**MICROCHIP**

# PAC1921
# High-Side Current/Power Sensor
# Evaluation Board
# User's Guide

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# QUALITY MANAGEMENT  SYSTEM
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**Object of Declaration: PAC1921 High-Side Current/Power Sensor Evaluation Board**

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.

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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:**

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# PAC1921
## HIGH-SIDE CURRENT/POWER SENSOR EVALUATION BOARD USER'S GUIDE

# Preface

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## 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 on-line help. Select the Help menu, and then Topics to open a list of available on-line help files.**

## INTRODUCTION

This chapter contains general information that will be useful to know before using the PAC1921 High-Side Current/Power Sensor Evaluation Board. Items discussed in this chapter include:

• Document Layout
• Conventions Used in this Guide
• Warranty Registration
• Recommended Reading
• The Microchip Web Site
• Customer Support
• Document Revision History

## DOCUMENT LAYOUT

This document describes how to use the PAC1921 High-Side Current/Power Sensor Evaluation Board as a development tool to emulate and debug firmware on a target board. The manual layout is as follows:

• **Chapter 1. "Product Overview"** – Important information about the PAC1921 High-Side Current/Power Sensor Evaluation Board.
• **Chapter 2. "Installation and Operation"** – Includes instructions on installing and starting the application.
• **Chapter 3. "Hardware Description"** – Shows hardware details of the PAC1921 High-Side Current/Power Sensor Evaluation Board.
• **Chapter 4. "Software Description"** – Describes the main operations in the software.
• **Appendix A. "Schematic and Layouts"** – Shows the schematic and layout diagrams for the PAC1921 High-Side Current/Power Sensor Evaluation Board.
• **Appendix B. "Bill of Materials (BOM)"** – Lists the parts used to build the PAC1921 High-Side Current/Power Sensor Evaluation Board.

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## 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)`<br>`{ ...`<br>`}` |

## 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 PAC1921 High-Side Current/Power Sensor Evaluation Board. Other useful documents are listed below. The following Microchip documents are available and recommended as supplemental reference resources.

### PAC1921 Data Sheet (DS20005293)

This data sheet describes the operation and features of the PAC1921 high-side power/current monitor device with a configurable analog output.

## 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

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

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Technical support is available through the web site at:

http://www.microchip.com/support

## DOCUMENT REVISION HISTORY

### Revision A (June 2015)

- Initial Release of this Document.

**NOTES:**

# Chapter 1. Product Overview

## 1.1 INTRODUCTION

The PAC1921 is a dedicated power monitoring device with a configurable output. The PAC1921 High-Side Current/Power Sensor Evaluation Board package provides users with the means to exercise device functionality while connected either to target systems (Sys mode) or while utilizing on-board sources (Demo mode).

## 1.2 PAC1921 EVALUATION SYSTEM

The evaluation system has three major parts, as shown in Figure 1-1:

- Customer-provided Windows® PC with an available USB port
- Microchip PAC1921 Graphical User Interface (GUI) (based on National Instruments™ LabVIEW™ software)
- Microchip PAC1921 High-Side Current/Power Sensor Evaluation Board
- USB Cable for GUI communications (Standard-A plug to Mini-B plug)
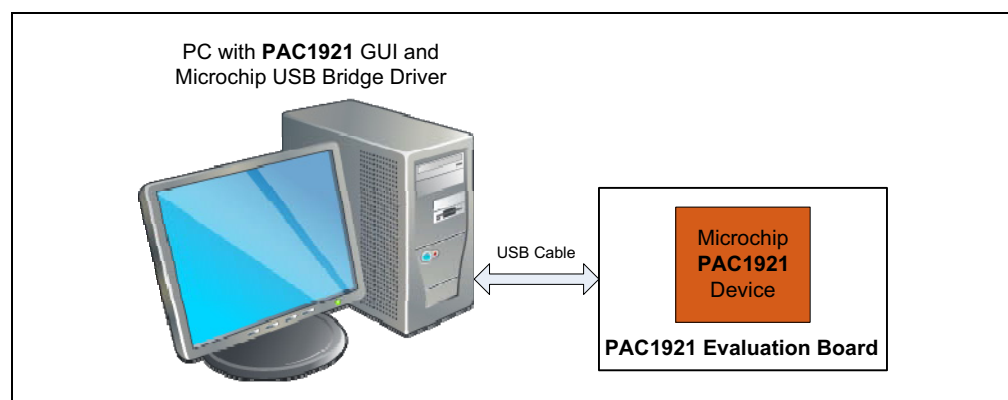


*FIGURE 1-1:*      *PAC1921 Evaluation System.*

> **Note:** Screen captures in this document were taken on a PC with Windows® 7 Professional using the default desktop colors. The colors on your screen may vary, especially if a Windows theme has been applied on the PC.

## 1.3   WHAT IS THE PAC1921 HIGH-SIDE CURRENT/POWER SENSOR EVALUATION BOARD?

The evaluation system is comprised of the ADM00592 and a LabVIEW software-based application which allows the user to do the following:

• View and change register values
• Saving settings of all registers allowing for quick configuration at a later time
• Graphing registers

The hardware platform provides the following features to the user:

• Headers for connecting a sense resistor
• USB-to-SMBus bridge for communications
• Capability to connect directly to an external SMBus master

### 1.3.1   Board Layout

The evaluation board was designed for ease of use and user experimentation. Figure 1-2 shows the top silkscreen for the board.
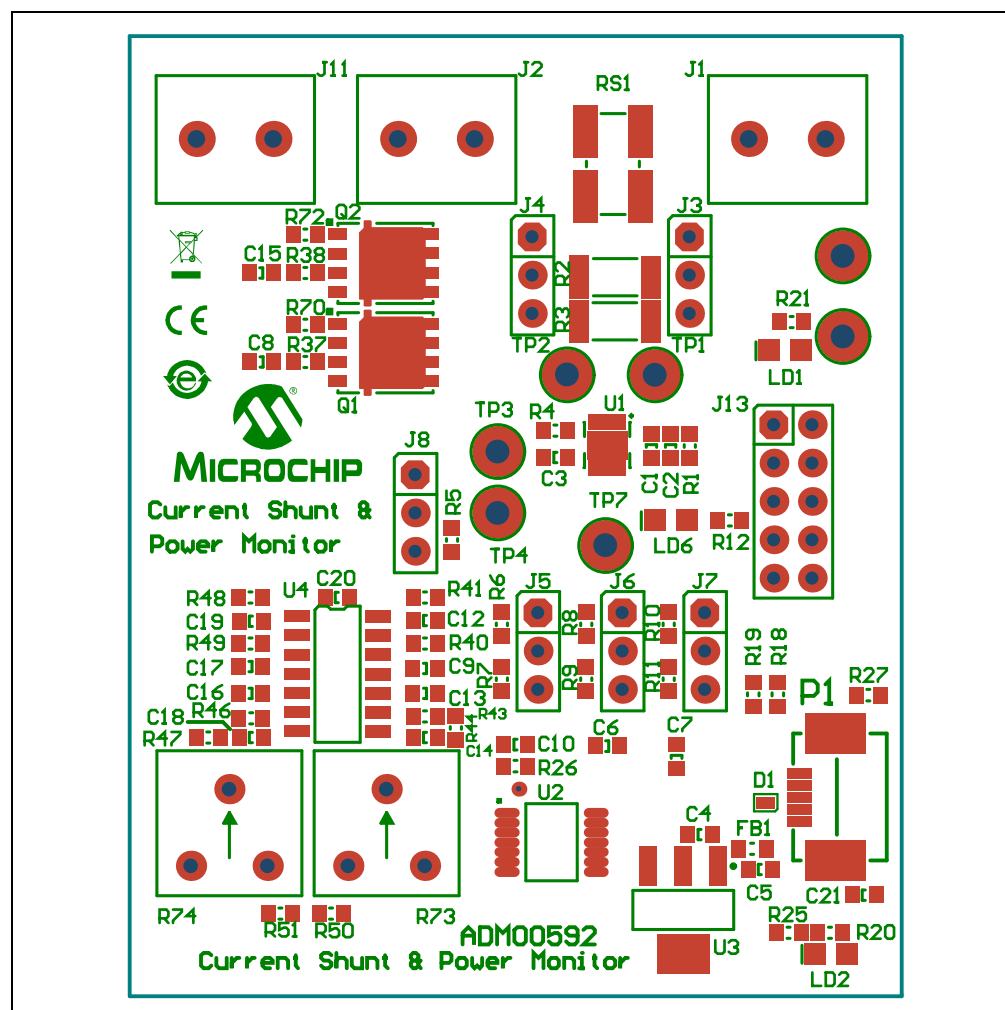


**FIGURE 1-2:**      *PAC1921 High-Side Current/Power Sensor Evaluation Board – Top Silkscreen.*

## 1.4 WHAT THE PAC1921 HIGH-SIDE CURRENT/POWER SENSOR EVALUATION BOARD KIT CONTAINS

This PAC1921 High-Side Current/Power Sensor Evaluation Board kit includes:

- PAC1921 High-Side Current/Power Sensor Evaluation Board (ADM00592)
- Supplied USB Mini Connector Cable
- Important Information Sheet

**NOTES:**

# Chapter 2. Installation and Operation

## 2.1 GETTING STARTED

### 2.1.1 System Requirements

To use the PAC1921 High-Side Current/Power Sensor Evaluation Board, the following are required:

- A PC running the Microsoft® Windows® operating system
- A display resolution of 800x600 or larger, for viewing several windows simultaneously
- An available USB port

## 2.2 INSTALLING THE EVALUATION BOARD SOFTWARE

Follow these steps in order to install the board's Graphical User Interface (GUI):

1. Download the software archive from the board's web page, unzip it and double-click the `Setup.exe` to start the installation. Figure 2-1 shows the initial installation screen, which displays briefly as the setup program loads.
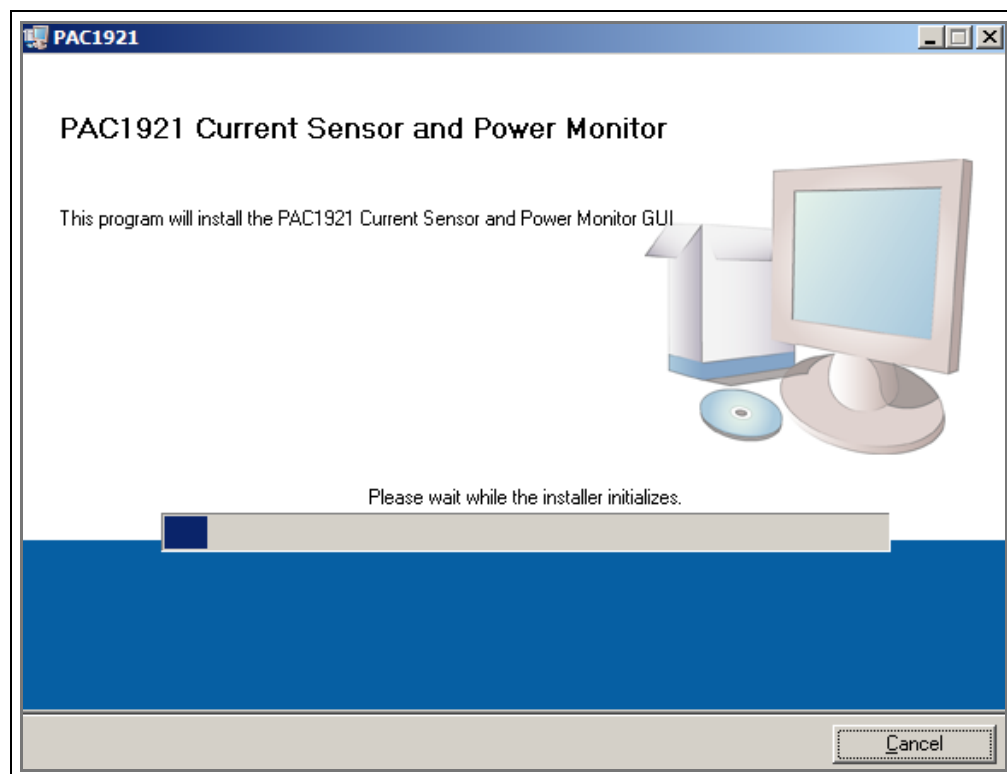


*FIGURE 2-1:* *Software Installation – Initialize Window.*

2.  Click **Next** in the Destination Directory window, shown in Figure 2-2. For proper operation, the files must be installed in the default locations. The default location for the software files is `C:\Program Files (x86)\Microchip\PAC1921` and for the LabVIEW™ software is `C:\Program Files\ National Instruments.`
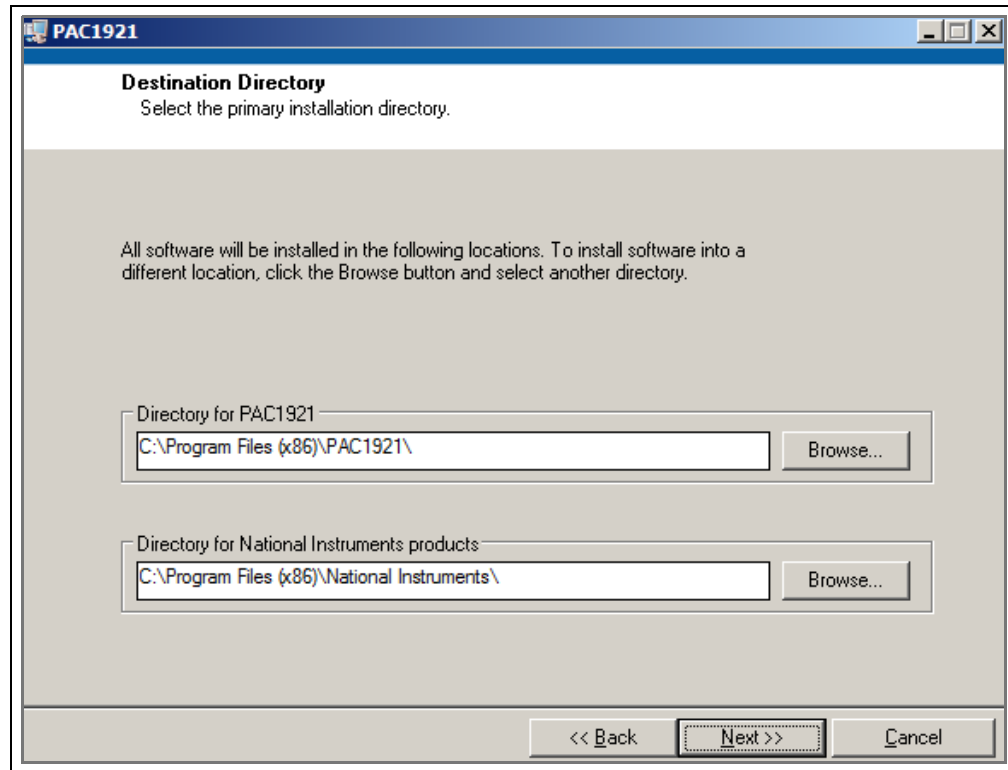


