User's Guide
SLAU659B–February 2017–Revised March 2018

# PGA460-Q1 Ultrasonic Signal Conditioner EVM With Transducer User's Guide

The PGA460-Q1 EVM evaluation module (EVM) allows users to evaluate the functionality of Texas Instrument's PGA460-Q1 ultrasonic sensor-signal conditioner IC. The PGA460-Q1 is a fully integrated system-on-chip, analog front-end (AFE) device for ultrasonic sensing. This user's guide describes both the hardware platform containing a sample PGA460-Q1 device and the graphical user interface (GUI) software used to configure the functionality and diagnostics. In addition to evaluating the PGA460-Q1 device, the other objective of this board is to display the ultrasonic echo profile and measurement results of either a transformer driven closed-top transducer or direct-driven open-top transducer when using the GUI.

**NOTE:** Texas Instruments recommends using the PGA460-Q1 EVM user's guide (this document) after reading and following the steps listed in the PGA460-Q1 EVM Quick Start Guide. To download this guide, go to the product folder: www.ti.com/product/PGA460-Q1.

## Contents



## List of Figures

**List of Tables**



## Trademarks

LaunchPad, BoosterPack, Code Composer Studio, MSP430 are trademarks of Texas Instruments.
SIMPLE SWITCHER is a registered trademark of Texas Instruments.
All other trademarks are the property of their respective owners.

# 1 Introduction

The PGA460-Q1 EVM is a fully assembled evaluation module (EVM) designed for the combined evaluation of the PGA460-Q1 ultrasonic-sensor signal conditioner IC, an ultrasonic transducer, and center-tap transformer or half-bridge driver. Because of the two driver options, the user can evaluate any two pin, open or closed top ultrasonic transducer in the operating frequency range of 30 to 80 kHz, or 180 to 480 kHz.

The accompanying MSP430F5529 LaunchPad™ Development Kit (MSP-EXP430F5529LP) is used as the USB-to-PC GUI communication bridge as an example on how to implement a master MCU to communicate with the PGA460-Q1 through USART or IO interfaces.

**NOTE:** The BOOSTXL-PGA460 requires an external master controller to evaluate the PGA460-Q1. The PGA460-Q1 is a slave device.

The MSP-EXP430F5529LP is controlled by commands received from the PGA460-Q1 EVM GUI, and returns data to the GUI for display and further analysis. If the MSP-EXP430F5529LP is not used, the BoosterPack™ plug-in module format of the PGA460-Q1 EVM allows alternative external master communication to the PGA460-Q1.

The BOOSTXL-PGA460 incorporates all required circuitry and components with the following features:

- PGA460-Q1 ultrasonic sensor signal conditioner IC
- Optional integrated-switch buck converter, TI's TPS62175, to generate a 5-V output to power the MSP-EXP430F5529LP when only using a battery or external supply
- Optional integrated-switch boost converter, TI's LMR62421, to generate a 7.2-V output to power the PGA460-Q1 when only using USB for power
- Discrete two-wire to one-wire interface (OWI) transceiver circuit using TI's LM2903 to enable TCI and one-wire UART communication
- 8-channel SPDT multiplexer and demultiplexer, TI's TS3L501E, to switch between asynchronous UART, synchronous UART (SPI equivalent without chip select), TCI, or one-wire UART interface communication modes available on the PGA460-Q1
- Onboard external 512 kBytes of SRAM to store synchronous output data from PGA460-Q1
- Daughter card for selection between transformer-driven closed-top transducer evaluation or direct-driven open-top transducer evaluation
- Multiple test points for key analog, digital, and test signals

Figure 1 shows the PGA460-Q1 EVM architecture, identifying the key components and blocks previously listed.

