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MCP19111
PMBus™ Protocol-Enabled
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Reference Design
User's Guide

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

EU Declaration of Conformity

Manufacturer: Microchip Technology Inc.
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This development/evaluation tool complies with EU RoHS2 Directive 2011/65/EU.

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

Derek Carlson
VP Development Tools

12-Sep-14
Date

NOTES:

Table of Contents

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

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.

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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

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• 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

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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^{2}C™ 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.

MCP19111 PMBus™ Protocol-Enabled POL Converter Reference Design

V$_{IN}$

GPA6		
GPB1		
GPA0		V$_{IN}$
TRACK	GPA2	HDRV
PGOOD	GPB2	BOOT
CNTL	GPA3	PHASE
ADDR1	GPB7	LDRV
ADDR0	GPB6	V$_{DD}$
SYNC	GPA1	V$_{DR}$
SMBus™Alert	GPA4	+I$_{SEN}$
SCL	GPA7	-I$_{SEN}$
SDA	GPB0	+V$_{SEN}$
ICDDAT	GPB4	-V$_{SEN}$
ICDCLK	GPB5	P$_{GND}$
MCLR	GPA5	GND

MCP19111
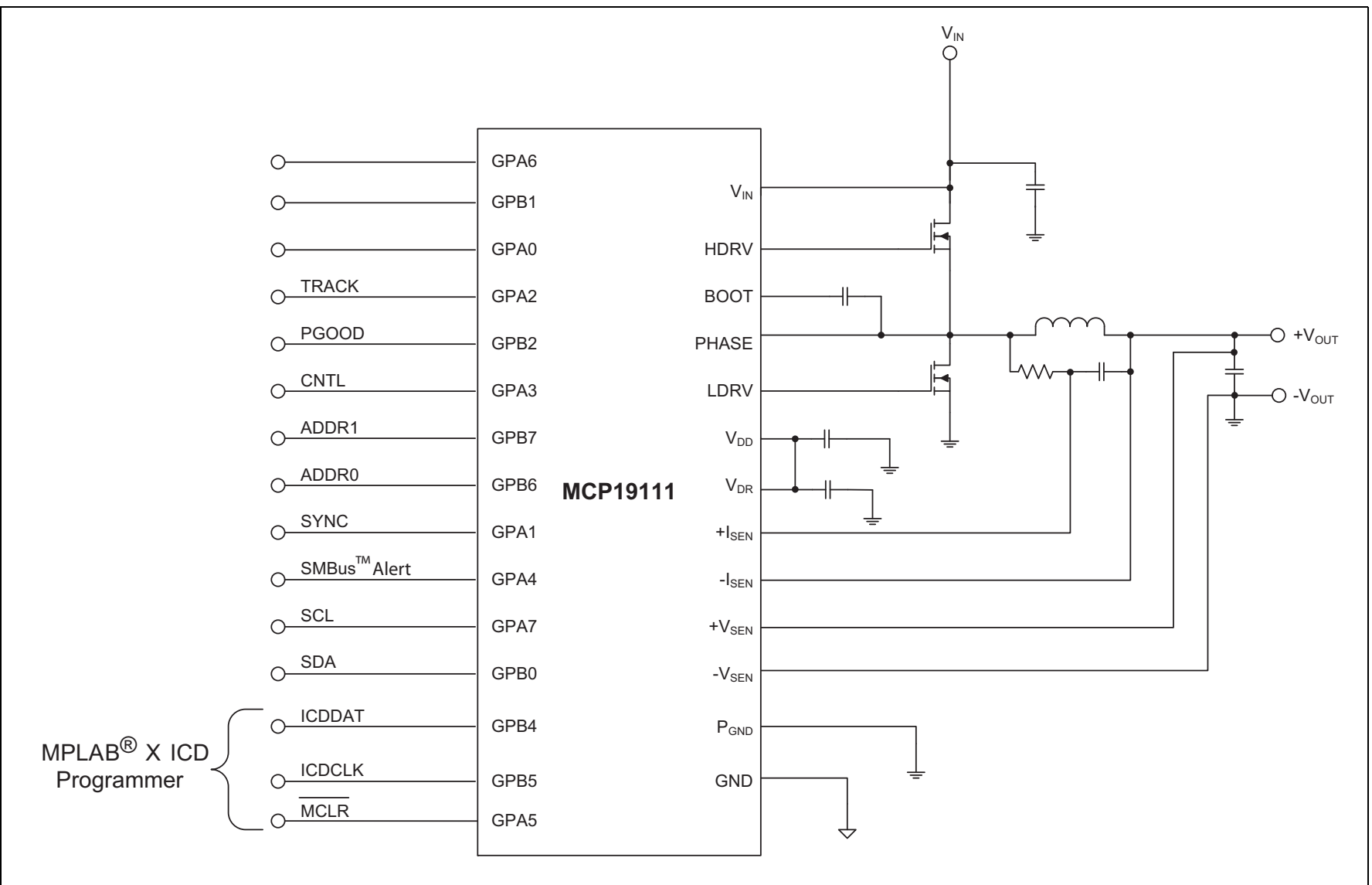
MPLAB® X ICD Programmer

+V$_{OUT}$

-V$_{OUT}$

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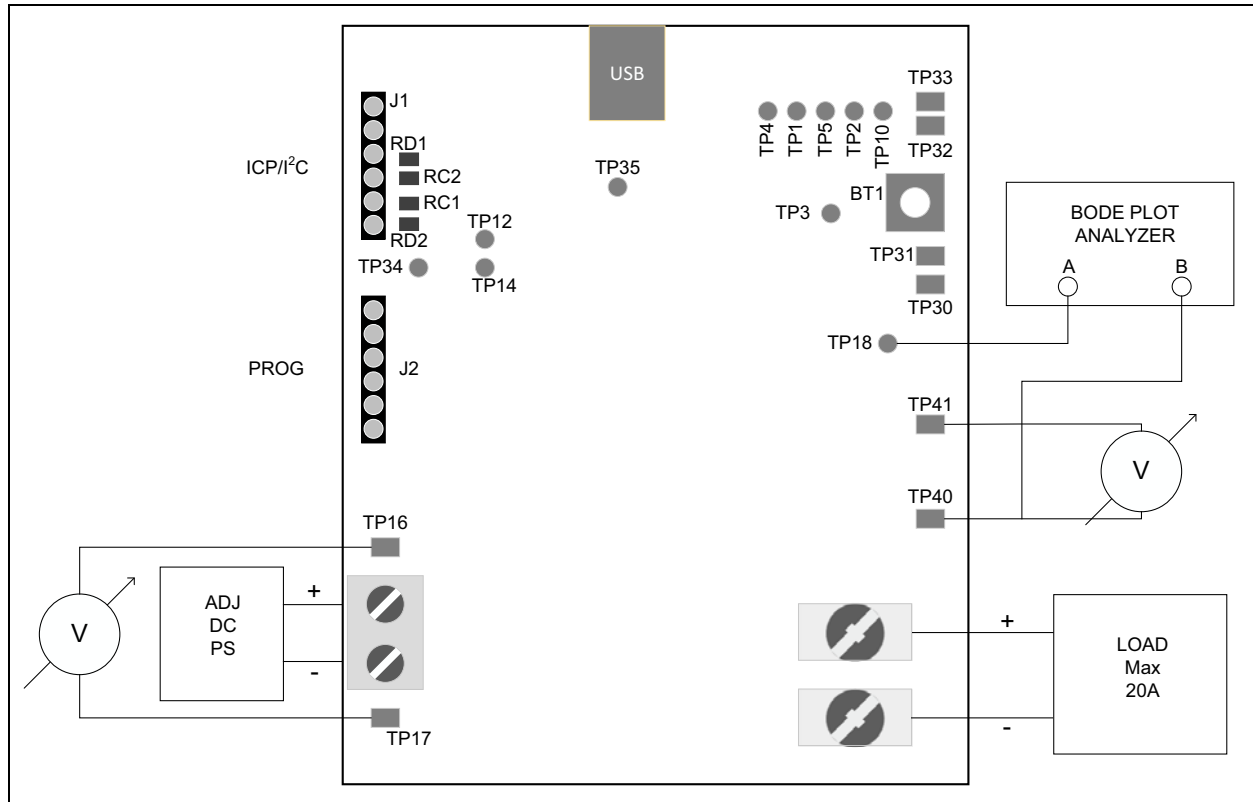

