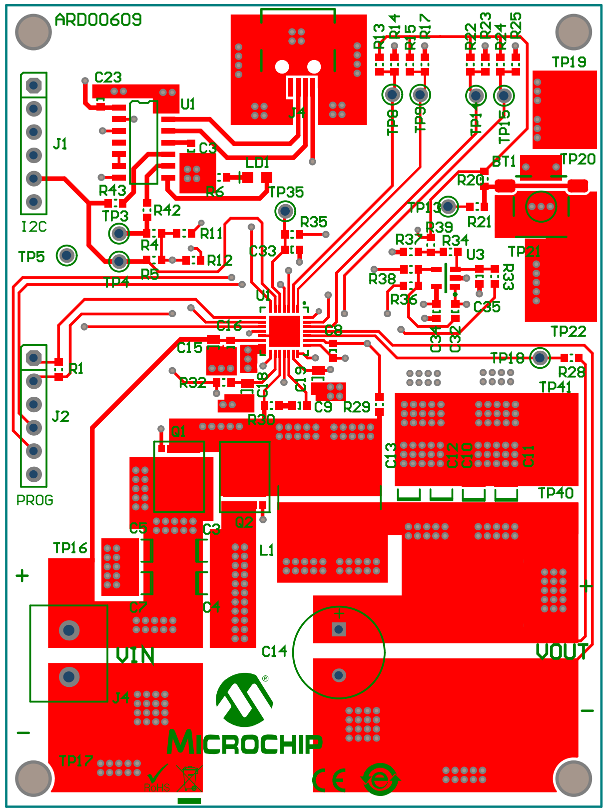
A.2 BOARD – SCHEMATIC 1



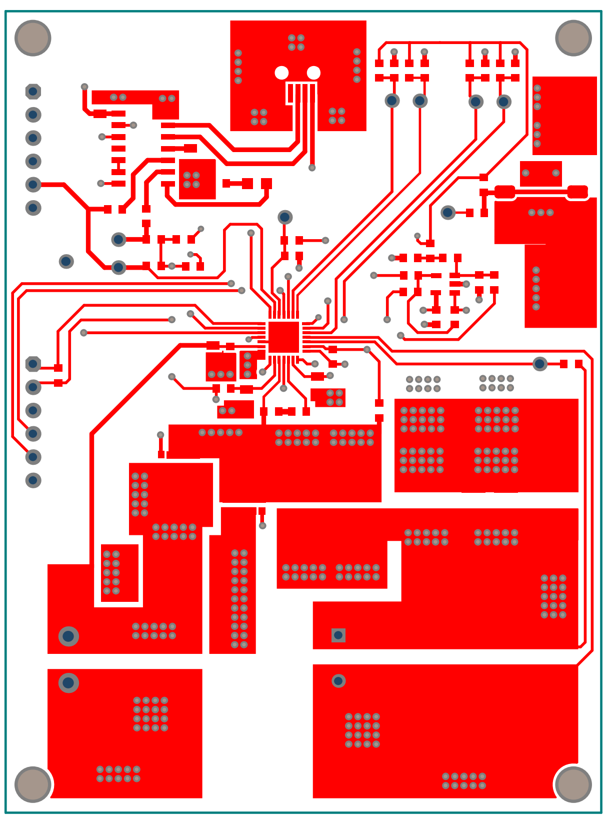
A.3 BOARD – SCHEMATIC 2



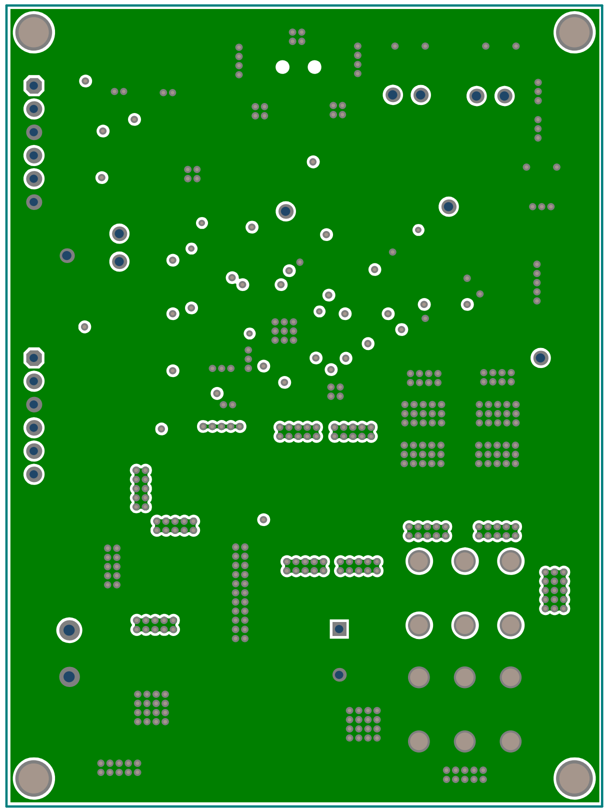
A.4 BOARD – TOP LAYER



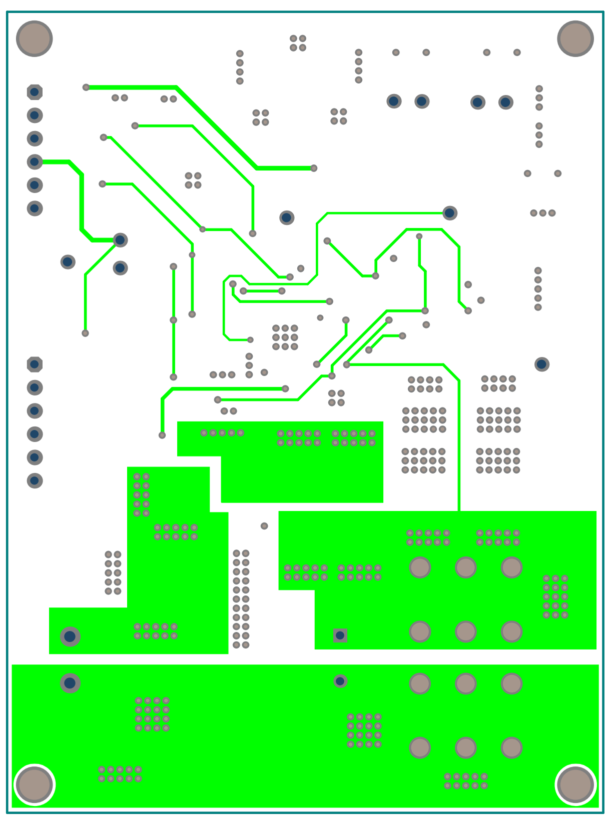
A.5 BOARD – TOP COPPER



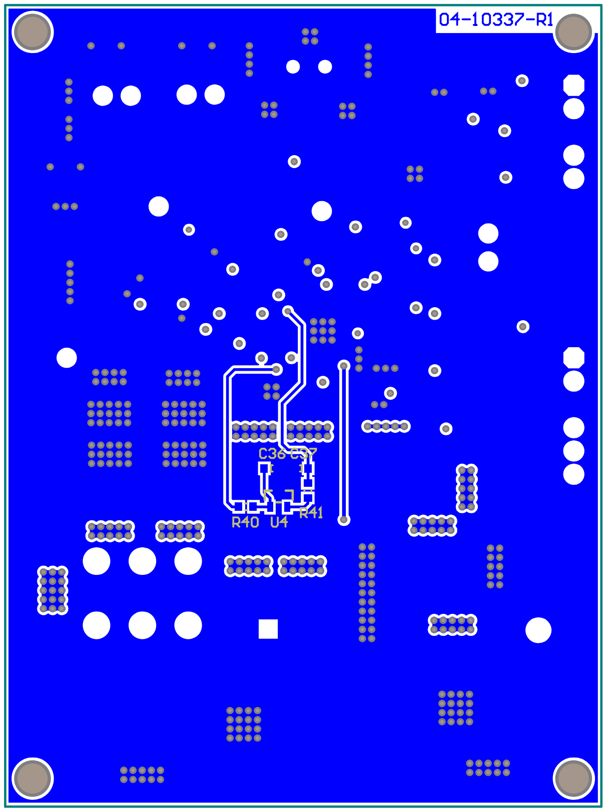
A.6 BOARD – MID LAYER 1



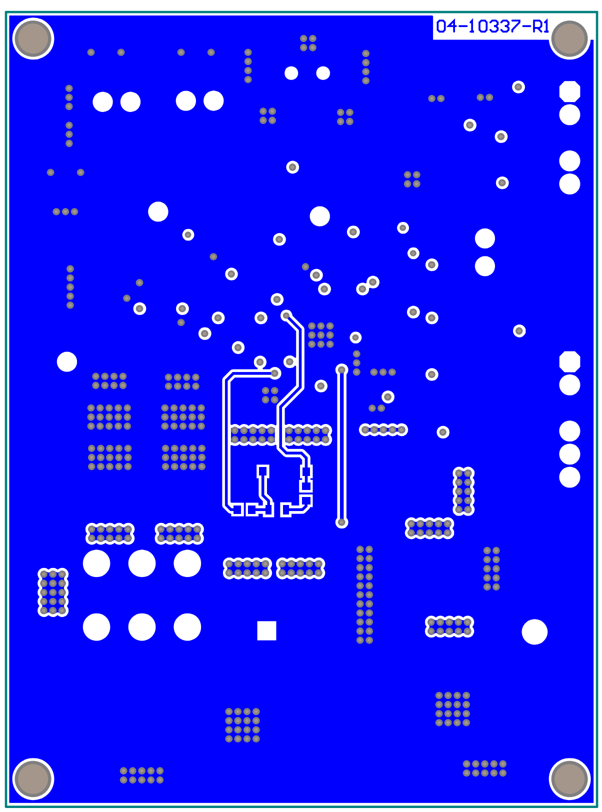
A.7 BOARD – MID LAYER 2



A.8 BOARD – BOTTOM LAYER



A.9 BOARD – BOTTOM COPPER



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 µF, 25V, 20%, X5R, SMD, 1210	Panasonic® – ECG	ECJ-4YB1E106M
2	C8, C9	Cap. Ceramic, 0.47 µF, 10V, 10%, X5R, 0603	TDK Corporation	C1608X5R1A474K080AA
4	C10, C11, C12, C13	Cap. Ceramic,100 µF, 6.3V, 20%, X5R, 1210	Murata Electronics®	GRM32ER60J107ME20L