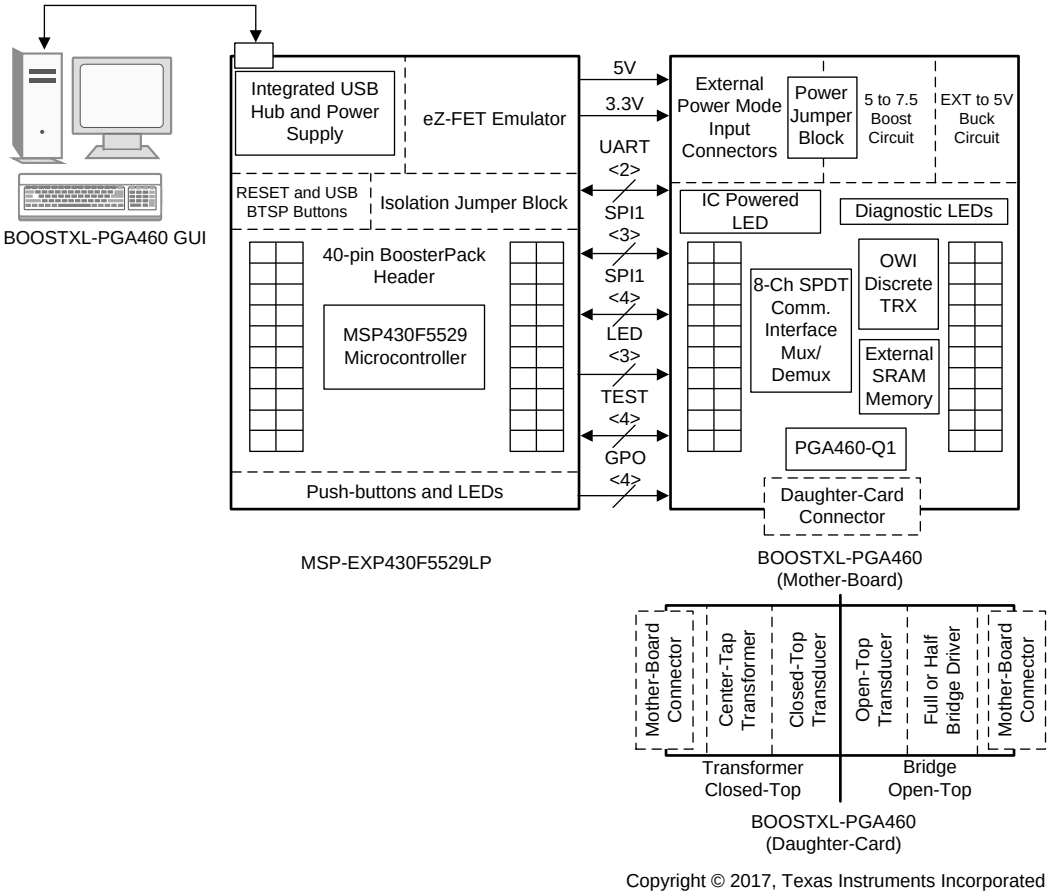





**Figure 1. PGA460-Q1 EVM Block Diagram**

## 2 Setup and Operation

### 2.1 Required Equipment for Device Evaluation

The following elements are required for proper operation and to receive consistent results as described in the user's guide:

- BOOSTXL-PGA460 BoosterPack (included with the purchase of the PGA460-F5529-BNDL)
- MSP-EXP430F5529LP (included with the purchase of the bundled PGA460-Q1 EVM)
- PGA460-Q1 EVM GUI (download from PGA460-Q1 product page)
- A computer with Windows 7 or later, and .NET Framework 4.5
- Micro-USB to USB cable (included with the purchase of the PGA460-F5529-BNDL)
- (Optional) A single power supply unit, battery, or AC/DC adapter to provide a voltage output from 6 V to 28 V, and a current output up to 500 mA.

## 2.2 Initial EVM Setup

### 2.2.1 Installing the Graphical User Interface Software

Before the PGA460-Q1 device can be evaluated, the GUI software must be available on a host computer. Run the GUI installer and save the executable (.exe) file in a convenient location (such as the computer Desktop or the *C:\Program Files (x86)\Texas Instruments* folder). Double click the executable file or desktop shortcut to run the application.

To download the PGA460-Q1 EVM GUI, go to www.ti.com/product/PGA460-Q1.

### 2.2.2 Setup Instructions

The user should receive three separate boards from Texas Instruments as shown in Figure 2.

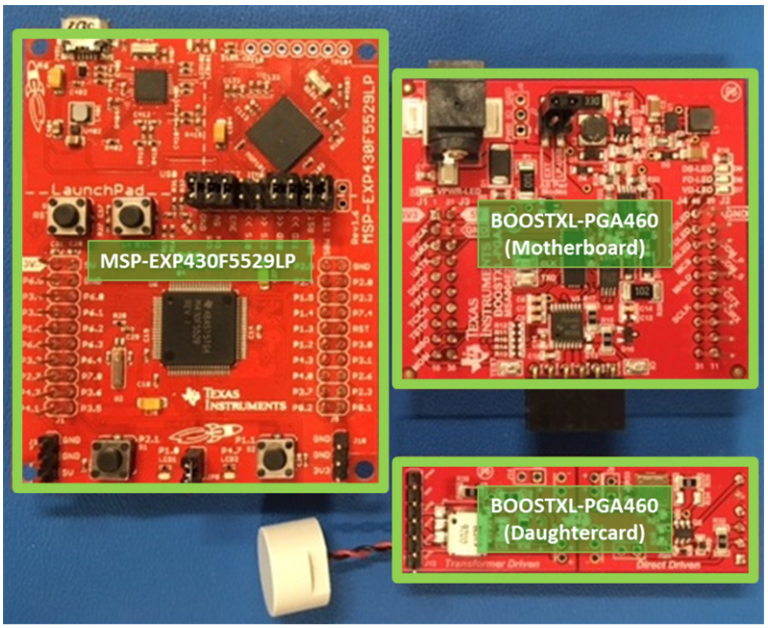



**Figure 2. EVM Boards Separated**

To properly evaluate the PGA460-Q1 EVM solution, connect and assemble all three boards as described in the steps that follow:

Step 1. Stack the BOOSTXL-PGA460 motherboard on top of the MSP-EXP430F5529LP. Pin 1 of the MSP-EXP430F5529LP must align with pin 1 of the PGA460-Q1 EVM.