FIGURE 2-1:   *Typical Test Setup.*

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/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).
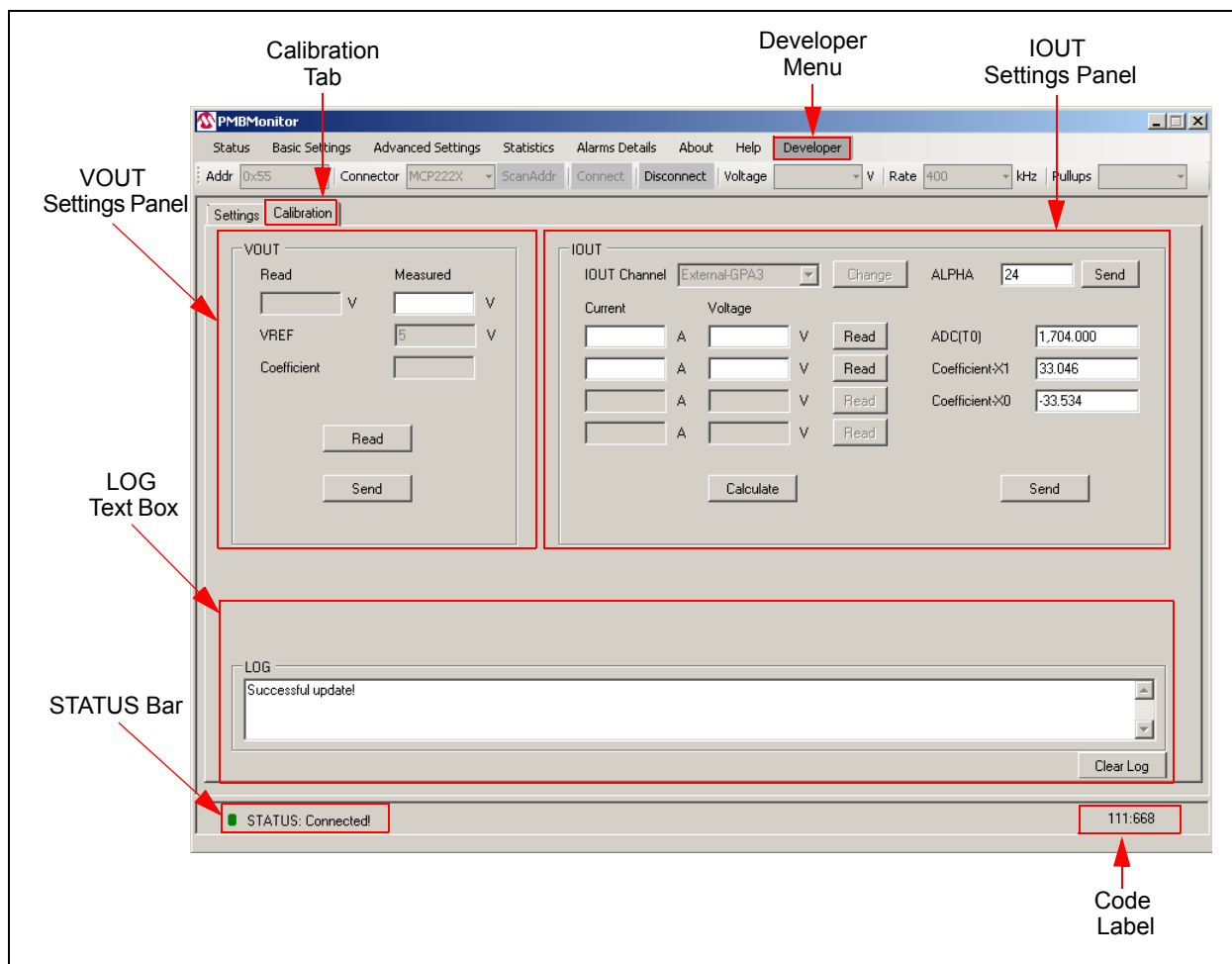

FIGURE 3-1: PMBMonitor GUI – Calibration Tab.