**FIGURE 2-2:**          *Software Installation – Setting the Destination Directory.*

3. Read and accept the license agreement, then click **Next**.
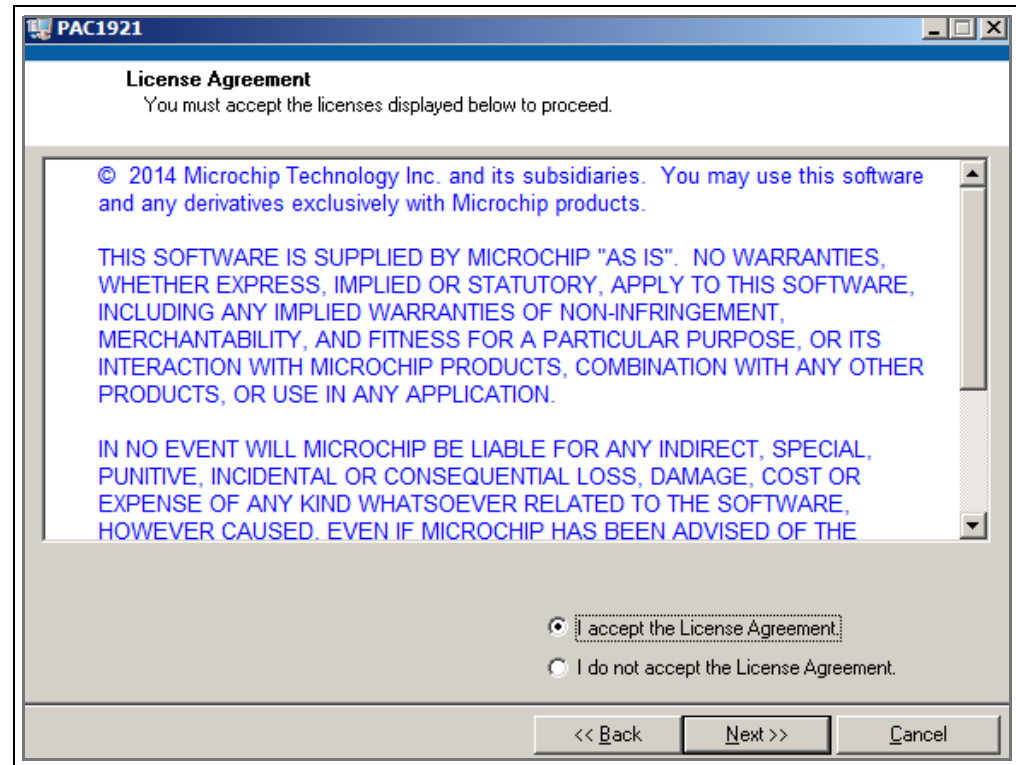


*FIGURE 2-3:        Software Installation – Software License Agreement.*

4. To use the LabVIEW software, read and accept the license agreement, then click **Next**.
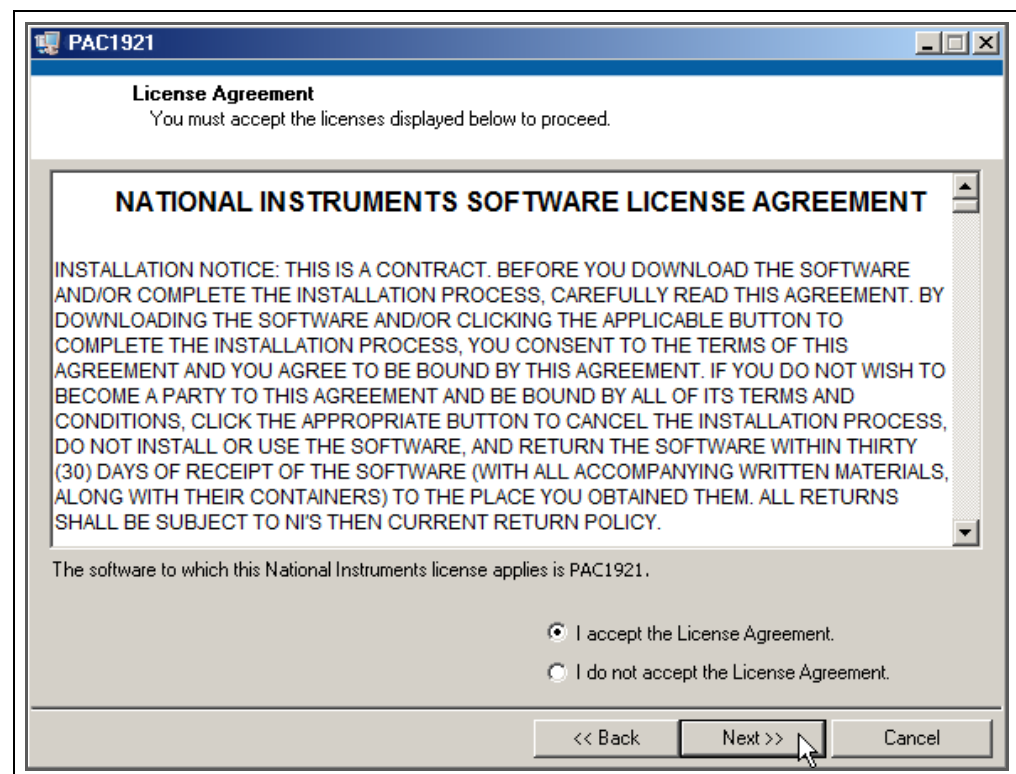


*FIGURE 2-4:        Software Installation – LabVIEW™ Software License Agreement.*

5. Follow the on-screen instructions to complete the installation. During installation, shortcuts will be created on the Windows Start Menu under *Programs>PAC1921* and on the desktop.
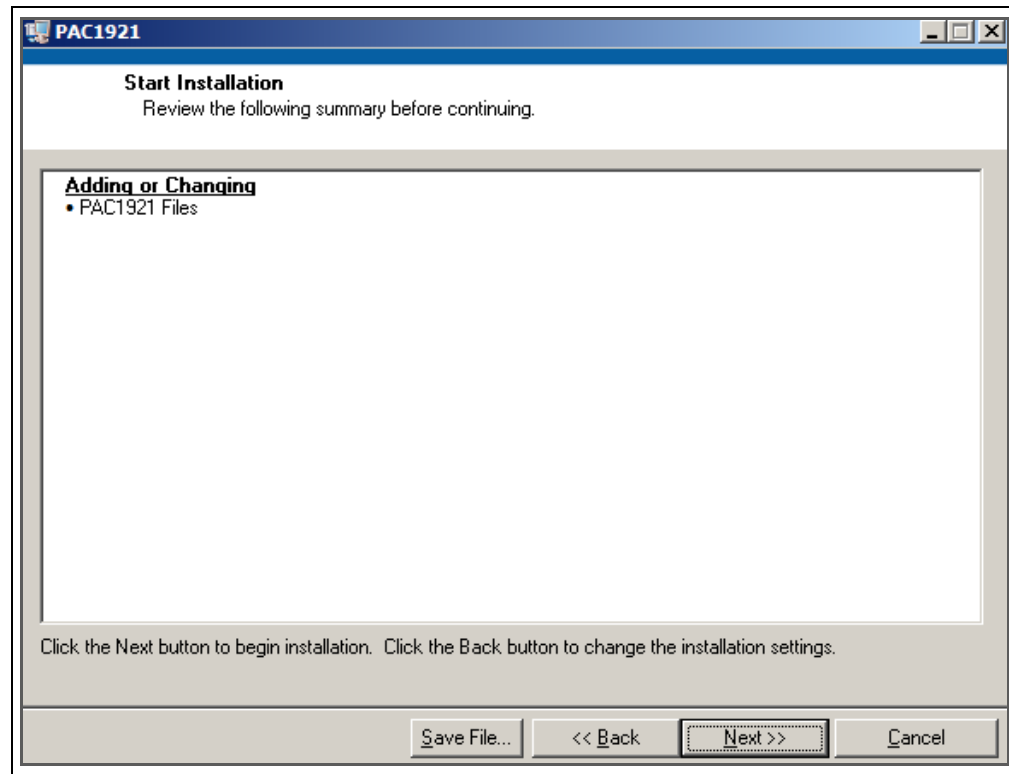


**FIGURE 2-5:** *Software Installation – LabVIEW™ Software Installation Screen.*
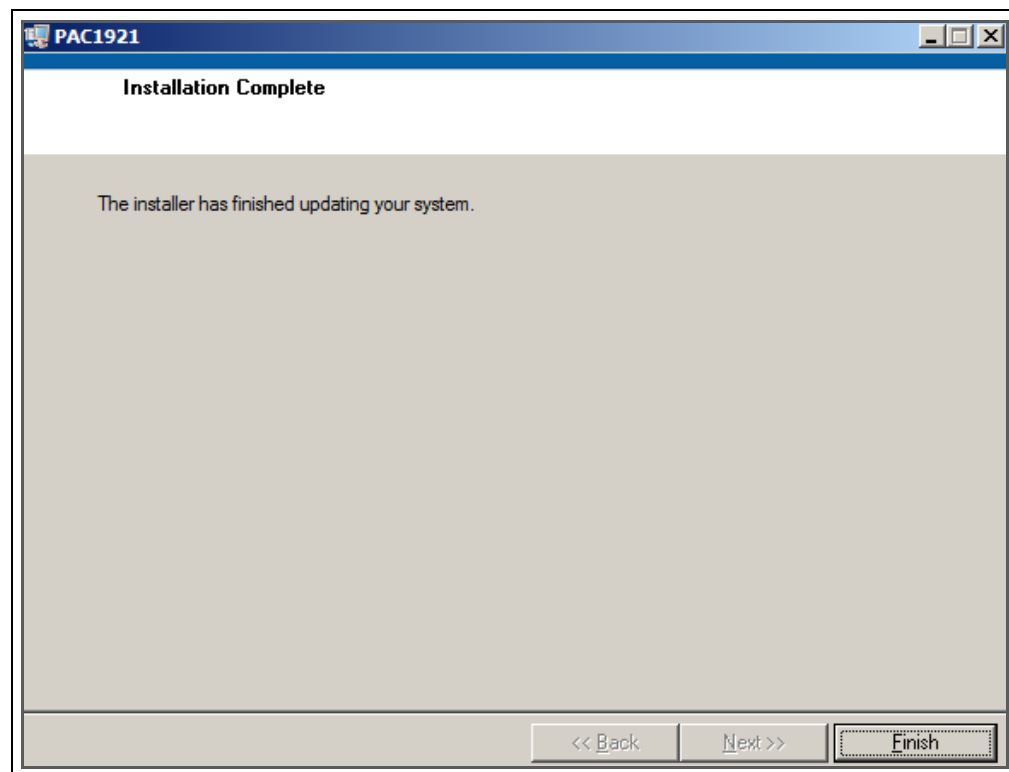


**FIGURE 2-6:** *Software Installation – LabVIEW™ Software Installation Complete.*

When the installation is complete, the program will automatically run (see Figure 2-7).
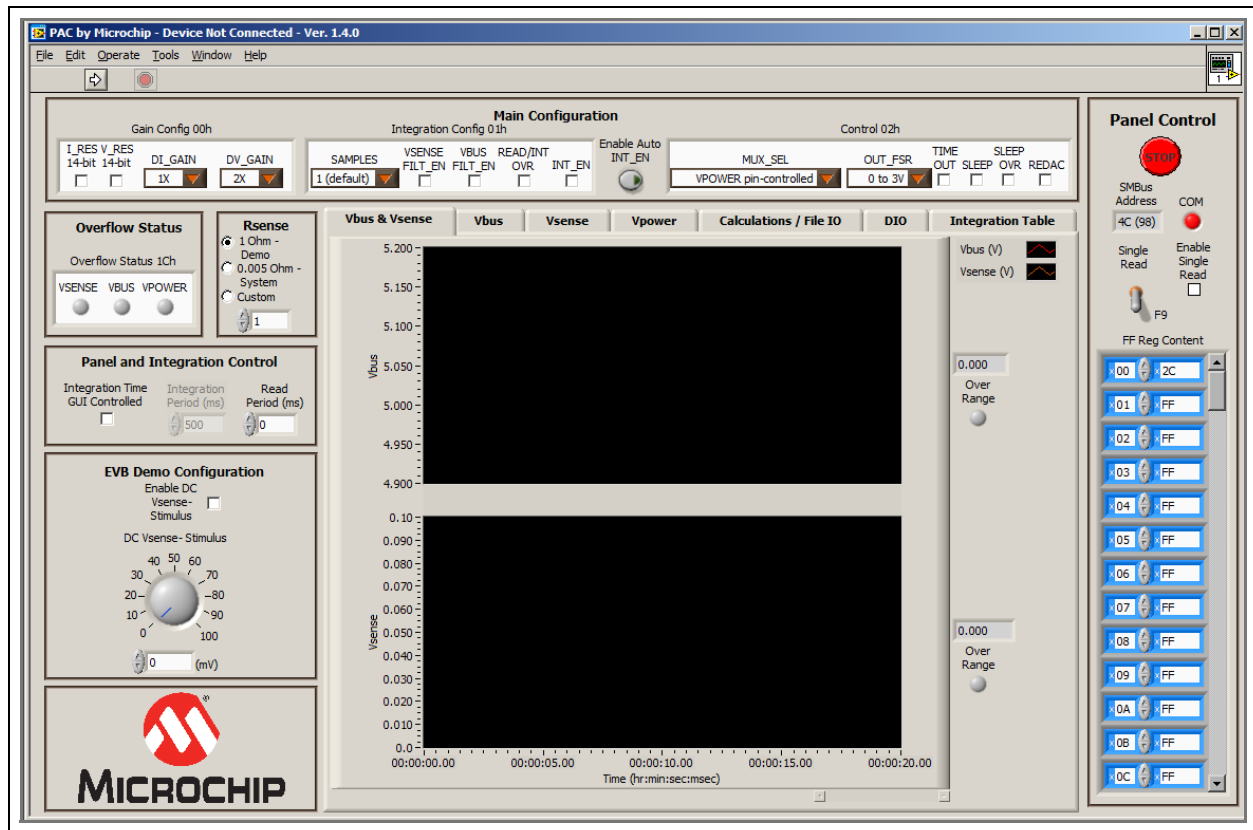


**FIGURE 2-7:** *PAC1921 GUI Start-up Screen.*

## 2.3 MICROCHIP USB BRIDGE INSTALLATION

Connect the USB mini connector to the evaluation board and the standard USB connector to any available USB port on the PC. If the Microchip USB bridge driver has not previously been installed on the selected USB port, download the MCP2221 Windows driver and installer from www.microchip.com at:

http://www.microchip.com/wwwproducts/Devices.aspx?product=MCP2221

Follow the on-screen instructions to complete the installation process.

**NOTES:**

# Chapter 3. Hardware Description

## 3.1 INTRODUCTION

The PAC1921 High-Side Current/Power Sensor Evaluation Board provides the means to evaluate features, and to view and modify registers. There are two modes for using the evaluation board:

• Demo mode: Monitors an on-board power source
• Sys mode: Monitors an external power source

LEDs indicate status information and test points are included to monitor system voltages with a user-provided voltmeter or oscilloscope.

The PAC1921 device is an SMBus-compliant, high-side current/power monitor in a 10-pin, 3 mm x 3 mm DFN package. For details regarding the PAC1921 device, refer to the *"PAC1921 Data Sheet"* (DS20005293).

### 3.1.1 Power Source

The board requires only one Universal Serial Bus (USB) connection to power the board. USB bus voltage is provided to the on-board test power sources and the USB-to-SMBus bridge. The evaluation board circuitry uses the on-board regulator to regulate the +5V USB power to +3.3V.

## 3.2 USB-TO-SMBus BRIDGE

The USB-to-SMBus is based on the MCP2221 USB-to-I$^2$C™ protocol converter, which provides the interface between the USB and the SMBus. Power is sourced to the microcontroller from the USB interface for device power and communication.

### 3.2.1 Direct SMBus Connect Option

It is also possible to connect an external SMBus master to the PAC1921 High-Side Current/Power Sensor Evaluation Board. A few modifications to the board are required, as explained below:

• Remove the jumpers on J13 and connect the SMBus master to the SMBus_DATA, SMBus_CLK and #READ/INT pins, as well as an external supply for +3.3V. Note that a return is also provided on this header for convenience (GND).
• The +3.3V can be supplied by the SMBus bridge by leaving the +3.3V jumper in place and retaining the USB connection.

## 3.3    OPERATING MODE

### 3.3.1    SMBus Mode

By default, the evaluation board is configured so that the PAC1921 operates in SMBus mode with an SMBus address of, `1001_100xb` (98h). The address can be changed to `1001_101xb` (9Ah) by moving jumper J8 to position 2-3. Cycle power to the evaluation board in order for the change to take effect.

## 3.4    LED INDICATORS

LED locations are indicated in Figure 3-1.
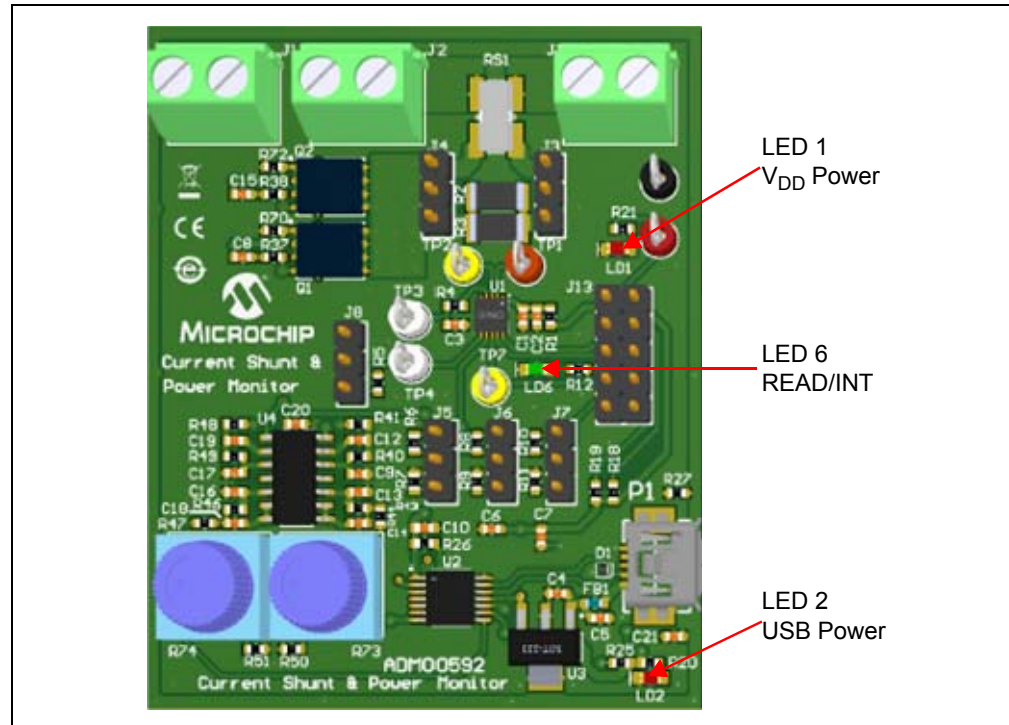


**FIGURE 3-1:**        *LED Indicator Locations.*

LEDs indicate the status of the signals, as described in Table 3-1:

**TABLE 3-1:        LED STATUS INDICATORS**

| LED | Signal | OFF | Green | Red |
|-----|--------|-----|-------|-----|
| LD1 | $V_{DD}$ Power | $V_{DD}$ is not present | N/A | $V_{DD}$ is present |
| LD2 | +5V USB Power | USB power is not present | N/A | +5V USB power is present |
| LD6 | READ/INT | Pin is not asserted (Read State) | Pin is asserted (Integrate State) | N/A |

## 3.5    JUMPER SETTINGS

This evaluation board has pin headers and jumper configurations to evaluate the features of the PAC1921. Jumper locations are indicated in Figure 3-2.