1	C14	Cap. Alum., 1000 µF, 6.3V, 20%, Radial	Nichicon Corporation	RL80J102MDN1KX
1	C19	Cap. Ceramic, 2.2 µF, 10V, 20%, X5R, 0805	TDK Corporation	C2012X5R1A225M085AA
4	C15, C18, C22, C23	Cap. Ceramic, 1 µF, 16V, 10%, X7R, 0805	TDK Corporation	C2012X7R1C105K125AA
4	C16, C34, C36, C37	Cap. Ceramic, 0.1 µF, 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 mΩ	Wurth 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, 0.0Ω, Jumper, 1/10W	Vishay/Dale	CRCW06030000Z0EA
5	R4, R5, R6, R9, R20	Res., SMD, 10 kΩ, 5%, 1/10W, 0603	Yageo Corporation	RC0603JR-0710KP
6	R11, R12, R22, R24, R25, R35	Res., SMD, 4.7 kΩ, 5%, 1/10W, 0603	Yageo Corporation	RC0603JR-074K7P
1	R26	Res., SMD, 820Ω, 5%, 1/10W, 0603	ROHM Semiconductor	MCR03ERTJ821
1	R28	Res., SMD, 51Ω, 1%, 1/10W, 0603	ROHM Semiconductor	MCR03ERTF51R0
1	R29	Res., SMD, 220Ω, 1%, 1/10W, 0603	ROHM Semiconductor	MCR03ERTF2200

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:

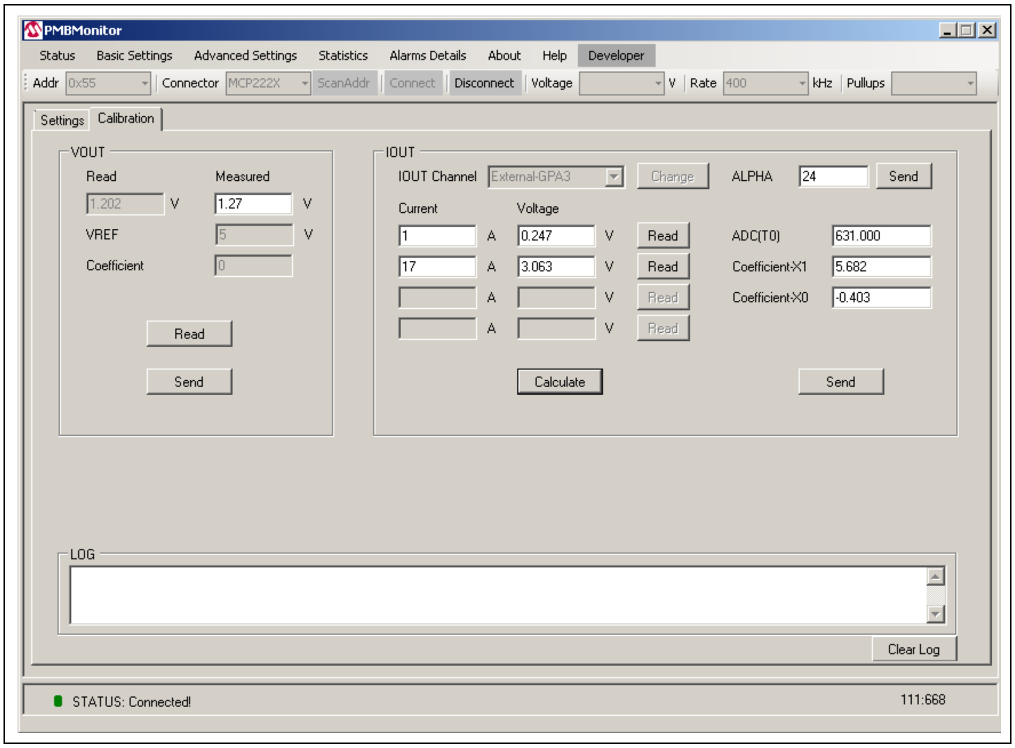


FIGURE C-1: MCP19111 Calibration Values Example.

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)
ΔT	=	246 ADC – 156 ADC = 88 ADC			
17A	@	27°C	→	$V(T_0)$ = 3.063	
17A	@	70°C	→	V(T) = 3.516V	

Use the simplest form of the equation:

EQUATION C-4:

$$V(T_0) = V(T) \times (1 - \alpha \times \Delta T)$$
$$3.063 = 3.516 \times (1 - 88 \times \alpha)$$
$$\alpha = 0.001464$$

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.

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