Step 2. Connect the PGA460-Q1 EVM daughtercard perpendicularly to the motherboard at J8 depending on which transducer driver-mode and top type. The transformer driven closed-top configuration is accessible at J13 of the daughtercard, while the bridge driven open-top configuration is accessible at J10 of the daughtercard. For details on the difference between the two daughtercard configuration options, see Section 2.3.

Step 3. Position the power mode jumper for the intended use-case (see Table 1).

Step 4. Connect the micro-USB cable to a PC (see Section 2.2.2.2).

Step 5. If using an external power supply, turn on the supply (see Section 2.2.2.2).

Figure 3 shows the assembled solution in the transformer-driven closed-top daughtercard configuration. To use the bridge-driven open-top configuration, connect the opposite end of the daughtercard to the motherboard.

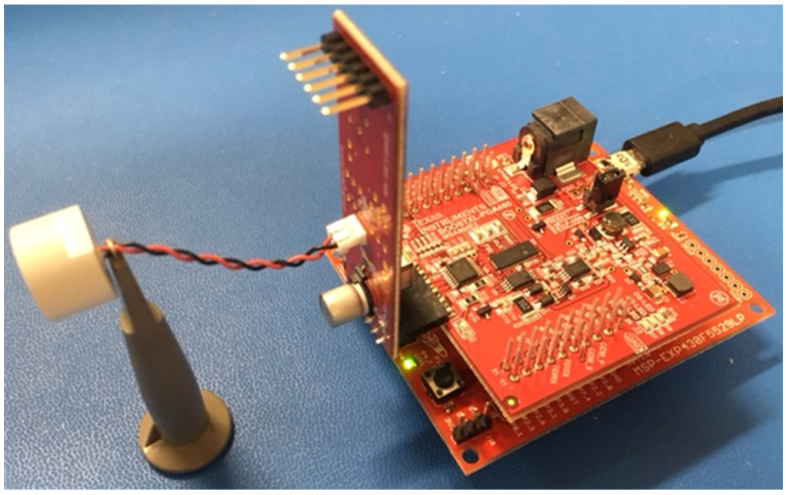


**Figure 3. EVM Boards – Assembled**

**WARNING**

**This EVM contains components that are sensitive to electrostatic discharge (ESD). Use proper laboratory techniques and equipment to minimize the chance of an ESD or electrical overstress (EOS) event.**

Figure 4 shows the functional blocks of the BOOSTXL-PGA460.