**Note:**    Refer to **Appendix A. "Schematic and Layouts"** to see the connections of each jumper position.
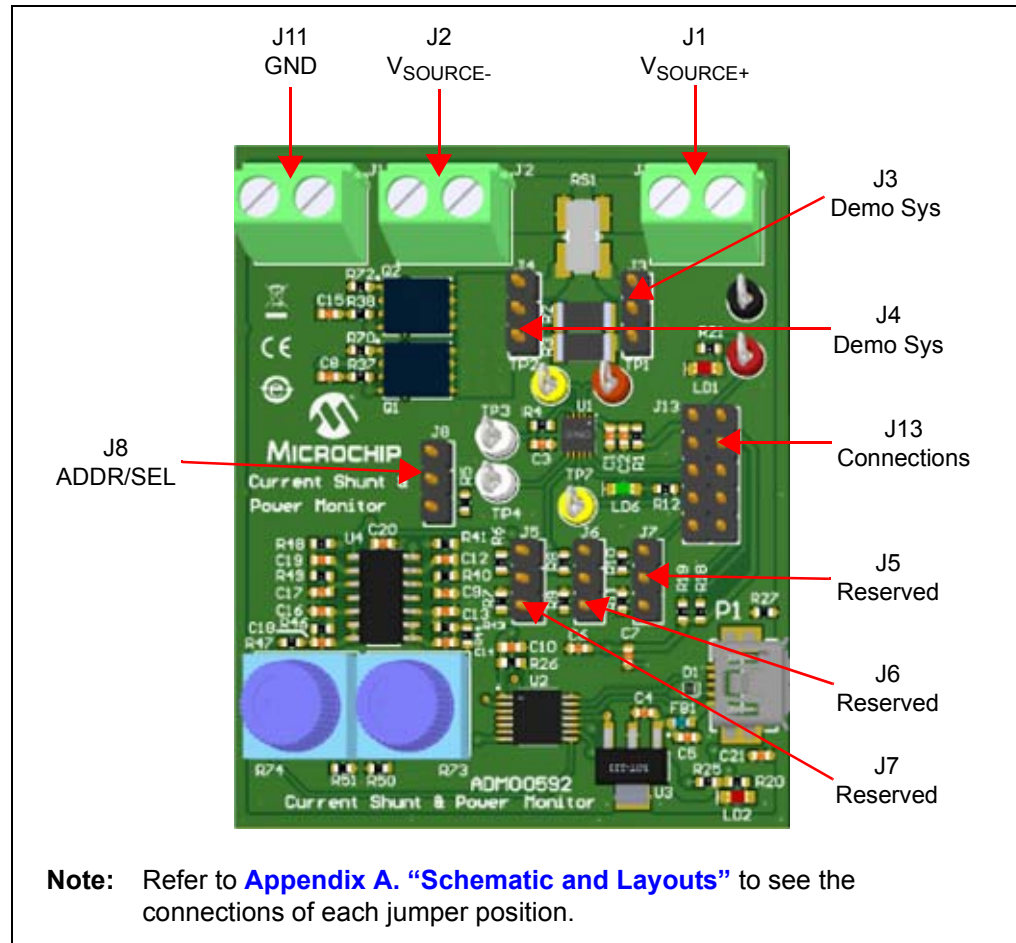
*FIGURE 3-2:        Jumper and External Connection Locations.*

Jumper settings are described in Table 3-2.

**TABLE 3-2:** **JUMPER SETTINGS**

| Pin Header | Label | Default Position | Alternate Position(s) |
|---|---|---|---|
| J1, J2 | Vsource+, Vsource- | External power source terminals. (See **Section 3.8.2 "Load Connection"**.) | |
| J3, J4 | Demo Sys | Select Demo mode $R_{SENSE+/-}$. Positions 3-2 are jumpered on both jumpers. (See **Section 3.7 "Demo Mode Setup and Operation"**.) | Select Sys mode $R_{SENSE+/-}$. Positions 1-2 are jumpered on both jumpers. (See **Section 3.8 "Sys Mode Setup and Operation"**.) |
| J5, J6, J7 | Reserved | Reserved for future use | |
| J8 | J8 (ADDR_SEL) (See **Section 3.3.1 "SMBus Mode"**) | In SMBus mode, sets SMBus address to `1001_100b` at power-up. Positions 1-2 are jumpered. | In SMBus mode, sets SMBus address to `1001_101b` at power-up. Positions 2-3 are jumpered. |
| J11 | GND | | Connect ground from external source for Sys mode. |
| J13 | GND, #READ/INT, SMBus_DATA, SMBus_CLK, VDD | USB bridge generates on-board 3.3V and provides SMBus host. Positions 1-2, 3-4, 5-6, 7-8, 9-10 are all jumpered. | (See **Section 3.2.1 "Direct SMBus Connect Option"**.) |

## 3.6    TEST POINTS

The PAC1921 High-Side Current/Power Sensor Evaluation Board provides test points for ground reference and signal access. Table 3-3 summarizes these test points.

**TABLE 3-3:** **TEST POINTS**

| Test Point | Marking | Signal Function Monitored |
|---|---|---|
| 1 | Vsense+ (orange) | SENSE+ |
| 2 | Vsense- (yellow) | SENSE- |
| 3 | OUT (white) | OUT Pin |
| 4 | ADDR_SEL | SMBus Address Select |
| 5 | Vdd (red) | $V_{DD}$ |
| 6 | GND (black) | Ground |
| 7 | #READ/INT (yellow) | $\overline{READ}$/INT Pin |

## 3.7    DEMO MODE SETUP AND OPERATION

Demo mode uses an on-board current source to exercise and demonstrate the features of the PAC1921 power monitor. The 100 mV constant-current source is provided using a +5V USB as the supply. Parallel sense resistors are provided to convert the current to a corresponding voltage for the PAC1921 to read at the SENSE+ and SENSE- inputs. The evaluation board is assembled with jumpers J3 and J4 positioned for Demo mode (see **Section 3.5 "Jumper Settings"**). Current is controlled by the evaluation board Demo Configuration section of the evaluation board GUI (see **Section 4.2.6 "EVB Demo Configuration Panel"**).

## 3.8    SYS MODE SETUP AND OPERATION

Sys mode uses external current sources to exercise and demonstrate the features of the PAC1921 power monitor.

### 3.8.1    Jumper Positions

To use Sys mode, reposition jumpers J3 and J4 (see Table 3-2) to disconnect the on-board demonstration current sources.

### 3.8.2    Load Connection

A 5 milliohm (1% tolerance) sense resistor, connected between J1 and J2, is provided on-board the PAC1921 evaluation board to measure system current.

Load connections to the system can be established, as shown in Figure 3-3.
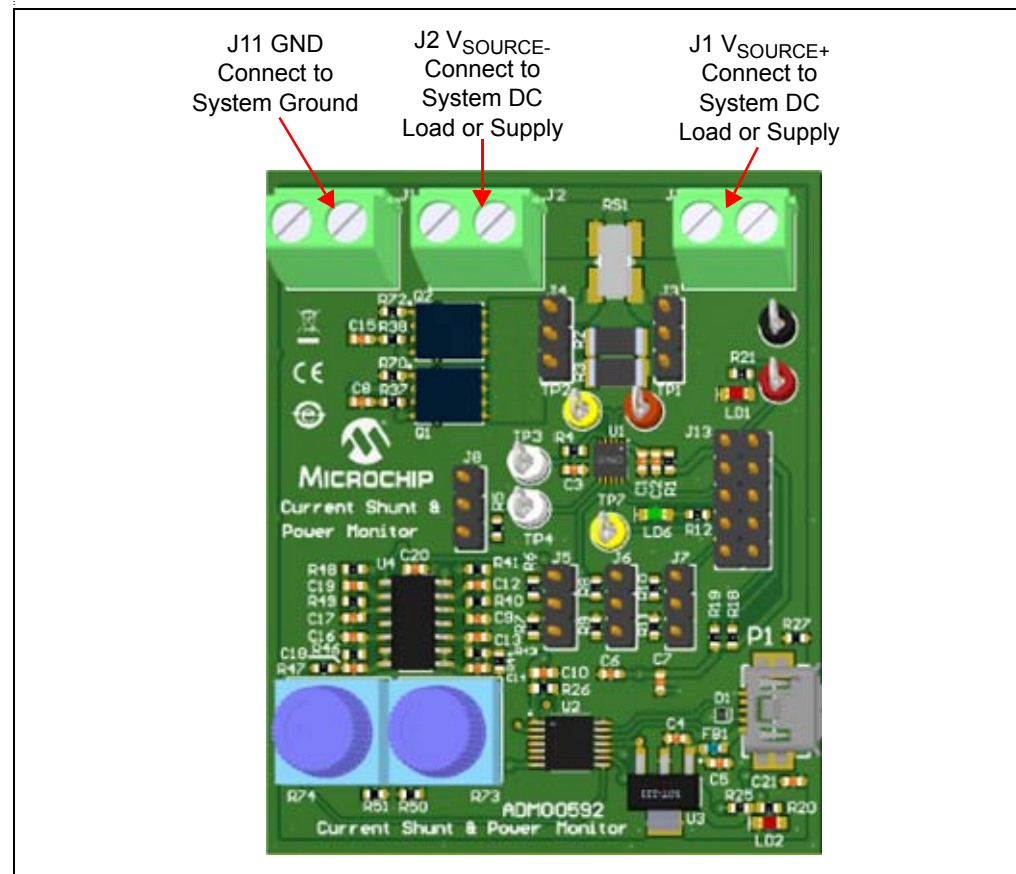


**FIGURE 3-3:**        *Load Connection Location.*

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**NOTES:**

# Chapter 4.  Software Description

## 4.1    OVERVIEW

To get the Graphical User Interface (GUI) and the Evaluation Board (EVB) running, follow these instructions:

1.  Start the PAC1921 GUI software: from the Windows Start menu, select *Programs>PAC1921*.

2.  Connect the USB mini connector end of the cable to the board and the standard USB connector of the cable to any available USB port on the PC. The $V_{DD}$ and USB power LEDs (LD1 and LD2, respectively) will illuminate RED, indicating that the PAC1921 is powered up and the MCP2221 USB bridge is connected to the PC.

The PAC1921 High-Side Current/Power Sensor Evaluation Board Graphical User Interface (GUI) is shown in Figure 4-1.
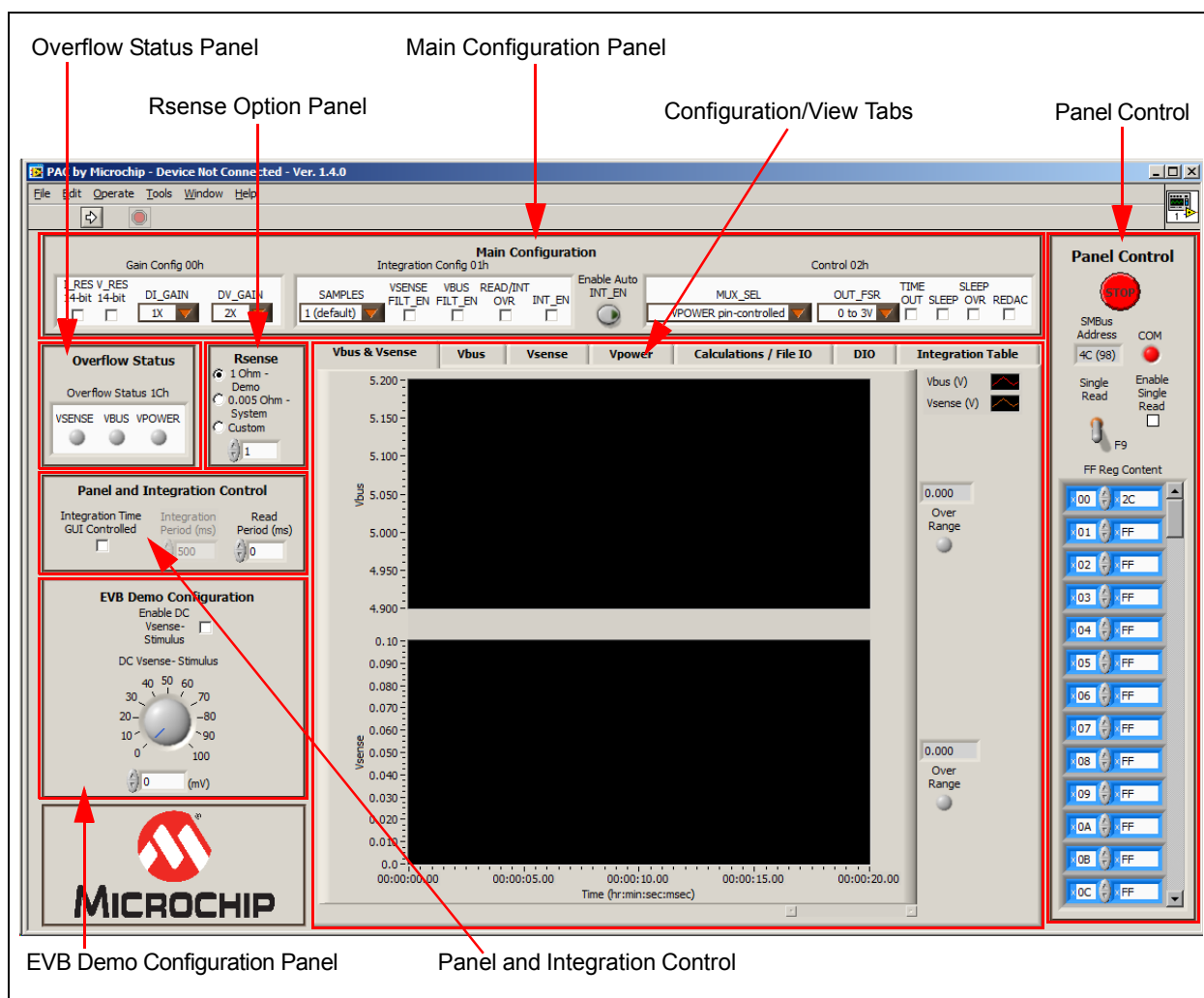


**FIGURE 4-1:**        *GUI Interface Panel.*

When the evaluation board is connected or disconnected, a message displays as shown in Figure 4-2. With the evaluation board connected, click **Auto-detect Address** to restart communications.
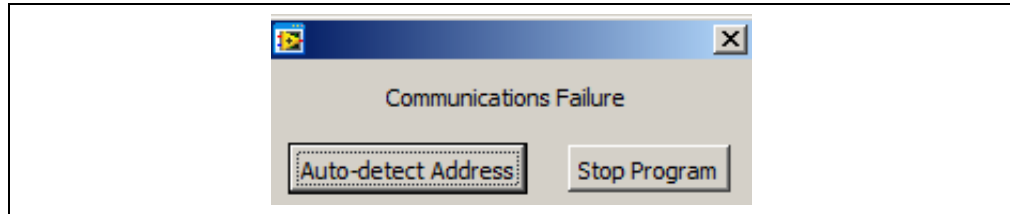


**FIGURE 4-2:**       *Communications Failure Message.*

### 4.1.1       Tips for Using the Evaluation Board GUI

• After a power-up of the evaluation board, the default settings are loaded. Users can save the setting configurations to user-named files, which can be reloaded at any time for quick reconfiguration (see **Section 4.3.3.1 "Configuration Save and Load"**).

• To configure the GUI and PAC1921 for free-run integration power measurement, press the <F2> function key on the keyboard.

• To reload the PAC1921 register defaults, press the <F6> function key on the keyboard.

• When using the GUI, the PAC1921 can enter a Sleep state; however, it wakes to service the GUI SMBus communications, then returns to Sleep. For this reason, the current consumption will be slightly higher than expected in Sleep state when using the GUI.

• When the PAC1921 enters Sleep state, the PAC1921 clears the measurement registers, and consequently, the GUI **Calculations/File IO** tab is cleared. To prevent the PAC1921 from entering Sleep, check the "SLEEP OVR" box in the Main Configuration section.