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.
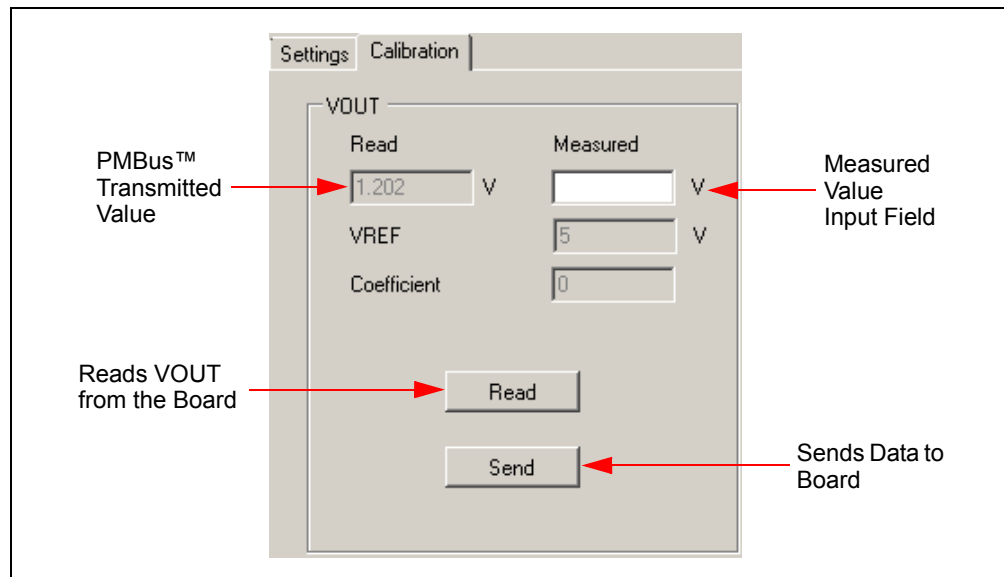2. In the VOUT Settings Panel, press the **Read** button.

PMBus™ Transmitted Value

Measured Value Input Field

Reads VOUT from the Board

Sends Data to Board

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.
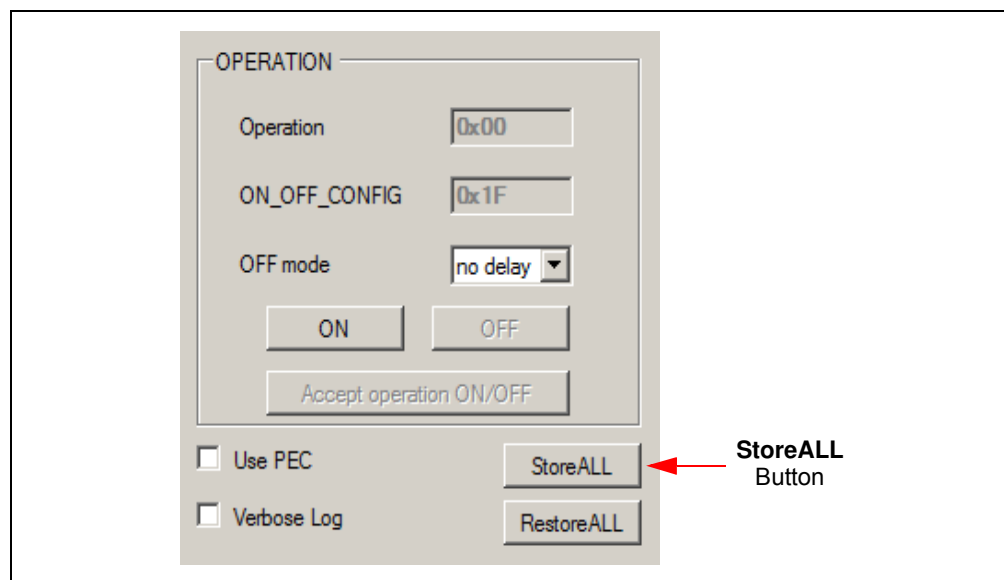

StoreALL Button

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.
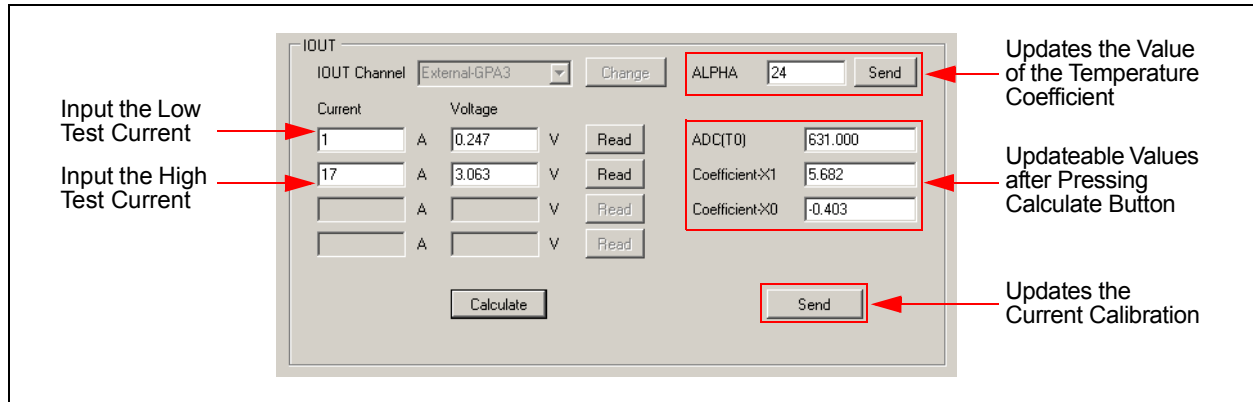