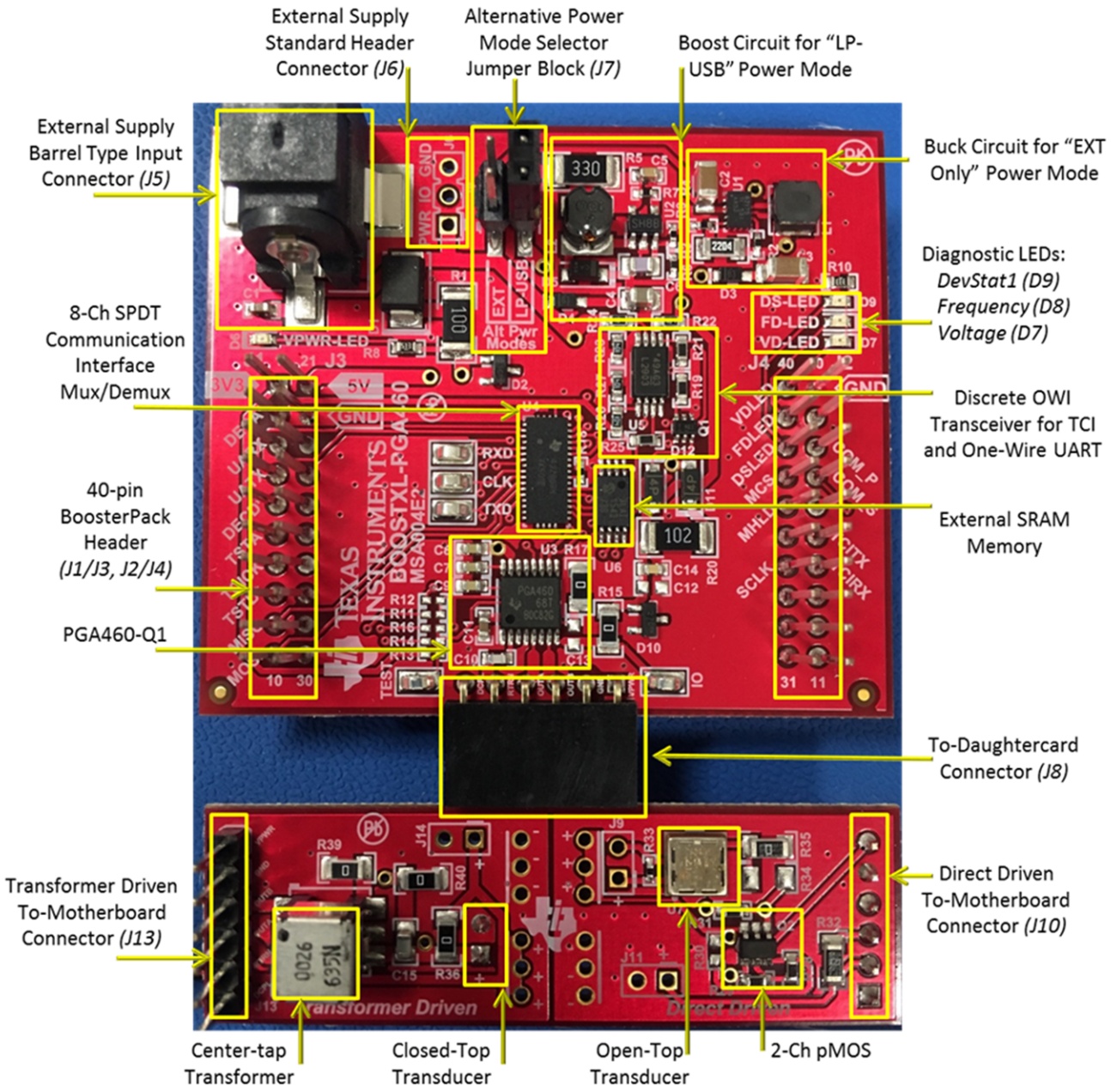
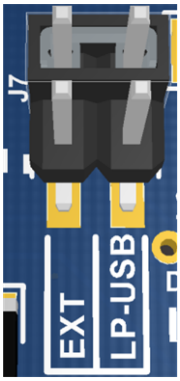
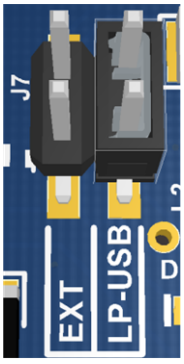



**Figure 4. BOOSTXL-PGA460 Functional Blocks**

#### 2.2.2.1 Power Mode Jumper Settings

The BOOSTXL-PGA460 has an alternative power-mode-selector jumper block (J7). Depending on the use-case, the assembled EVM can be powered from a variety of single or multiple power sources. Table 1 lists each power mode with the jumper position of the power mode selector block.

**Table 1. Power Mode Jumper Position**

| Power Mode | Jumper Position | Description | Visual Reference |
|---|---|---|---|
| Standard (Default) | All Open or Pin2-4 Short | The MSP-EXP430F5529LP is powered by USB, and the BOOSTXL-PGA460 is powered by an external source at J5 or J6. TI recommends full evaluation and development of the PGA460-Q1 be performed in the standard power mode for best results. |  |
| USB Only (Out-of-Box ) | Pin1-2 Short | The MSP-EXP430F5529LP and BOOSTXL-PGA460 are powered by USB.<br>This power mode uses the boost circuit to step-up the 5-V USB supply to a 7.2-V MAIN rail at a maximum current of 250 mA. The boost circuit will continuously sink 90 mA from the USB port (or other 5-V source). The center-tap voltage of the transformer and the high-side voltage of the direct driver will be referenced to 7.2 V. Only a single PGA460 can be powered by the USB Only mode.<br>Refer to the LMR62421 device for information on changing the supporting passive components to change the output voltage. |  |
| External Only (No USB Cable) | Pin3-4 Short | The MSP-EXP430F5529LP and BOOSTXL-PGA460 are powered by an external supply. The MSP-EXP430F5529LP is typically powered by USB.<br>This power mode is intended for non-USB or battery powered applications that use a local LED/LCD display, a wireless data transmitter and receiver, or no indicators.<br>The buck circuit is used to step down the external supply of 6 V to 28 V down to 5 V at a maximum current output of 100 mA. Do not attempt to power the MSP-EXP430F5529LP by both USB and this buck circuit. |  |

#### 2.2.2.2 Power-On the EVM

When the EVM is fully assembled and the correct power-mode jumper setting is set, the EVM is ready for power and communication with the GUI.

The complete EVM has successfully powered when the green LED (LED2) of the MSP-EXP430F5529LPilluminates, and the orange VPWR-LED (D6) of the PGA460-Q1 EVM illuminates.