## 4.2    INTERFACE DESCRIPTION AND OPERATION

### 4.2.1    Panel Control Section

The Panel Control section on the right side of the GUI, shown in Figure 4-3, affects the GUI operation.
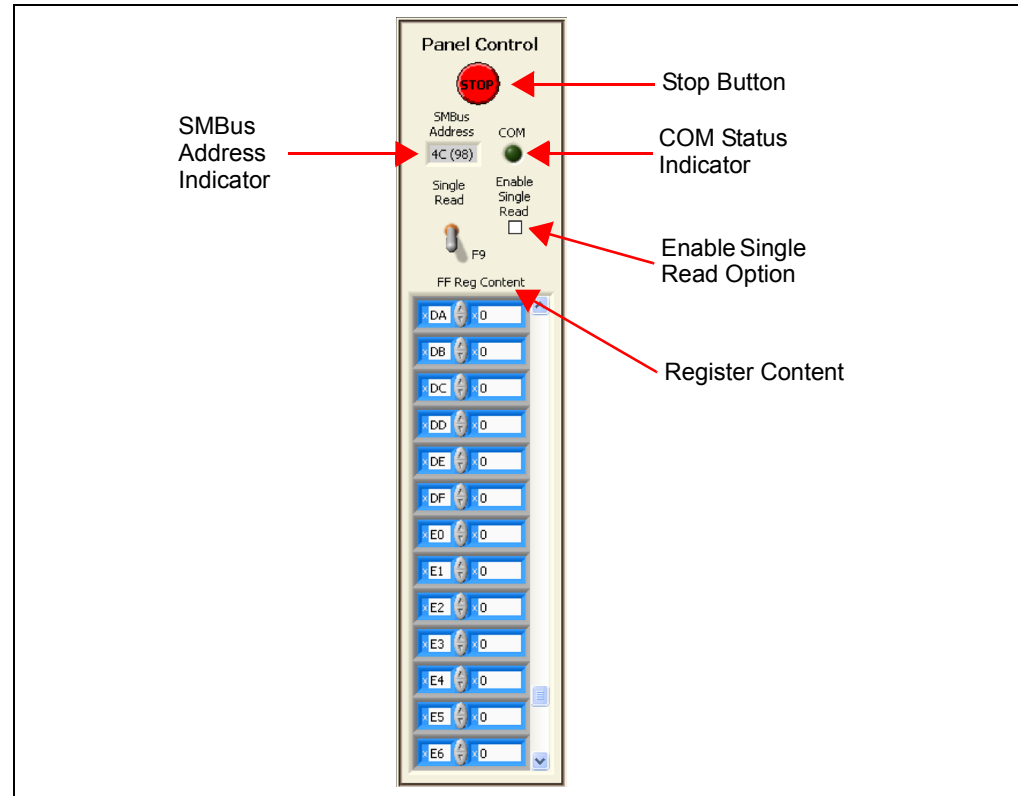


FIGURE 4-3:    Panel Control Section.

### 4.2.1.1    STOP AND RUN BUTTONS

Pressing the **Stop** button, as shown in Figure 4-3, interrupts the GUI software communications with the evaluation board. When the **Stop** button is clicked, the **Run** button is displayed on the menu bar (see Figure 4-4).
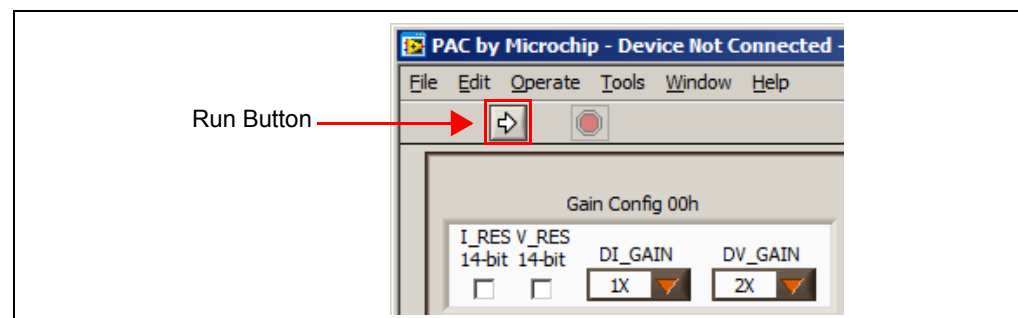


FIGURE 4-4:    Run Button.

To restart the communication between the software and the evaluation board, click the **Run** button. The arrow button disappears when the communications resume.

| | | |
|---|---|---|
| **Note 1:** | | Stopping and restarting the GUI does not affect register settings. To restore default register settings, disconnect power from the evaluation board, then reconnect power. |
| | **2:** | Stopping the GUI clears the "Enable DC Vsense- Stimulus" box (see **Section 4.2.6 "EVB Demo Configuration Panel"**). |

To close the program, use the **Close (X)** button in the upper right corner of the window.

### 4.2.1.2    SMBus ADDRESS

The "SMBus Address" box, shown in Figure 4-5, indicates the selected SMBus address. The SMBus address can be changed by moving a jumper (see **Section 3.3.1 "SMBus Mode"**).
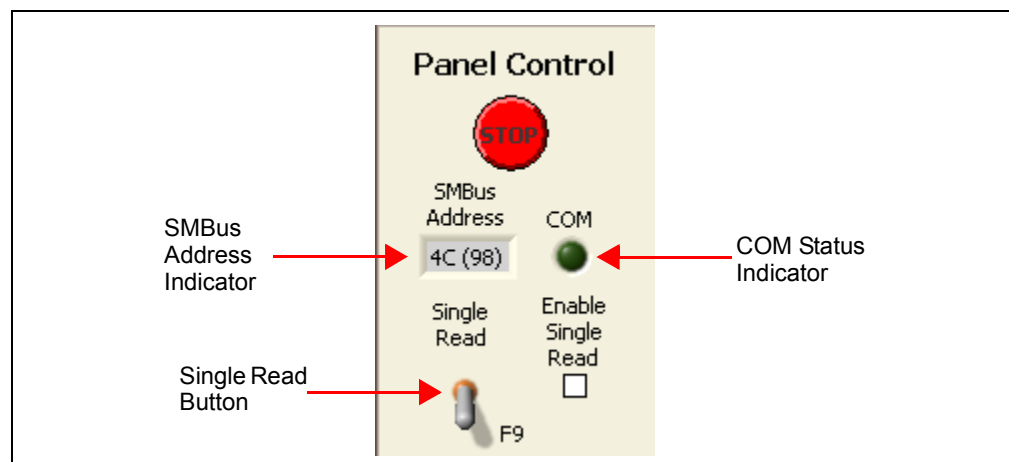


**FIGURE 4-5:**        *SMBus Address Indicator.*

### 4.2.1.3    COM STATUS INDICATOR

The "COM" status indicator, on the right side of the panel as shown in Figure 4-5, indicates the status of communications over the SMBus. During normal operation, the "COM" indicator is black. If the SMBus communications fail, the "COM" indicator turns red.

### 4.2.1.4    SINGLE READ/CONTINUOUS READ

The panel defaults to continuous register reads (toggle switch in down position, as shown in Figure 4-5). To stop continuous register reads, check the "Enable Single Read" box. In order to capture the register values at a given time, click the switch, which will briefly flip to "Single Read".

### 4.2.1.5    REGISTER CONTENT

"Reg Content", shown in Figure 4-3, is a scrollable list of the PAC1921 registers and the last read value. It is important to note that not all addresses are physical memory locations on the device; these registers will read '0'. Likewise, some registers shown (undocumented in the data sheet) may have data. Editing these registers can cause unexpected results.

To update a register value, locate the register address in the left column, type the new value in the corresponding cell in the right column, and press **Enter** on the keyboard or click on another part of the GUI.

#### 4.2.1.5.1 Numbering Systems Views

The "Reg Content" section allows values to be displayed using different numbering systems: Decimal, Hex, Octal, Binary or SI Notation.

To view a value using a different numbering system, click the indicator to the left of the value in the cell, shown circled in Figure 4-6.
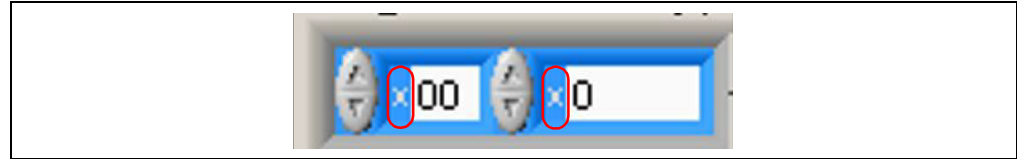


*FIGURE 4-6:* *Numbering System Indicators.*

### 4.2.2 Main Configuration Panel

The Main Configuration section, shown in Figure 4-7, contains the PAC1921 configuration controls in registers 00h, 01h and 02h. Refer to the data sheet for register bit descriptions.
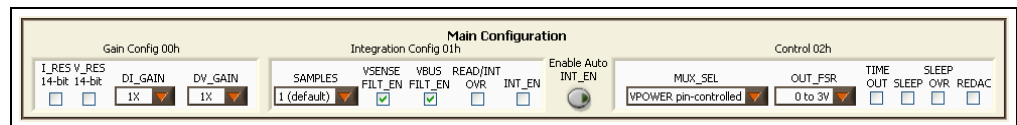


*FIGURE 4-7:* *Main Configuration Panel.*

#### 4.2.2.1 ENABLE AUTO INT_EN

The "Enable Auto INT_EN" control is a GUI control convenience. Under normal operation, for most of the integration parameter settings, changes do not take effect until the PAC1921 is placed in the Read state. When the "Enable Auto INT_EN" control is activated (light green – shown as "Enabled" in Figure 4-8), it automatically places the PAC1921 into the Read state and back to Integrate state whenever a Main Configuration control is changed. It also updates the GUI calculations. When the "Enable Auto INT_EN" control is disabled (dark green), the user must place the device in the Read state before the "I_RES", "V_RES", "SAMPLES", "VSENSE FILT_EN" and "VBUS FILT_EN" changes take effect, and to update the GUI calculations.

It is recommended that the "Enable Auto INT_EN" control be activated when using the GUI.
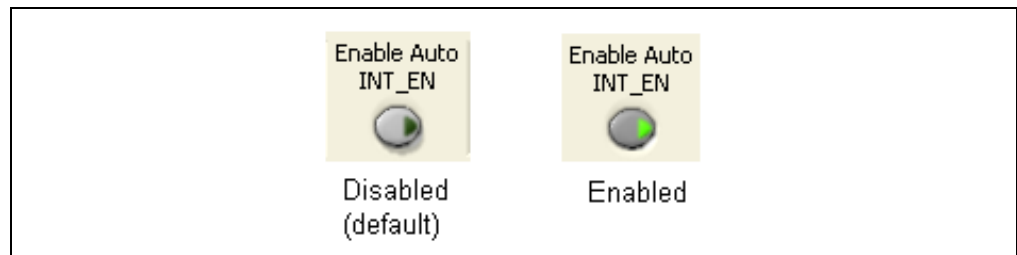


*FIGURE 4-8:* *Enable Auto INT_EN GUI Control.*

### 4.2.3 Overflow Status Panel

The Overflow Status section, shown in Figure 4-9, represents the three bits in the Overflow Status Register 1Ch. When an indicator turns red, it indicates an overflow.
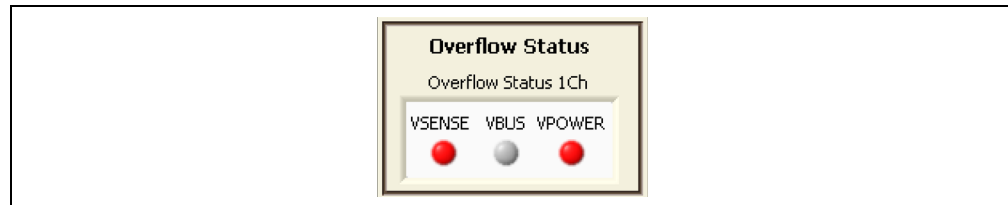


*FIGURE 4-9:     Overflow Status.*

### 4.2.4 Rsense Panel

The Rsense section, shown in Figure 4-10, needs to reflect the value of the $R_{SENSE}$ resistor in use on the evaluation board. This value is used in calculations done by the GUI. In Demo mode, select the **1 Ohm - Demo** button. In Sys mode, select the **0.005 Ohm - System** button. If another resistor is used, check the **Custom** option button and fill the corresponding value in the spin box underneath the option.
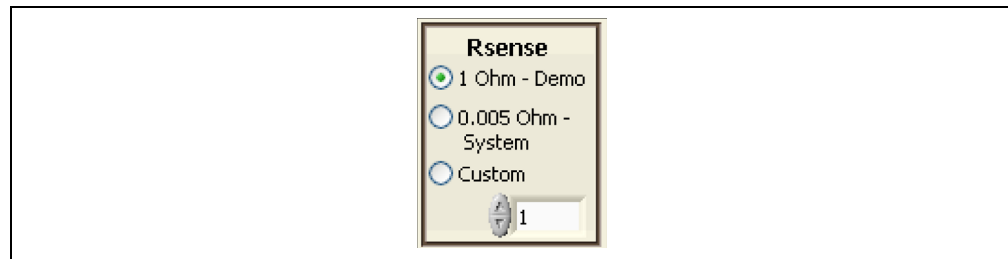


*FIGURE 4-10:     Rsense Configuration Panel.*

### 4.2.5 Panel and Integration Control Panel

The Panel and Integration Control section, shown in Figure 4-11, contains GUI controls which set and clear the INT_EN bit. When using these controls, check the "READ/INT OVR" box in the Main Configuration section to allow the INT_EN bit to override the READ/INT pin state.

> **Note:** Read Period (ms) is always enabled.

"READ/INT OVR" Box is Checked
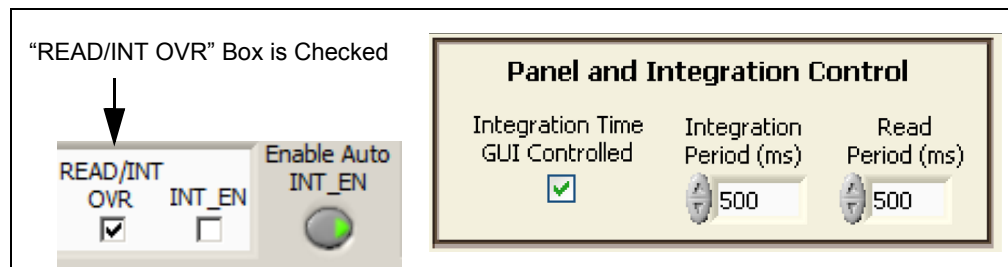


*FIGURE 4-11:     Panel and Integration Control.*

### 4.2.6    EVB Demo Configuration Panel

The EVB Demo Configuration panel, shown in Figure 4-12, contains GUI controls which affect the Demo mode. To inject current onto $V_{SENSE-}$, check the "Enable DC Vsense- Stimulus" box. To set the current level, rotate the "DC Vsense- Stimulus" dial or type a value between 0 and 100 in the (mV) spin box below the dial.
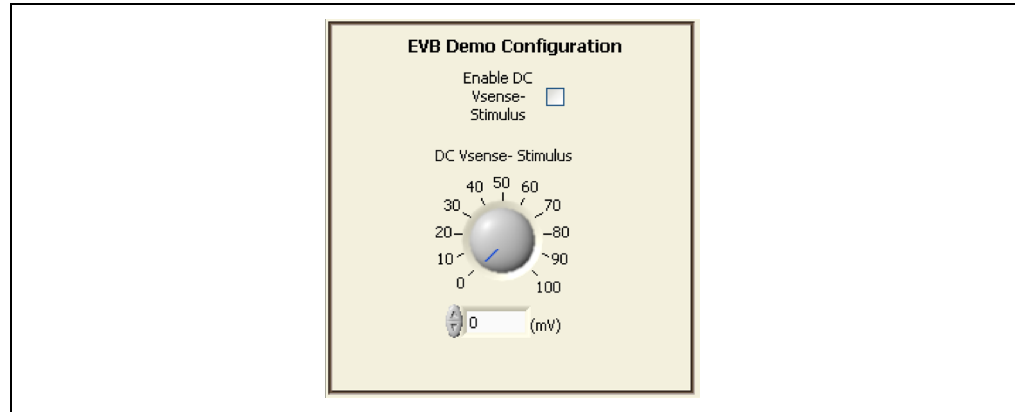