FIGURE 3-4: *IOUT Settings Panel.*

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

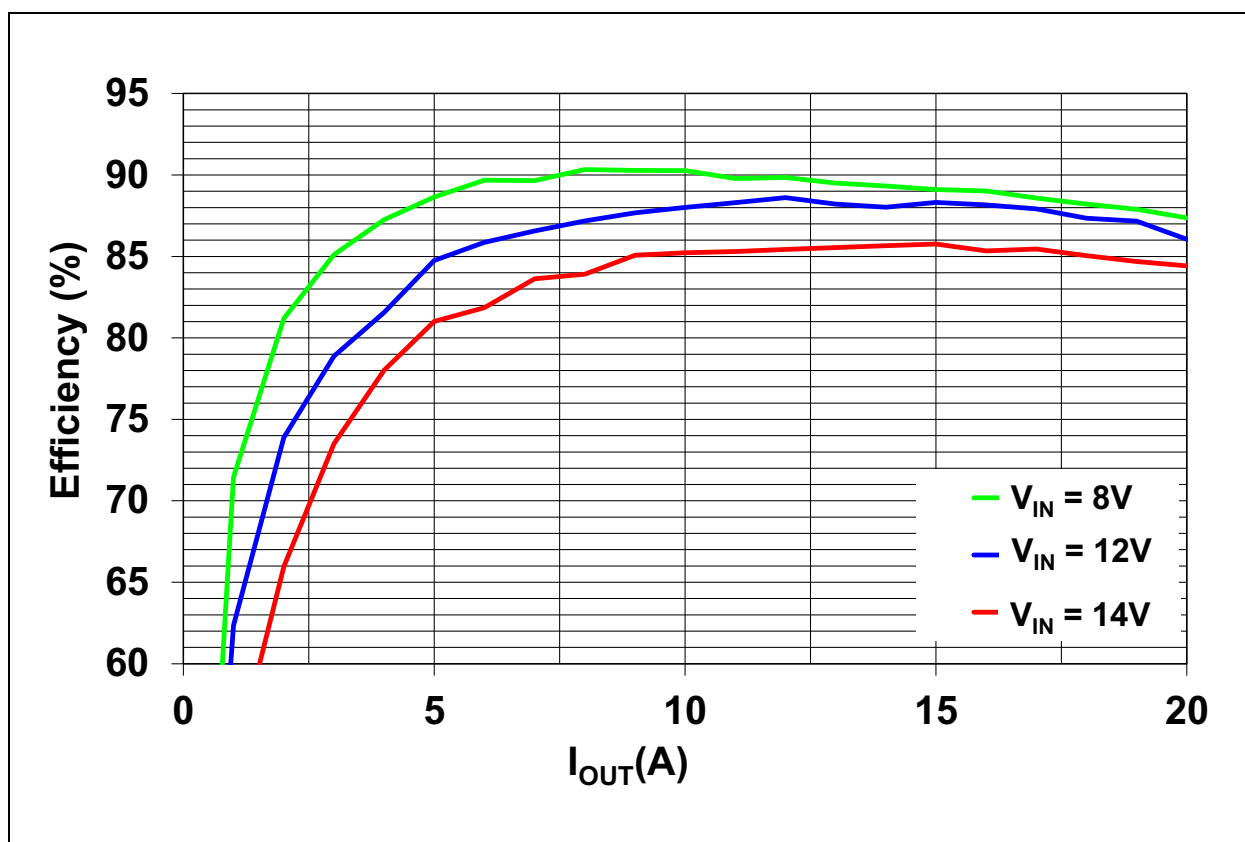| Parameter	Value	Comments
Input Voltage Range (V)	8-14	—
Output Voltage (V)	1.2	±2.5% Tolerance
Maximum Output Current (A)	20	Steady-State Output Current
Output Voltage Ripple (mV)	<30	V_{IN} = 12V, I_{OUT} = 20A
Input Voltage Ripple (mV)	<400	V_{IN} = 12V, I_{OUT} = 20A
Output Voltage Overshoot during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

FIGURE 4-1:   Efficiency.