### 2.3 Daughtercard Configurations

The PGA460-Q1 EVM offers evaluation of two ultrasonic sensor configurations.

### 2.3.1 Transformer Driven

The transformer-driven configuration uses a center-tap transformer to boost the DC VPWR voltage to a high-voltage sinusoidal driving signal at the secondary. The transformer installed on the daughtercard is a fixed-type EPCOS B78416A2232A003. The transformer driven configuration is typically reserved for closed-top transducers, which require higher driving voltages than open-top transducers. For this reason, the closed-top 58.5-kHz muRata MA58MF14-7N is paired with the transformer.

To use the temperate or time decouple features, desolder the R40 resistor, which shorts the coupling capacitor to GND by default.

To use separate transmitter and receiver sense elements, desolder the R36 resistor, which shorts the return path of the transmitting net to the INP path of the PGA460-Q1. Install the receiver sense transducer element to J14.

**WARNING**

**The typical use case of the PGA460-Q1 EVM is intended to limit and drive the transducer below 50 $V_{RMS}$. The transformer may generate a driving voltage of 50 $V_{RMS}$ or more at the transducer if any of the following conditions or modifications are applied:**

- The supplied transformer is replaced with a high voltage transformer with an increased turns ratio.
- The center-tap of the transformer is supplied with a voltage beyond typical or recommended conditions.
- The PGA460-Q1 device is not current limited in software.

**Use appropriate high voltage safety measures if operating the EVM beyond 50 $V_{RMS}$ at the transducer.**

### 2.3.2 Direct (Bridge) Driven

The direct driven configuration uses either a half-bridge or full-bridge to generate an alternating square wave to drive the transducer. By default, the half-bridge driver configuration is enabled to allow the use of single transducer for transmit and receive. The PGA460-Q1 cannot drive a single transducer in the full-bridge configuration without the support of additional circuitry. Refer to the Application Note *PGA460 Full-Bridge Driver Solutions for Ultrasonic Transducers* (SLAA780) for details on a full-bridge solutions. Given that low-side drivers are integrated into the PGA460-Q1, an external 2-channel p-channel MOSFET (FDC6506P) is required. In half-bridge configuration, only one channel is used.

The peak-to-peak drive voltage is referenced to VPWR and GND in half-bridge, and VPWR to –VPWR in full-bridge. Because of the lower voltage generated at the transducer, the open-top 40-kHz muRata MA40H1S-R is paired with the direct driver.

To enable the full-bridge driver for a bi-static transducer pair:

Step 1. Desolder the R35 resistor, which typically shorts the minus terminal of the transducer to ground.

Step 2. Solder a 0-Ω short at R34, which shorts the minus terminal of the transducer to the OUTB driver.

Step 3. Solder a 1-kΩ 0603 resistor at R30, which creates an OUTA based pulldown for the gate of the second channel of the p-channel MOSFET.

Step 4. Desolder the R32 resistor, which typically shorts the plus terminal of the transmitting transducer to the INP return path.

Step 5. Install the receiver sense transducer element to J11.

The decoupling feature is not available on the direct driven circuit of the daughtercard.

# 3 Software

## 3.1 Installation

Download and install the GUI from www.ti.com. Navigate to the default installation path of the executable file by clicking on the Windows *Start* button. Click on *All Programs* and then navigate to the Texas Instruments folder to find the PGA460Q1GUI application. Run the latest version of the PGA460Q1GUI.exe file. If the user must move the .exe file from the original install location, the USB2ANY.dll and Microsoft.VisualBasic.PowerPacks.Vs.dll files must be moved with the .exe to the same directory, otherwise, the GUI will fail to load.

## 3.2 Flash Program MSP-EXP430F5529LP

If the MSP-EXP430F5529LP has not been flash programmed with the required PGA460-Q1 EVM batch (.bat) firmware, the GUI will automatically prompt the user to do this at start-up, or after the MSP-EXP430F5529LP is plugged-in to the USB port.

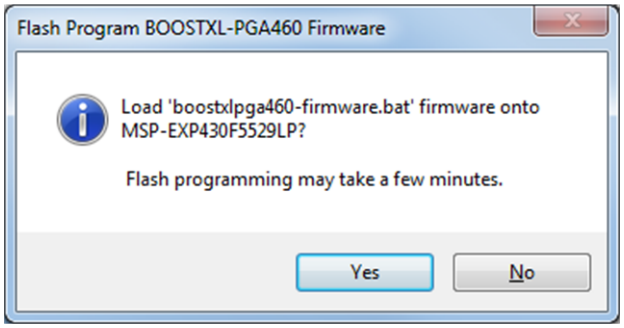



**Figure 5. Automatic Prompt to Flash Program MSP-EXP430F5529LP**

The GUI installs the *boostxlpga460-firmware.bat* file to the *My Documents* folder under the *PGA460-Q1 EVM* folder. The GUI runs through the command prompt to flash program the MSP-EXP430F5529LP. The MSP-EXP430F5529LP can be flash programmed manually from the GUI under the *File* menu by selecting *Flash Program* and then *MSP-EXP430F5529LP*. The file named *boostxlpga460-firmware.bat* in the default installation location must then be selected and run.