**FIGURE 4-12:**      *Evaluation Board Demo Configuration.*

## 4.3    TAB DESCRIPTIONS

### 4.3.1    Vbus & Vsense Tab

The **Vbus & Vsense** tab, shown in Figure 4-13, displays plots for calculated $V_{BUS}$ in volts and calculated $V_{SENSE}$ in volts. The plots are not self-scaling. If the value in the box at the right of the plot (indicated with arrows) falls outside the Y-axis range on the plot, click the top and/or bottom value on the axis and type in a new value.
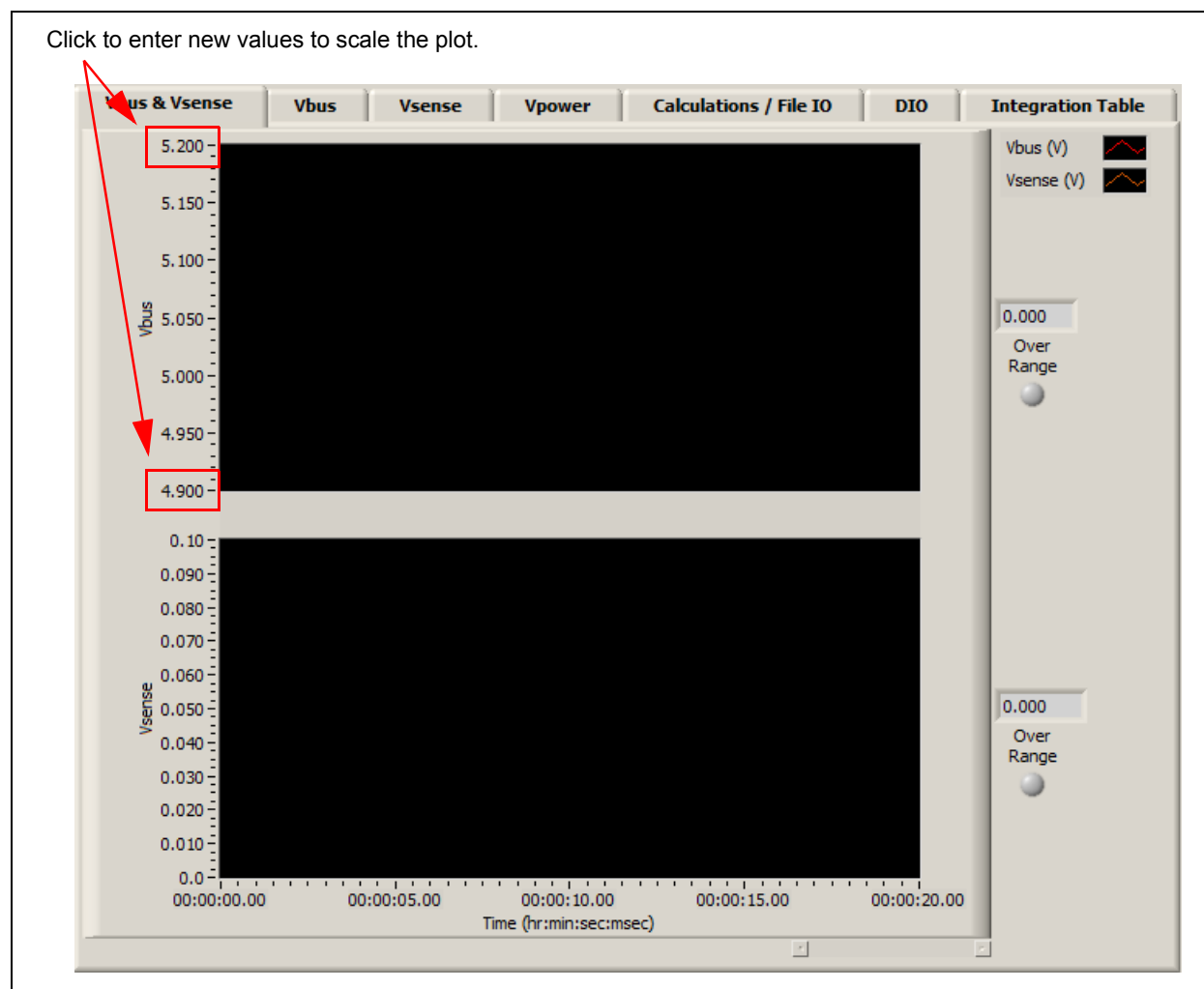


**FIGURE 4-13:**    *Vbus & Vsense Tab.*

To change the look of the plot lines, click the applicable graphic in the legend on the right of the tab to display a menu of options, as shown in Figure 4-14.
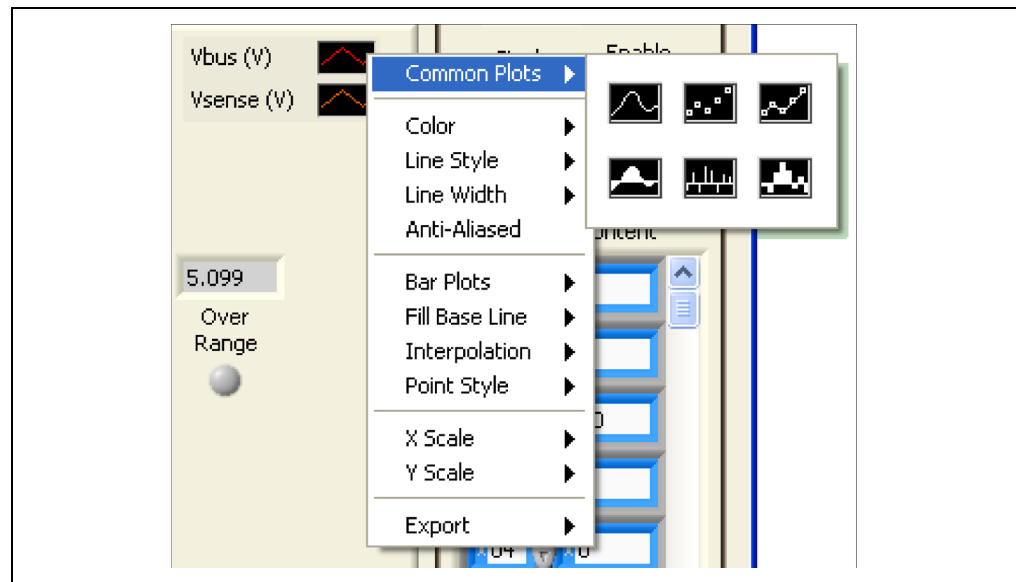


*FIGURE 4-14:*      *Plot Legend Context Menu.*

### 4.3.2      Vbus, Vsense and Vpower Tabs

There are separate tabs to show individual plots for **Vbus**, **Vsense** and **Vpower**. They operate similarly to the **Vbus & Vsense** tab described above.

### 4.3.3    Calculations/File IO Tab

The **Calculations/File IO** tab, shown in Figure 4-15, displays register data (in decimal by default). It also shows calculated results which were obtained by applying the data sheet equations to the register data.
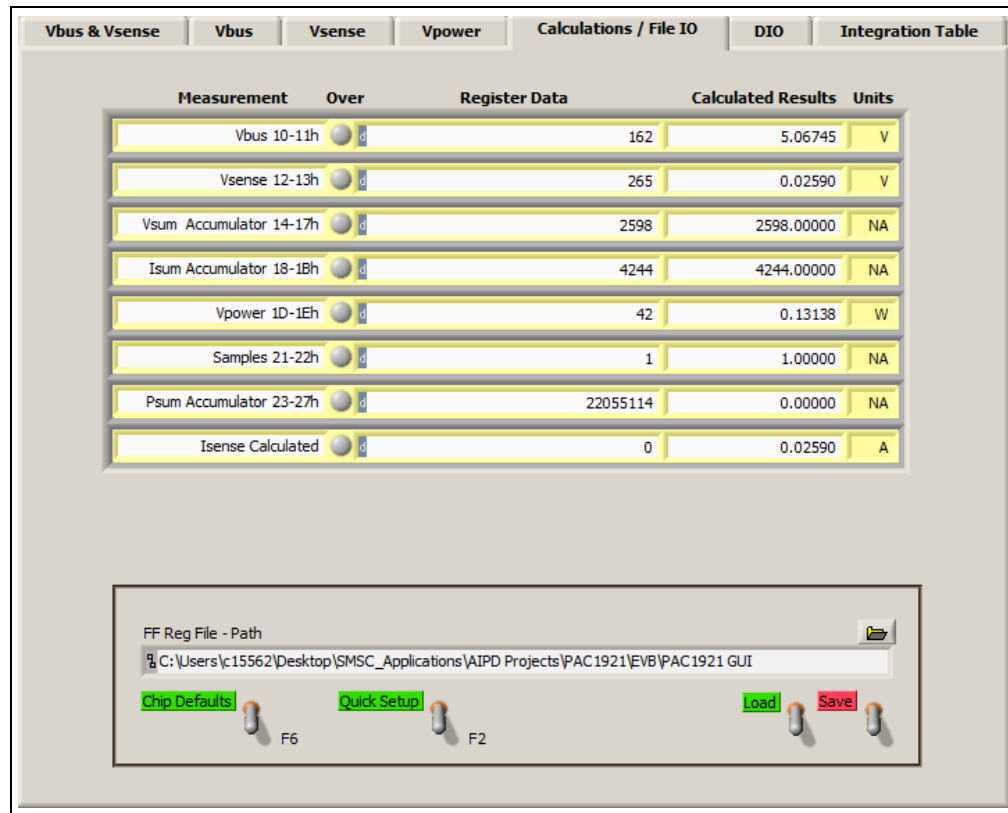


*FIGURE 4-15:*    *Calculations/File IO Tab.*

An example of using the equations to calculate power is as follows.

The value of one LSB in the $V_{POWER}$ Result registers, in watts, can be calculated according to Equation 4-1.

**EQUATION 4-1:    LSB CALCULATION**

$$1LSB \ = \ \frac{\dfrac{0.1V}{R\Omega \times DI\_GAIN} \times \dfrac{32V}{DV\_GAIN}}{1023 \ \times 2^6}$$

Where:

| | | |
|---|---|---|
| 1LSB | = | LSB value in watts for $V_{POWER}$ Result Registers 1Dh and 1Eh |
| 0.1V | = | Maximum $V_{SENSE}$ voltage |
| R | = | Value of $R_{SENSE}$ resistor in ohms |
| DI_GAIN | = | Digital current gain |
| 32V/DV_GAIN | = | Maximum voltage |
| 1023 | = | $(2^{10} – 1)$ = 10-bit FSR |
| $2^6$ | = | Adjustment for 6 unused register bits when read as a 16-bit number |

The power calculation using the $V_{POWER}$ Result registers value from Figure 4-15 is shown in Equation 4-2.

**EQUATION 4-2: POWER CALCULATION**

$$\frac{\dfrac{0.1V}{1\Omega \times 1} \times \dfrac{32V}{1}}{1023} \times (42) \ = \ 0.13138W$$

Where:

| | | |
|---:|:--:|:---|
| 0.1V | = | Maximum $V_{SENSE}$ voltage |
| 1Ω | = | Value of $R_{SENSE}$ resistor |
| 1 | = | Digital current gain |
| 32V/1 | = | Maximum voltage |
| 1023 | = | 10-bit FSR |
| 42 | = | Decimal value of $V_{POWER}$ Result Registers 1Dh and 1Eh |

### 4.3.3.1 CONFIGURATION SAVE AND LOAD

The **Calculations/File IO** tab contains controls, as shown in Figure 4-16, which save the settings currently configured in the PAC1921 to allow quick reconfiguration at any time.
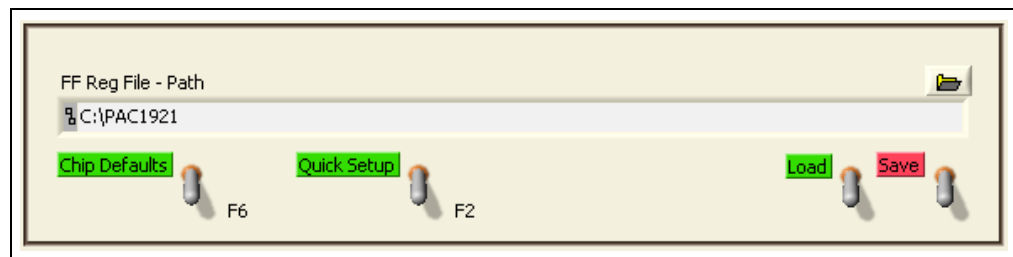


*FIGURE 4-16:* Save/Load Section.

To save configuration settings, configure the PAC1921 as desired, then display the **Calculations/File IO** tab. The "FF Reg File Path" box defaults to where the GUI software is installed. To change the location, type in a path, or click the folder icon to use a Windows® system-based navigation aid to select the folder where the configuration file will be saved. The file should be named with the .txt extension or similar text file format. Once a file name and location have been chosen, click the **Save** switch, and the file is saved.

> **Note:** If a file with the same name already exists, the file will be overwritten without warning and old data will be lost.

The data is saved in two columns, separated by tabs. The first column is the register address and the second column is the register data.

Once a file is saved, it can be recalled at any time by selecting the file in the "FF Reg File Path" box and clicking the **Load** switch.

Click the **Chip Defaults** switch or press the <F6> function key on the keyboard to reload register defaults on the PAC1921.

Click the **Quick Setup** switch or press the <F2> function key on the keyboard to set up the GUI and PAC1921 for free-run integration power measurement. The **Quick Setup** switch does the following:

- Enables the "Enable Auto INT_EN" option.
- Enables the "READ/INT OVR" option.
- Enables the "INT_EN" option.
- Sets "MUX_SEL" to VPOWER free-run.
- Enables the "Enable DC Vsense- Stimulus" option.

### 4.3.4    Integration Table Tab

The **Integration Table** tab, shown in Figure 4-17, shows the maximum integration periods for a selected number of samples with various settings.

| | INTEGRATION PERIOD POWER MEASUREMENT | | | INTEGRATION PERIOD VSENSE OR VBUS MEASUREMENT | |
|---|---|---|---|---|---|
| SAMPLES | 14-BIT ADC RESOLUTION POST FILTERS ON | 11-BIT ADC RESOLUTION POST FILTERS OFF | MIXED ADC RESOLUTION POST FILTERS ON | 14-BIT ADC RESOLUTION POST FILTERS ON | 11-BIT ADC RESOLUTION POST FILTERS OFF |
| 1 | 2.72ms | 0.93ms | 2.1ms | 1.41ms | 0.51ms |
| 2 | 4.05ms | 1.46ms | 3.1ms | 2.02ms | 0.72ms |
| 4 | 6.79ms | 2.41ms | 5.1ms | 3.43ms | 1.24ms |
| 8 | 12.2ms | 4.32ms | 9.2ms | 6.06ms | 2.08ms |
| 16 | 23ms | 8.05ms | 17.5ms | 11.5ms | 3.95ms |
| 32 | 46ms | 16.1ms | 34.9ms | 22.9ms | 7.89ms |
| 64 | 92ms | 32.1ms | 70ms | 45.7ms | 15.7ms |
| 128 | 184ms | 64.2ms | 139ms | 91.3ms | 31.4ms |
| 256 | 368ms | 128.3ms | 278ms | 183ms | 62.7ms |
| 512 | 736ms | 257ms | 556ms | 365ms | 126ms |
| 1024 | 1471ms | 513ms | 1112ms | 730ms | 251ms |
| 2048 | 2941ms | 1026ms | 2223ms | 1460ms | 502ms |

*Tabs: Vbus & Vsense | Vbus | Vsense | Vpower | Calculations / File IO | DIO | Integration Table*

**FIGURE 4-17:**    *Integration Table Tab.*

## 4.4    EVALUATION BOARD EXAMPLES

### 4.4.1    Power Pin-Controlled Integration Example

This example provides steps to experiment with pin-controlled integration in SMBus mode and see the effects of gain.

1. In the Main Configuration section, check the "READ/INT OVR" box. This allows the INT_EN bit to override the READ/INT pin state. Also check the "Enable Auto INT_EN" control to set automatic GUI updates.

2. In the Panel and Integration Control section, check the "Integration Time GUI Controlled" box, and set the "Read Period (ms)" to 500 ms. This causes the INT_EN bit to toggle between high for 500 ms (putting the PAC1921 in the Integrate state) and low for 500 ms (putting the device in the Read state).

3. In the EVB Demo Configuration section, check the "Enable DC Vsense-Stimulus" box and type 40 mV in the "DC Vsense- Stimulus (mV)" box.

4. Observe the plots on the **Vbus & Vsense** tab, as shown in Figure 4-18. The evaluation board demo $V_{BUS}$ is ~5.1V and $V_{SENSE}$ is ~0.04V.
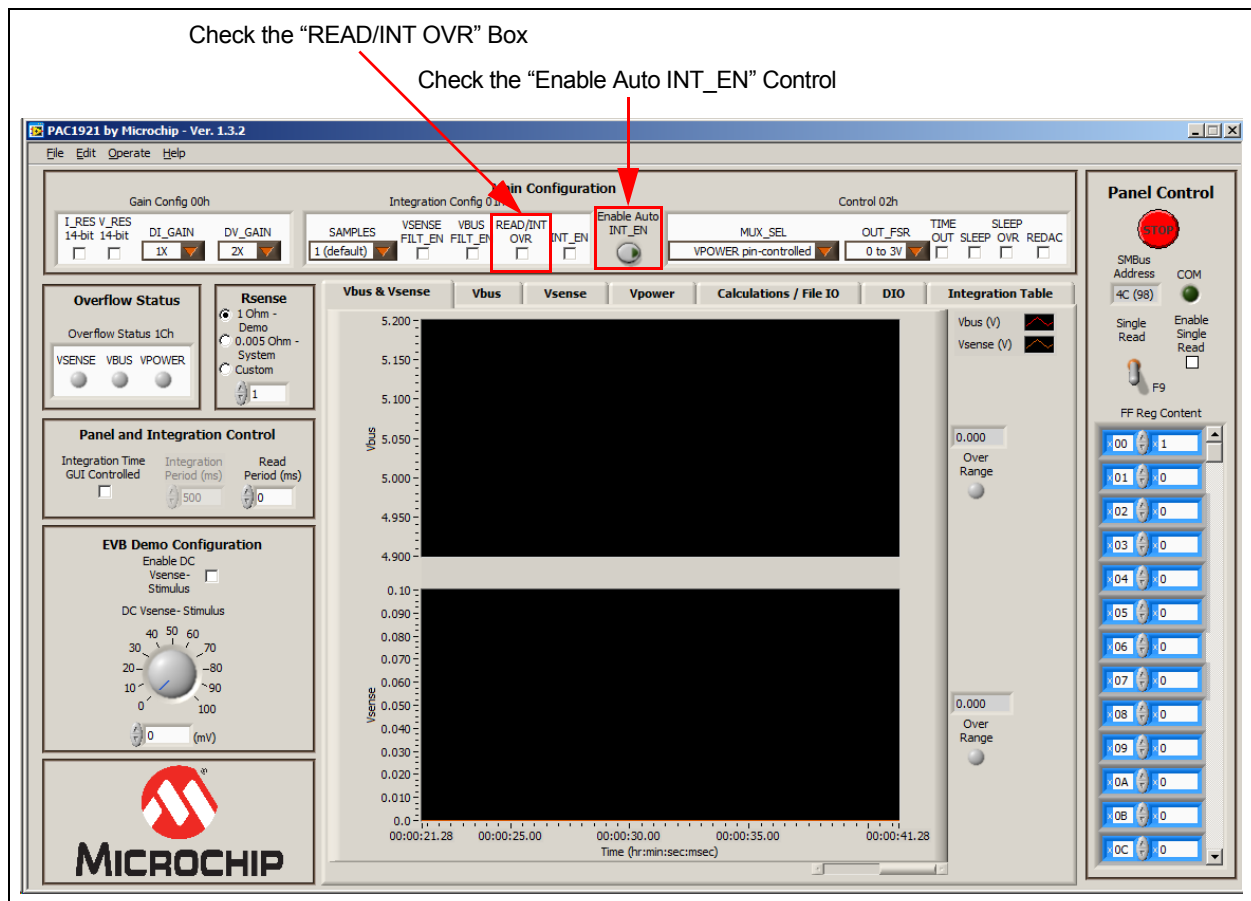


**FIGURE 4-18:**    *Pin-Controlled Integration, No Gain.*

5.   Observe the data on the **Calculations/File IO** tab, as shown in Figure 4-19.



**FIGURE 4-19:**      *Pin-Controlled Integration without Gain.*

6.   To see the effects of gain, change "DI_GAIN" to 2X and "DV_GAIN" to 4X in the Gain Config 00h section, as shown in Figure 4-20.
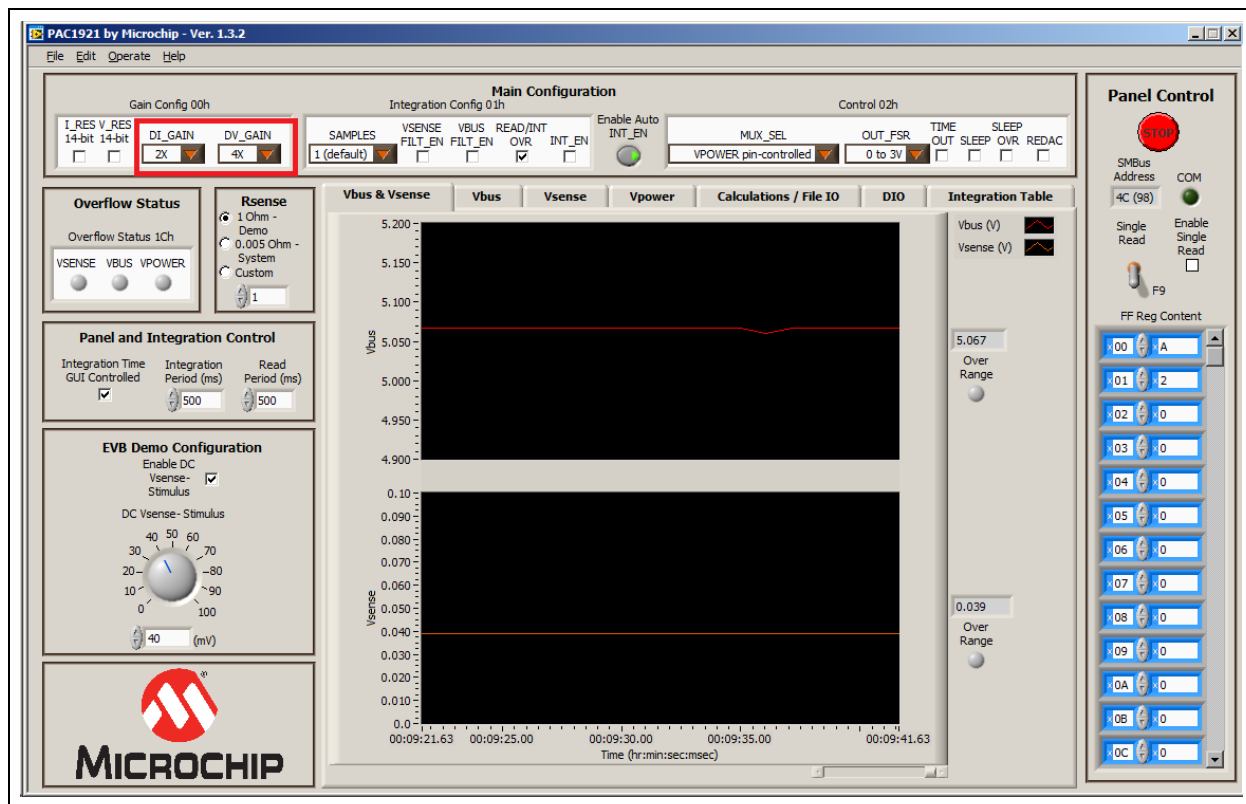


**FIGURE 4-20:**      *Pin-Controlled Integration with Gain.*

7. Observe the data on the **Calculations/File IO** tab, as shown in Figure 4-21. Notice that the Register Data values (with the exception of the accumulators) reflect the gain.

| Measurement | Over | Register Data | Calculated Results | Units |
|---|---|---|---|---|
| Vbus 10-11h | d | 648 | 5.06745 | V |
| Vsense 12-13h | d | 794 | 0.03881 | V |
| Vsum Accumulator 14-17h | d | 1461220 | 1461220.00000 | NA |
| Isum Accumulator 18-1Bh | d | 3581976 | 3581976.00000 | NA |
| Vpower 1D-1Eh | d | 502 | 0.19629 | W |
| Samples 21-22h | d | 564 | 564.00000 | NA |
| Psum Accumulator 23-27h | d | 18560477924 | 0.00000 | NA |
| Isense Calculated | d | 0 | 0.03881 | A |

**FIGURE 4-21:**     *Pin-Controlled Integration with Gain.*

### 4.4.2    Power Free-Run Integration Example

This section provides steps to experiment with free-run integration in SMBus mode and see the effects of filtering, resolution and sampling. It starts by showing the fastest integration period and progressively shows higher accuracy.

1.  Press the <F2> function key on the keyboard. This performs Quick Setup, which checks the "READ/INT OVR" box, the "INT_EN" bit box and the "Enable DC Vsense- Stimulus" box, enables the "Enable Auto INT_EN" control and sets "MUX_SEL" to VPOWER free-run. Integration begins using the 1 sample default.

2.  In the Main Configuration section, click the "I_RES" and "V_RES" boxes so 11-bit shows; this lowers the resolution from 14 bits to 11 bits.

3.  In the Main Configuration section, uncheck the "VSENSE FILT_EN" and "VBUS FILT_EN" boxes to disable the ADC post filters.

4.  In the EVB Demo Configuration section, type 40 mV in the "DC Vsense-Stimulus" spin box.

5.  Observe the plots on the **Vbus & Vsense** tab, as shown in Figure 4-22, adjusting the Y-axis values as desired. These settings result in the shortest integration period.
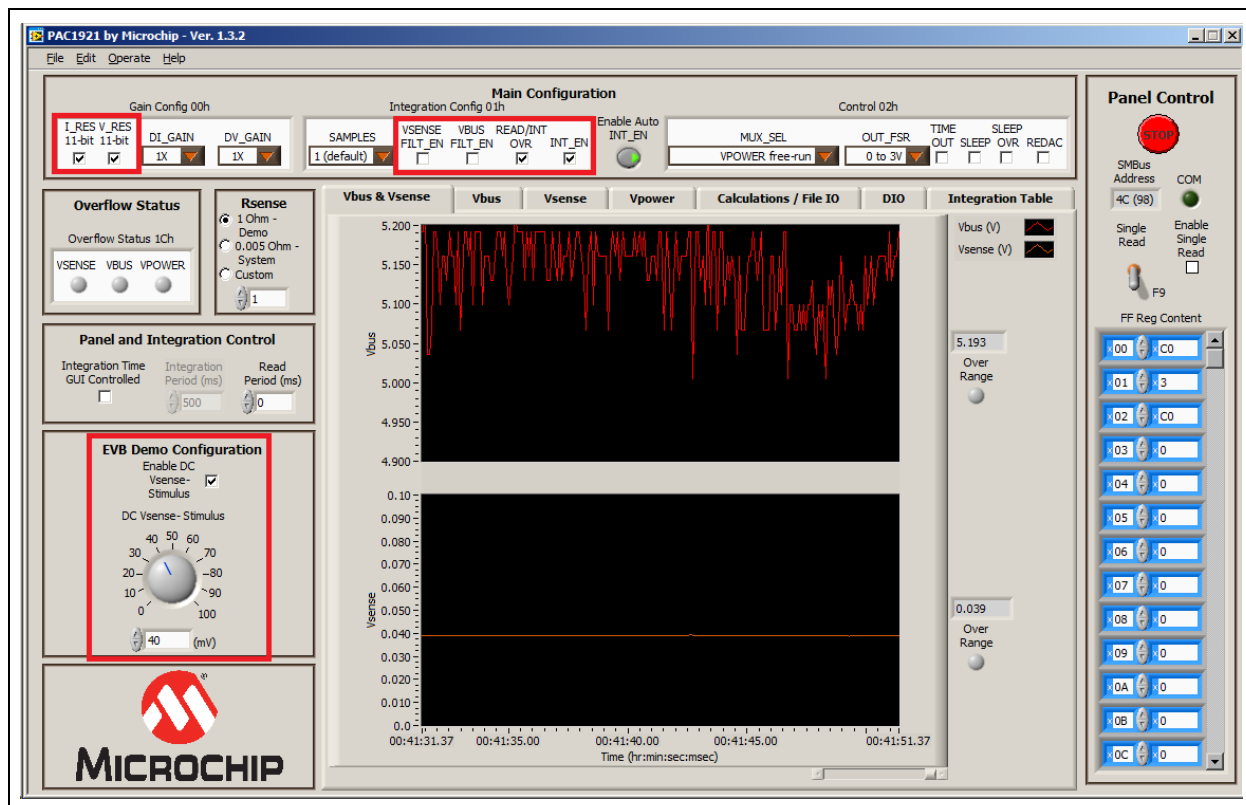


*FIGURE 4-22:*        *Free-Run Integration, Shortest Period.*

6. Check the "VSENSE FILT_EN" and "VBUS FILT_EN" boxes to enable the ADC post filters, and observe the improvement in the plots on the **Vbus & Vsense** tab, as shown in Figure 4-23.
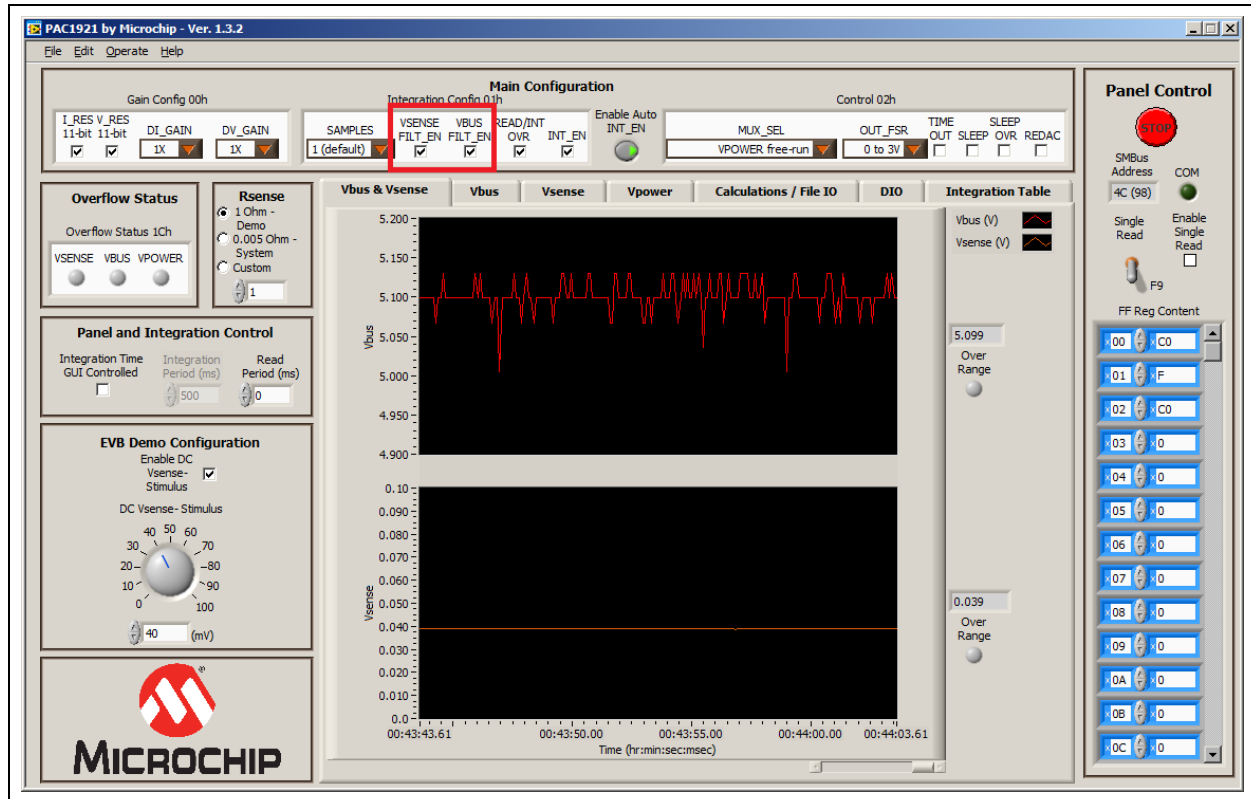


**FIGURE 4-23:** *Free-Run Integration with ADC Post Filters Enabled.*

7.  Uncheck the "I_RES" and "V_RES" boxes to enable 14-bit resolution, and observe the improvement in the plots on the **Vbus & Vsense** tab, as shown in Figure 4-24.
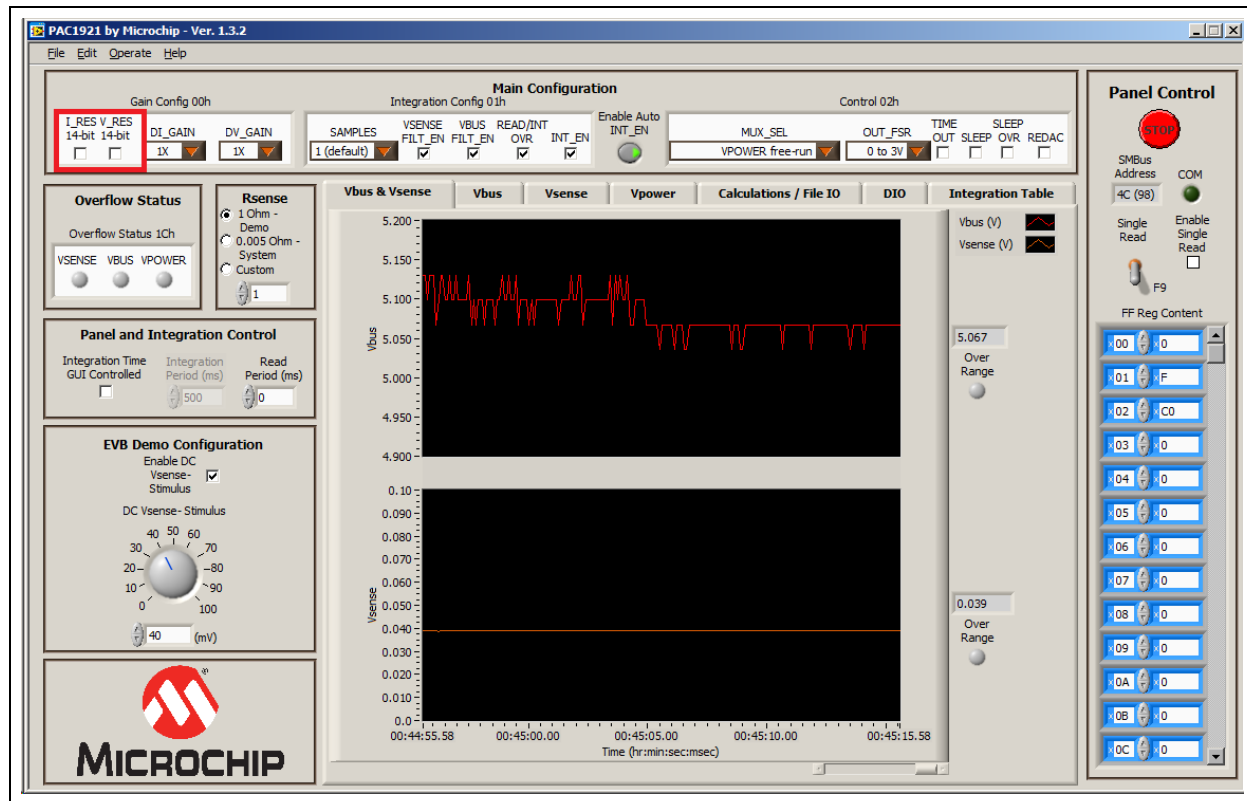