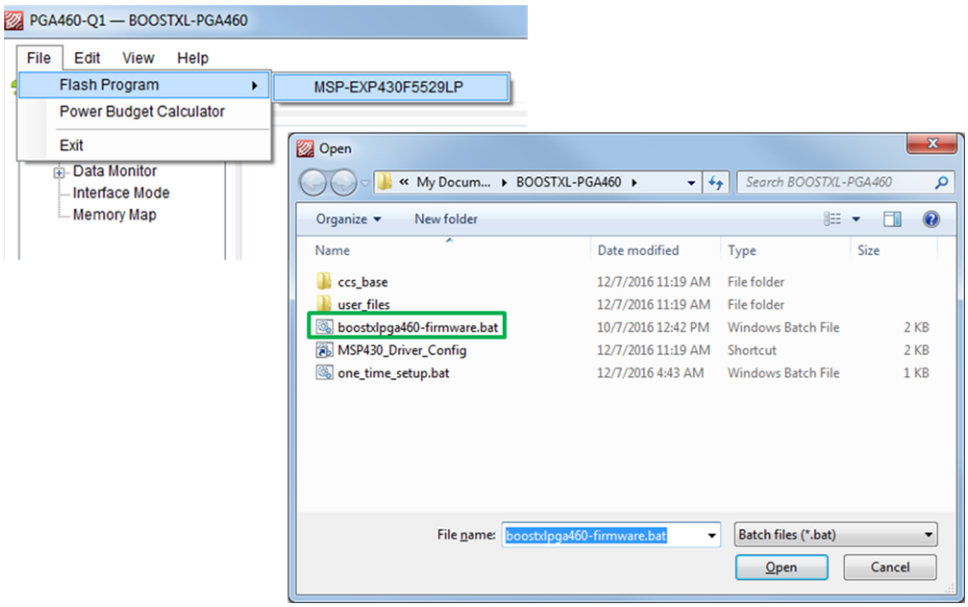



**Figure 6. Manually Flash Program MSP-EXP430F5529LP**

The MSP-EXP430F5529LP must be flash programmed only once, typically the first instance of connecting the MSP-EXP430F5529LP and running the GUI. The GUI does not prompt the user to reprogram the MSP-EXP430F5529LP until the flash memory is erased, programmed with different firmware, becomes corrupt, or does not allow the MSP-EXP430F5529LP to enumerate the USB2ANY host interface.

If the firmware batch file fails to install, ensure it is being run from the same directory containing the supporting folders, ccs_base and user_files. To ensure the Code Composer Studio™ software drivers are installed for the MSP430™ library, run the *one_time_setup.bat* file located in the *My Documents* under PGA460-Q1 EVM (although these drivers should have been previously installed by the PGA460-Q1 EVM install wizard).

The *boostxlpga460-firmware.bat* in *My Documents* is only compatible with a 64-bit operating system. For a 32-bit version of the *boostxlpga460-firmware.bat* file, navigate to the install path of the PGA460-Q1 EVM GUI, and unzip *pga460_fw_installer_32bit.zip*. When running the firmware installer in the PGA460-Q1 EVM GUI, select this version of the *boostxlpga460-firmware.bat* file instead.

### 3.3 PGA460-Q1 GUI Start-Up Screen

The PGA460-Q1 GUI enables users to quickly assess whether the EVM hardware is operational, explore the PGA460-Q1 device features, and modify the register configuration for optimal performance.

Figure 7 shows the default starting screen of the PGA460-Q1 GUI. If the EVM is connected properly, the screen should display the following EVM Status indicators in the bottom left corner of the GUI:

- USB controller: USB2ANY I/F Found
- USB firmware: 2.7.0.0
- Connection status: Connected
- PGA460-Q1 status: Ready