**FIGURE 4-24:** *Free-Run Integration with 14-Bit Resolution.*

8. Change the number of "SAMPLES" to 8 and observe the improvement in the plots on the **Vbus & Vsense** tab, as shown in Figure 4-25.
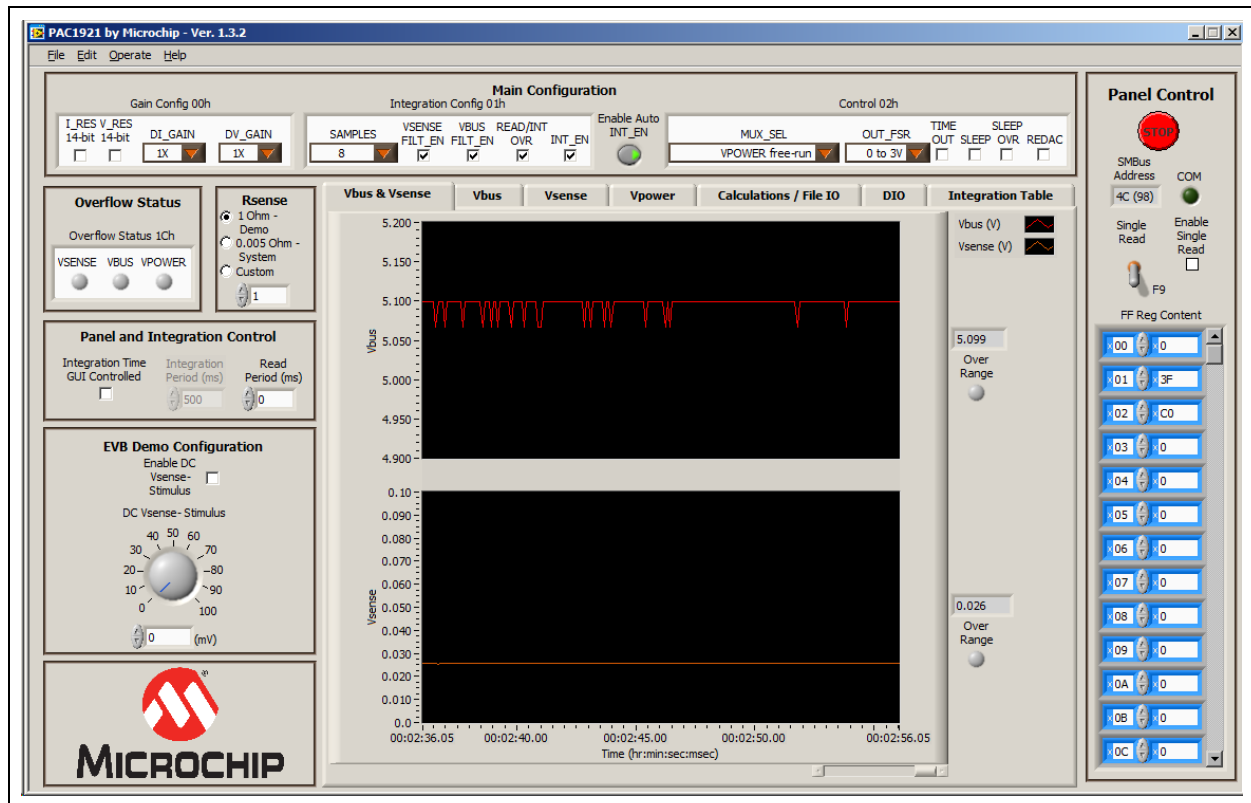


**FIGURE 4-25:** *Increased Sample Effect.*

## 4.5 TROUBLESHOOTING

### 4.5.1 GUI Controls Unresponsive After Installation

Restart the computer. In some cases, a restart is required after installation.

### 4.5.2 GUI Freezes

If the GUI freezes for unknown reasons, communications cannot be stopped and the program cannot be closed. Disconnect the USB cable from the evaluation board, then close the program. Reconnect the evaluation board, then restart the GUI.

**NOTES:**

# Appendix A. Schematic and Layouts

## A.1    INTRODUCTION

This appendix contains the following schematics and layouts for the PAC1921 High-Side Current/Power Sensor Evaluation Board:

- Board – PAC1921 Current Shunt and Power Monitor Schematic
- Board – USB Bridge and Sig Gen Schematic
- Board – Top Silk
- Board – Top Copper and Silk
- Board – Top Copper
- Board – Bottom Copper
- Board – Bottom Copper and Silk
- Board – Bottom Silk

## A.2    BOARD – PAC1921 CURRENT SHUNT AND POWER MONITOR SCHEMATIC



**PAC1921 High-Side Current/Power Sensor Evaluation Board User's Guide**

## A.3 BOARD – USB BRIDGE AND SIG GEN SCHEMATIC

**Steady state current generator**

IDEMO  Idemo

Q1 GMCP87050  D  S  14

U4D MCP6004  4  D  13
OUTD  12  $V_{DD}$  $V_{SS}$  +D  11

R37 120R 0603 1%
C8 1 µF 16V 0603

C12 2200 pF 50V 0603
C9 2200 pF 50V 0603
R40 15.4k 0603 1%
R41 12.1k 0603 1%

U4C MCP6004  C  8  9
OUTC  10  $V_{DD}$  $V_{SS}$  +C  11

C14 0.022 µF 50V 0603
R43 7.5k 0603 1%
R44 3.32k 0603 1%
GP1

R73 10k 3386F 10%
R50 12.1k 0603 1%
C13 2200 pF 50V 0603

R70 20R 0603 1%

**Waveform Current Generator**

+5V_USB

Idemo

Q2 GMCP87050  D  S

C20 0.1 µF 16V 0603
R38 120R 0603 1%
C15 1 µF 16V 0603

U4A MCP6004  A  1  2
OUTA  3  $V_{DD}$  $V_{SS}$  +A  11

C19 0.1 µF 16V 0603
R49 15.4k 0603 1%
R48 12.1k 0603 1%

U4B MCP6004  B  6  7
OUTB  5  +B  11

C17 0.1 µF 16V 0603
C18 0.1µF 16V 0603
R46 7.5k 0603 1%
R47 3.32k 0603 1%
GP3

R74 10k 3386F 10%
R51 12.1k 0603 1%
C16 0.1 µF 16V 0603

R72 20R 0603 1%

JP9  Shunt 2.54 mm 1x2 Handle
JP10  Shunt 2.54 mm 1x2 Handle
JP11  Shunt 2.54 mm 1x2 Handle
JP12  Shunt 2.54 mm 1x2 Handle

+3.3V
C7 10 µF 10V 0603
+3.3V
R18 12.1k 0603 1%
R19 12.1k 0603 1%
+3.3V
R26 12.1k 0603 1%
+3.3V

$V_{DD}$

J13
SMBUS_CLK  SMBus_CLK  SMBusCLK
SMBUS_DATA  SMBus_DATA  SMBusDATA
#READ/INT  #READ/INT
HDR-2.54 Male 2x5

R25 2k 0603 1%
GP0

+3.3V
C6 0.1 µF 16V 0603

U2
1  $V_{DD}$  $V_{SS}$  14
2  GP0  D+  13
3  GP1  D-  12
4  RST  $V_{USB}$  11  +3.3V
5  UART RX  SCL  10  SMBusCLK
6  UART TX  SDA  9  SMBusDATA
7  GP2  GP3  8  GP3
MCP2221

GP0
GP1
RESET
RX
TX
OUT  GP2

+3.3V
C10 0.47 µF 6.3V 0603

LD2  USB Power  RED
R20 1k 0603 1%
+5V_USB

LD1  $V_{DD}$ Power  RED
R21 1k 0603 1%
$V_{DD}$

+3.3V
U3
$V_{OUT}$  GND  $V_{IN}$  1
MCP1825S/3.3V

C5 0.1 µF 16V 0603
C4 10 µF 10V 0603

+5V_USB
FB1
$V_{BUS}$

D1 ESD5V3

R27 1M 0603 1%
C21 100 pF 50V 0603

P1
1  $V_{BUS}$
2  D-
3  D+
4  ID
5  GND
USB MINI-B Female

PAD1  Rubber Pad Cyl D7.9H5.3
PAD2  Rubber Pad Cyl D7.9H5.3
PAD3  Rubber Pad Cyl D7.9H5.3
PAD4  Rubber Pad Cyl D7.9H5.3

**Schematic and Layouts**

## A.4 BOARD – TOP SILK



## A.5 BOARD – TOP COPPER AND SILK
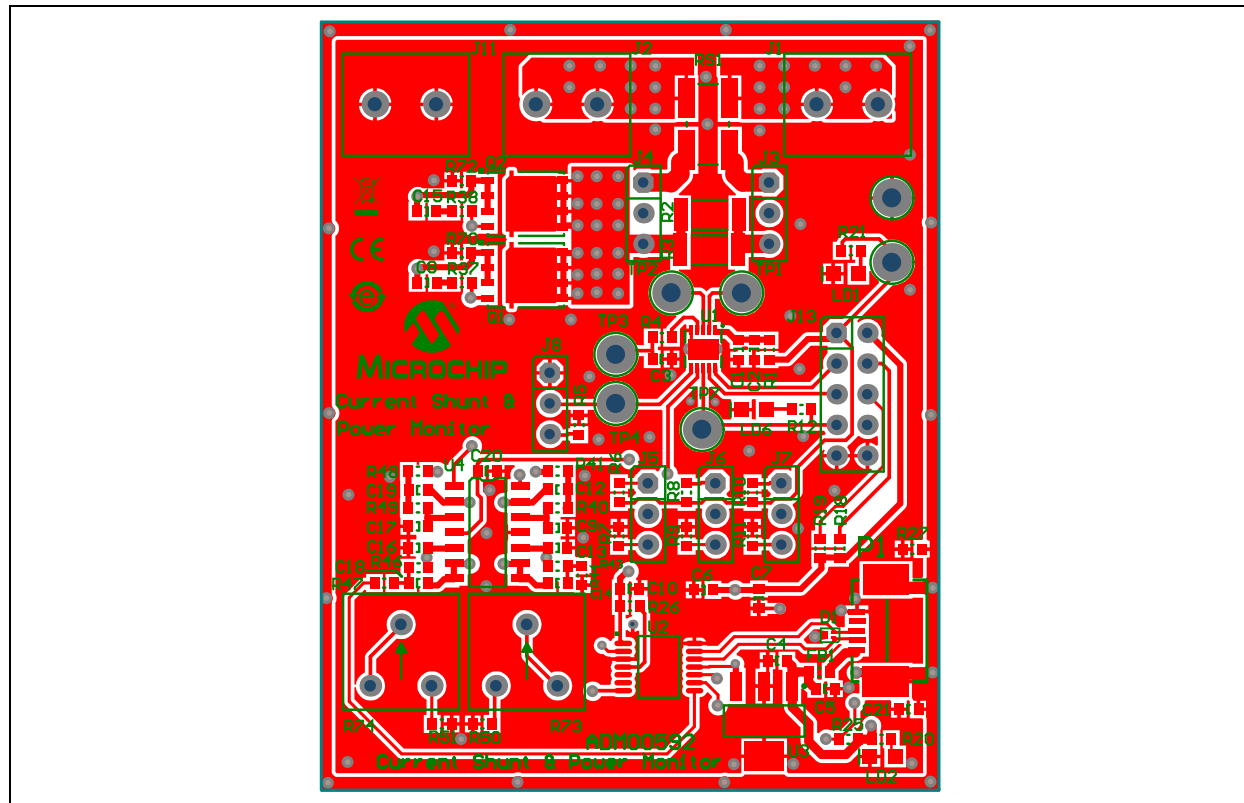
## A.6    BOARD – TOP COPPER

## A.7    BOARD – BOTTOM COPPER

04-10305-R3
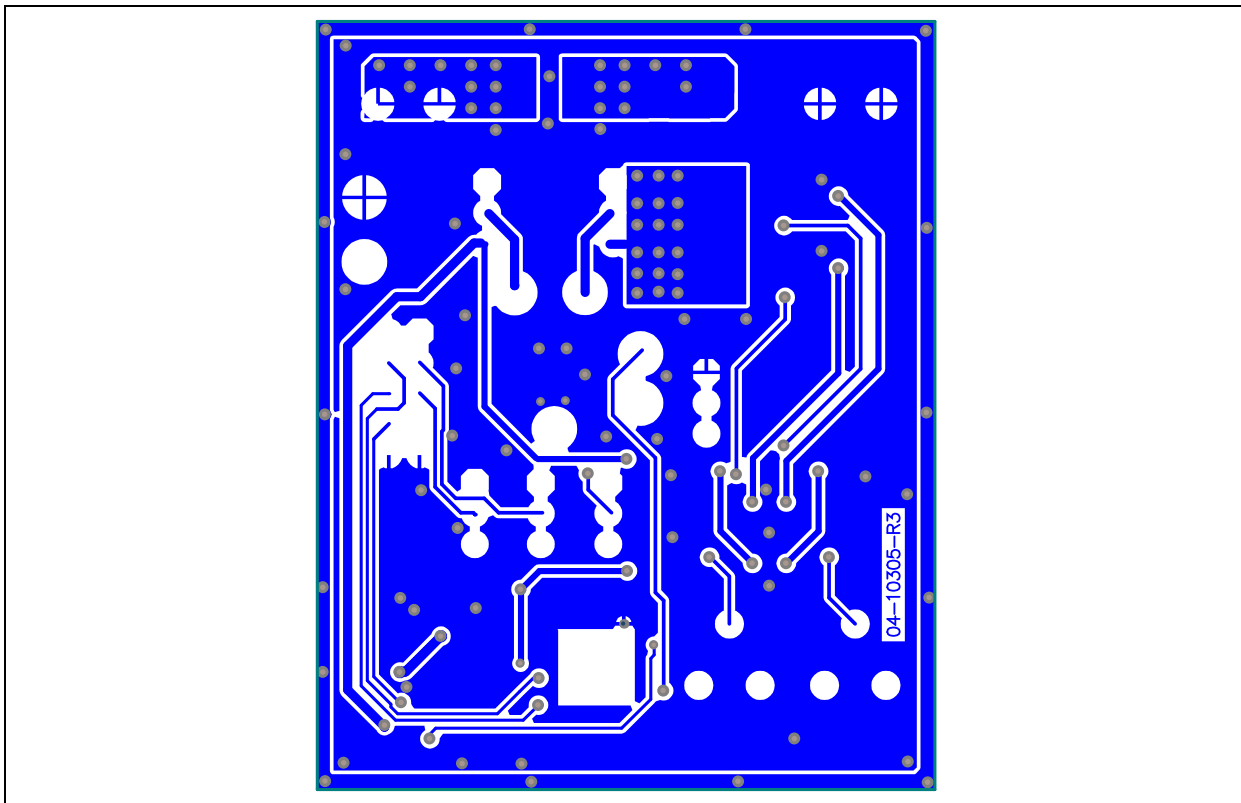
## A.8    BOARD – BOTTOM COPPER AND SILK
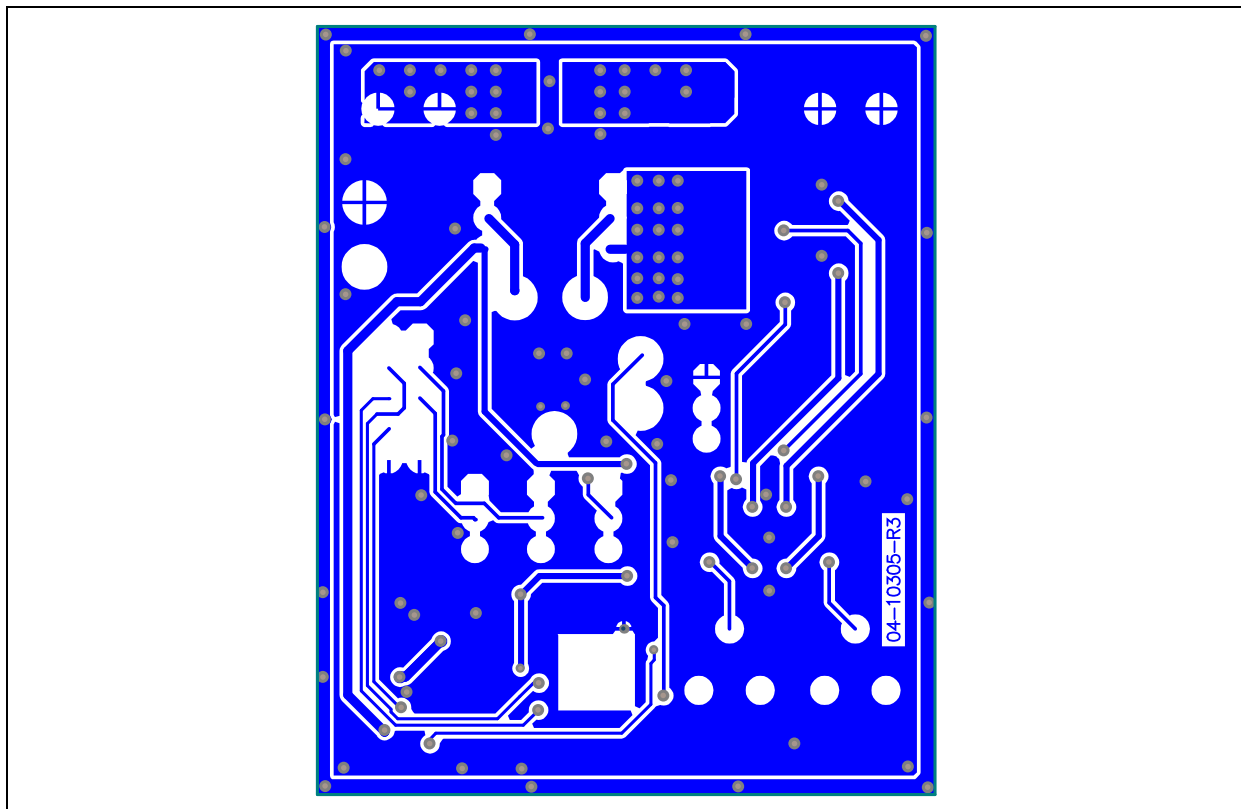


## A.9    BOARD – BOTTOM SILK
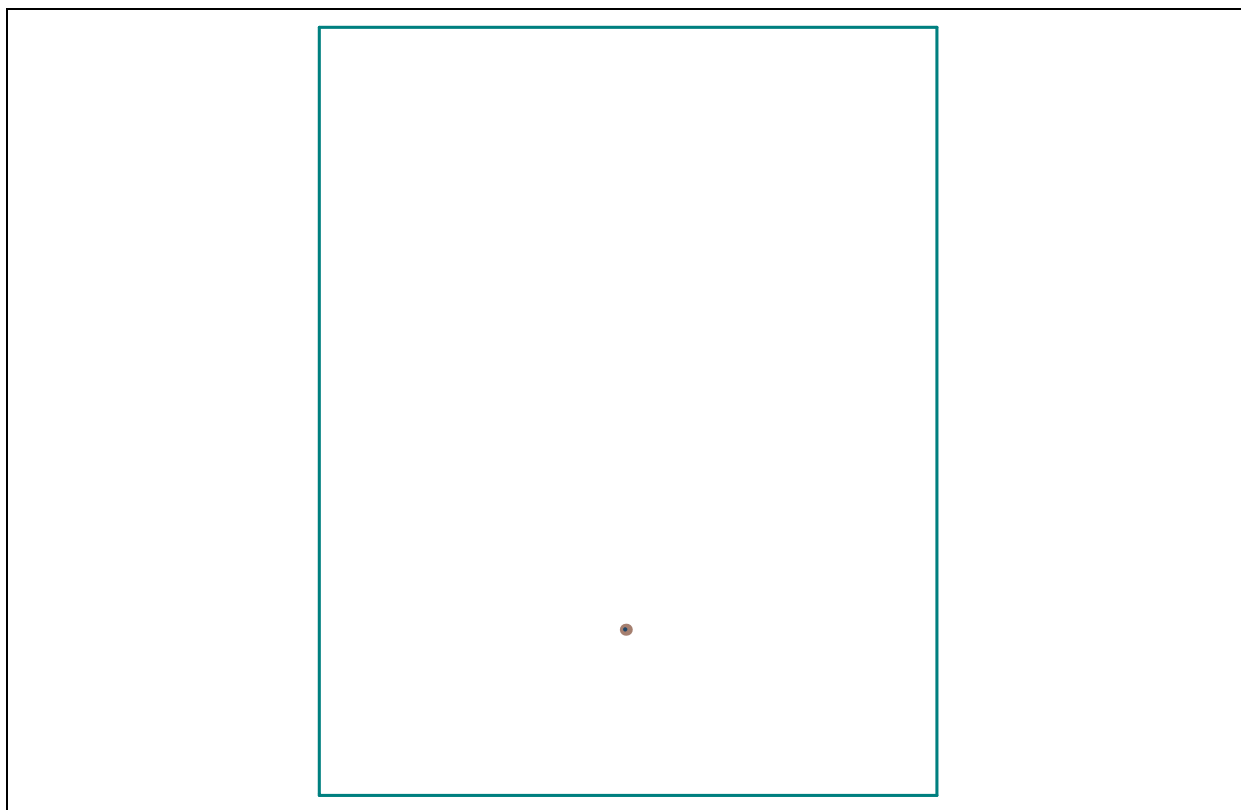
# Appendix B. Bill of Materials (BOM)

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

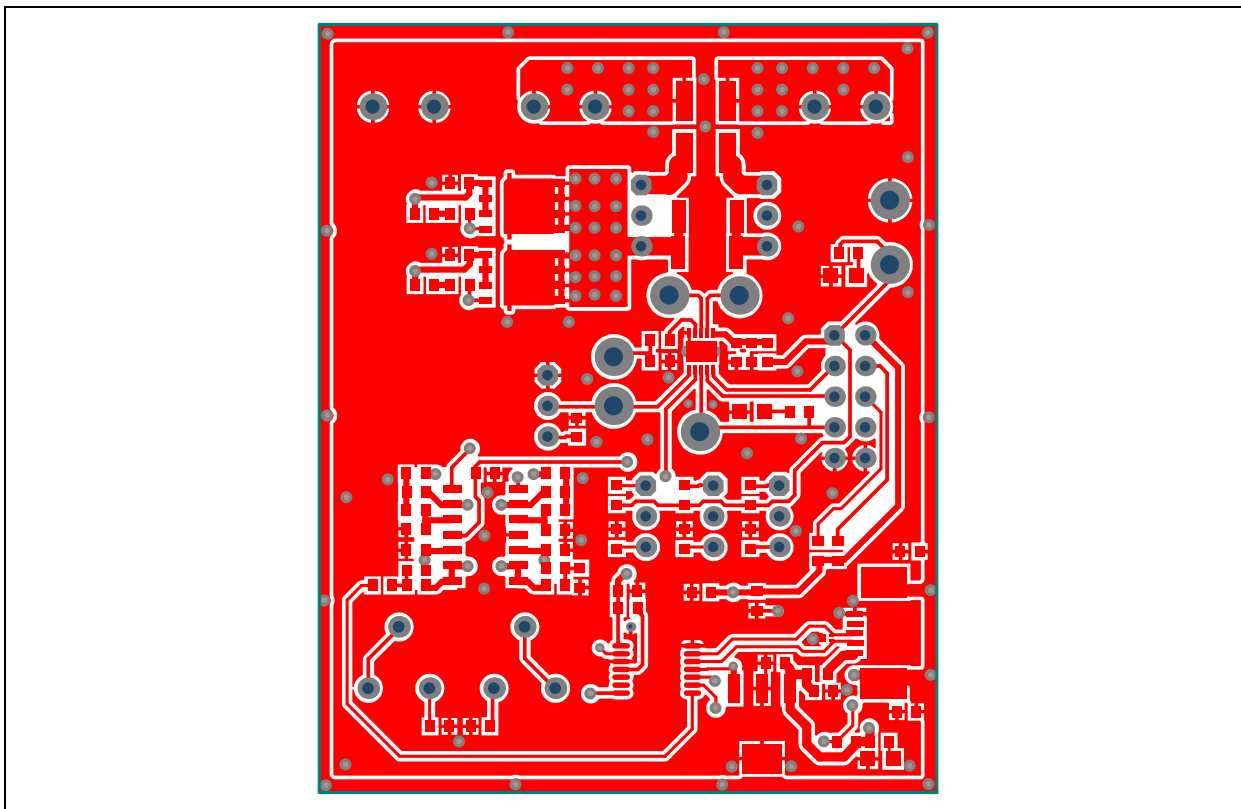| Qty | Reference | Description | Manufacturer | Part Number |
|---|---|---|---|---|
| 8 | C1, C5, C6, C16, C17, C18, C19, C20 | Cap. Ceramic, 0.1 µF, 16V, 10%, X7R, SMD, 0603 | NIC Components Corp. | NMC0603X7R104K16TRPF |
| 1 | C10 | Cap. Ceramic, 0.47 µF, 6.3V, 10%, X5R, SMD, 0603 | Murata Electronics® | GRM188R60J474KA01D |
| 1 | C14 | Cap. Ceramic, 0.022 µF, 50V, 10%, X7R, SMD, 0603 | TDK Corporation | C1608X7R1H223K |
| 3 | C2, C8, C15 | Cap. Ceramic, 1 µF, 16V, 10%, X7R, SMD, 0603 | Taiyo Yuden Co., Ltd. | EMK107B7105KA-T |
| 1 | C21 | Cap. Ceramic, 100 pF, 50V, 1%, C0G, SMD, 0603 | TDK Corporation | C1608C0G1H101F |
| 1 | C3 | Cap. Ceramic, 0.001 µF, 50V, 20%, X7R, SMD, 0603 | KEMET™ | C0603C102M5RAC |
| 2 | C4, C7 | Cap. Ceramic, 10 µF, 10V, 20%, X5R, SMD, 0603 | Panasonic® | ECJ-1VB1A106M |
| 3 | C9, C12, C13 | Cap. Ceramic, 2200 pF, 50V, 10%, X7R, SMD, 0603 | KEMET | C0603C222K5RACTU |
| 1 | D1 | DIO TVSARR, ESD5V3U2U, 5.3V, SMD, SOT-883 | Infineon Technologies | ESD5V3U2U-03LRH E6327 |
| 1 | FB1 | Ferrite, 500 mA, 0.1R, SMD, 0603 | Laird-Signal Integrity | LI0603E470R-10 |
| 3 | J1, J2, J11 | Conn. Terminal, 5.08 mm, 15A, Female, 1x2, TH R/A | On Shore Technology Inc. | EDZ250/2 |
| 1 | J13 | Conn. HDR-2.54, Male, 2x5, 0.100" (2.54 mm), TH Vert. | Samtec, Inc. | TSW-105-07-G-D |
| 6 | J3, J4, J5, J6, J7, J8 | Conn. HDR-2.54, Male, 1x3, Tin, 5.84 MH, TH Vert. | Samtec, Inc. | TSW-103-07-T-S |
| 10 | JP3, JP4, JP5, JP6, JP7, JP8, JP9, JP10, JP11, JP12 | Mech. HW Jumper, 2.54 mm, 1x2, Handle Gold | TE Connectivity, Ltd. | 881545-2 |
| 2 | LD1, LD2 | DIO LED Red, 1.95V, 20 mA, 220 mcd, Clear, SMD, 0805 | Kingbright Corp. | APT2012SURCK |
| 1 | LD6 | DIO LED Green, 2V, 30 mA, 120 mcd, Diffuse, SMD, 0805 | Avago Technologies US Inc. | HSMM-C170 |
| 1 | P1 | Conn. USB Mini-B Female, SMD, R/A | Hirose Electric Co., Ltd. | UX60SC-MB-5ST(80) |
| 4 | PAD1, PAD2, PAD3, PAD4 | Mech. HW Rubber Pad, Cylindrical, D7.9, H5.3, Black | 3M | SJ61A11 |
| 2 | Q1, Q2 | MCHP Analog PWM Controller, 1 MHz, MCP87050-U/MF, PDFN-8 | Microchip Technology Inc. | **MCP87050T-U/MF** |

**Note  1:**   The components listed in this Bill of Materials are representative of the PCB assembly. The released BOM used in manufacturing uses all RoHS-compliant components.

# PAC1921

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

| Qty | Reference | Description | Manufacturer | Part Number |
|---|---|---|---|---|
| 1 | R1 | Res., TKF, 100R, 1%, 1/10W, SMD, 0603 | ROHM Semiconductor | MCR03EZPFX1000 |
| 1 | R12, | Res., TKF, 2k, 1%, 1/10W, SMD, 0603 | Stackpole Electronics, Inc. | RMCF0603FT2K00 |
| 2 | R2, R3 | Res., TKF, 2R, 5%, 3/4W, SMD, 2010 | Panasonic® - ECG | ERJ-12ZYJ2R0U |
| 2 | R20, R21 | Res., TKF, 1k, 1%, 1/10W, SMD, 0603 | Panasonic - ECG | ERJ-3EKF1001V |
| 1 | R25 | Res., TKF, 2k, 1%, 1/10W, SMD, 0603 | Stackpole Electronics, Inc. | RMCF0603FT2K00 |
| 1 | R27 | Res., TKF, 1M, 1%, 1/10W, SMD, 0603 | Panasonic - ECG | ERJ-3EKF1004V |
| 4 | R4, R5, R37, R38 | Res., TKF, 120R, 1%, 1/10W, SMD, 0603 | Panasonic - ECG | ERJ-3EKF1200V |
| 2 | R40, R49 | Res., TKF, 15.4k, 1%, 1/10W, SMD, 0603 | Panasonic - ECG | ERJ-3EKF1542V |
| 2 | R43, R46 | Res., TKF, 3.32k, 1%, 1/10W, SMD, 0603 | ROHM | MCR03EZPFX3321 |
| 2 | R43, R46 | Res., TKF, 7.5k, 1%, 1/10W, SMD, 0603 | Panasonic - ECG | ERJ-3EKF7501V |
| 1 | R51 | Res., TKF, 12.1k, 1%, 1/10W, SMD, 0603 | Panasonic - ECG | ERJ-3EKF1212V |
| 12 | R6, R7, R8, R9, R10, R11, R18, R19, R26, R41, R48, R50 | Res., TKF, 12.1k, 1%, 1/10W, SMD, 0603 | Panasonic - ECG | ERJ-3EKF1212V |
| 2 | R70, R72 | Res., TKF, 20R, 1%, 1/10W, SMD, 0603 | Panasonic - ECG | ERJ-3EKF20R0V |
| 2 | R73, R74 | Res., Trimmer Cermet, 10k, 10%, 500 mW, TH, 3386F | Bourns®, Inc. | 3386F-1-103TLF |
| 1 | RS1 | Res., Shunt, 0.005R, 1%, 2W, 1%, 2412 | Ohmite® Manufacturing | LVK25R005FER |
| 1 | TP1 | Conn. TP Loop, Orange, TH | Keystone Electronics Corp. | 5013 |
| 2 | TP2, TP7 | Conn. TP Loop, Yellow, TH | Keystone Electronics Corp. | 5014 |
| 2 | TP3, TP4 | Conn. TP Loop, White, TH | Keystone Electronics Corp. | 5012 |
| 1 | TP5 | Conn. TP Loop, Red, TH | Keystone Electronics Corp. | 5010 |
| 1 | TP6 | Conn. TP Loop, Black, TH | Keystone Electronics Corp. | 5011 |
| 1 | U1 | MCHP Analog Current Sense Monitor, PAC1921-1-AIA-TR, DFN-10 | Microchip Technology Inc. | **PAC1921-1-AIA-TR** |
| 1 | U2 | MCHP Interface USB I$^2$C™ UART, MCP2221-I/ST, TSSOP-14 | Microchip Technology Inc. | **MCP2221-I/ST** |
| 1 | U3 | MCHP Analog LDO, 3.3V, MCP1825ST-3302E/DB, SOT-223-3 | Microchip Technology Inc. | **MCP1825S-3302E/DB** |
| 1 | U4 | MCHP Analog Op Amp, 4-Ch, 1 MHz, MCP6004-I/SL, SOIC-14 | Microchip Technology Inc. | **MCP6004-I/SL** |

**Note  1:**   The components listed in this Bill of Materials are representative of the PCB assembly. The released BOM used in manufacturing uses all RoHS-compliant components.

**NOTES:**

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