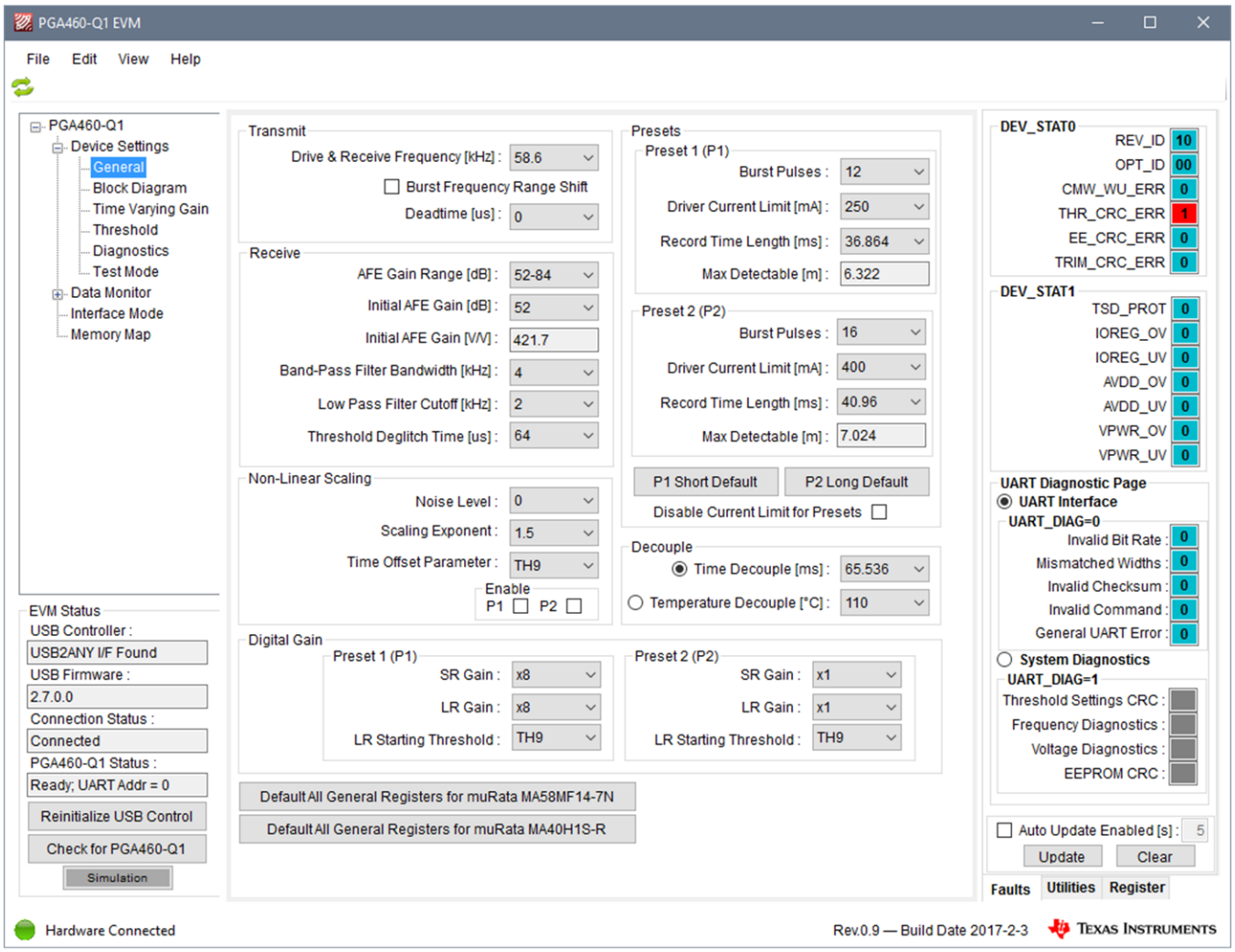



**Figure 7. PGA460-Q1 EVM GUI Starting Screen With Successful EVM Connection Status**

The default start-up GUI view is of the block diagram page, which provides a high-level perspective of the internal blocks and configurable features of the device. This perspective is intended to present which user-controlled settings are most important for proper device operation. A more detailed settings perspective can be found on the *General* page. When the settings have been properly adjusted for the specific driver mode and transducer combination, navigate to the *Data Monitor* page. The *Data Monitor* page displays the ultrasonic echo data dump and measurement results the user must optimize for a particular sensor configuration, environment, and target combination. The user can immediately click the *START* button from the *Run Options* group box to determine if the entire EVM is working. All pages and tabs of the GUI features are described in the sections that follow.

The GUI is partitioned into three panels: left, center, and right. The left and right panels are secondary panels for utilities, supporting tools, calculators, and background functions. The center panel displays and allows the user to update all device related pages.

## 3.4 PGA460-Q1 GUI Left Panel

The left panel of the GUI contains the listing of pages in a tree view format, and the current status of connectivity for the USB, motherboard, and daughtercard of the EVM.

### 3.4.1 Tree View Page Listing

To navigate between the various pages available on the GUI, the user must click on the corresponding node on the tree-view page listing. A total of twelve nodes are listed, and each loads a different page (see Figure 8 for an example).

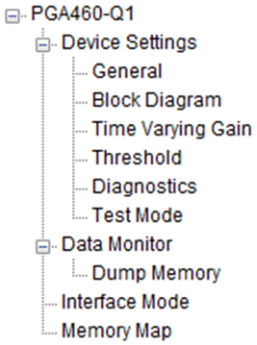



**Figure 8. Tree View Page Listing**

### 3.4.2 EVM Status

The GUI can automatically detect the presence of the MSP-EXP430F5529LP when flash programmed with the *boostxlpga460-firmware.bat* file. In the event of a successful, partially successful, or failed connection between the PC, MSP-EXP430F5529LP, and PGA460-Q1 EVM, the EVM status fields are updated according to Table 2.

**Table 2. EVM Status Possibilities**

| EVM Status | Success | Partial Success | Failure |
|---|---|---|---|
| USB Controller | USB2ANY I/F Found | USB2ANY I/F Found | Not Detected |
| USB Firmware | 2.7.0.0 | 2.7.0.0 | (blank) |
| Connection Status | Connected | Connected | Error or (blank) |
| PGA460-Q1 Status | Ready | N/A or Wrong Addr | N/A or Wrong Addr |

Table 3 lists a definition for each EVM Status field.

**Table 3. EVM Status Field Definitions**

| EVM Status | Definition |
|---|---|
| USB Controller | The MSP-EXP430F5529LP is programmed with TI's USB2ANY host interface (I/F) controller firmware. The GUI calls API functions for the USB2ANY to execute. The USB2ANY I/F is the only compatible USB controller for the PGA460-Q1 EVM GUI. |
| USB Firmware | The USB2ANY firmware can be updated for improvements or bug fixes. Version 2.7.0.0 is the only firmware version tested and known to be working for the PGA460-Q1 EVM GUI. |
| Connection Status | Typically, only one USB2ANY is connected to a PC, though the USB2ANY APIs are able to distinguish multiple USB2ANY devices on the same USB bus. For a single USB2ANY I/F, the status will read *Connected*, but for multiple, the status will read *Multiple Found. Using n*. TI advises that a single USB2ANY I/F be connected to your PC during the evaluation of the PGA460-Q1 EVM. |
| PGA460-Q1 Status | When a UART read command is successfully executed on the PGA460-Q1, the status will updated to *Ready*. At the GUI's start-up, a read command is attempted on all eight UART devices address options the PGA460-Q1 can be programmed to. The address of the detected PGA460-Q1 will be displayed in this status field. If the status reads back *N/A or Wrong Addr*, use the following checklist to troubleshoot:<br>• Is the BoosterPack correctly stacked on the LaunchPad?<br>• Is the PGA460-Q1 EVM powered with a voltage of 6 to 28 V?<br>• Is the power supply unit able to source at least 20 mA?<br>• Is the *Disable PGA460-Q1 EVM Communication* state set (Menu Bar → Edit)? This should be enabled to allow the GUI to operate correctly with the EVM.<br>• If the device was powered after the GUI was first initialized, click the *Check for PGA460-Q1* to retry the PGA460-Q1 check. |

In the event the GUI does not automatically detect the presence of the EVM, the *Reinitialize USB Control* button is available to manually check for the USB controller. When the USB controller is manually detected and successfully connected, the *Check for PGA460-Q1* button can be used to manually scan for a connected PGA460-Q1 device by issuing the aforementioned read command loop for every possible address.

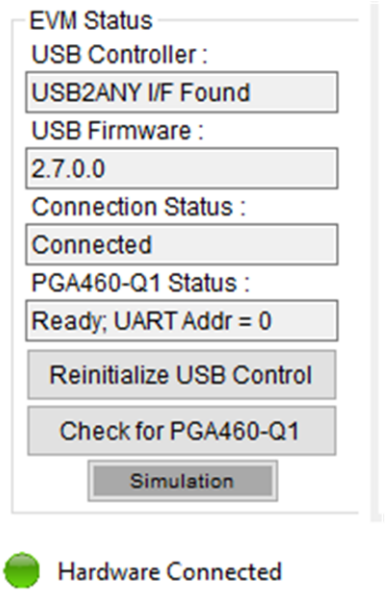



**Figure 9. EVM Status – Success**

In the event that no PGA460-Q1 EVM is connected, but the user is still interested in an example of the GUI configuration for a working device, the *Simulation* button will populate all controls with default values and allow the user to run the GUI with simulated results. The PGA460-Q1 Status field displays *Ready (Simulation)* when in simulation mode. When an actual PGA460-Q1 device is connected, the status updates automatically.

## *3.5 PGA460-Q1 GUI Center Panel*

The center panel is the primary interface for the user to configure the PGA460-Q1 device settings, read, write, and program device memory, and monitor the ultrasonic time-of-flight performance.

### 3.5.1 Device Settings

The device settings give the user access to the PGA460-Q1 user EEPROM and RAM, which includes driver strength, receiver sensitivity, time varying gain, time varying threshold, system diagnostics, and digital-signal processing controls. The device EEPROM is preprogrammed with generic settings for out-of-box performance, but requires optimization by adjusting the device settings.

### 3.5.1.1 General

The *General* page is the most critical page for the initial configuration of the PGA460-Q1 device. The *General* page must be updated according to the specific driver mode, transducer specifications, and maximum distance to detect (see Figure 10).

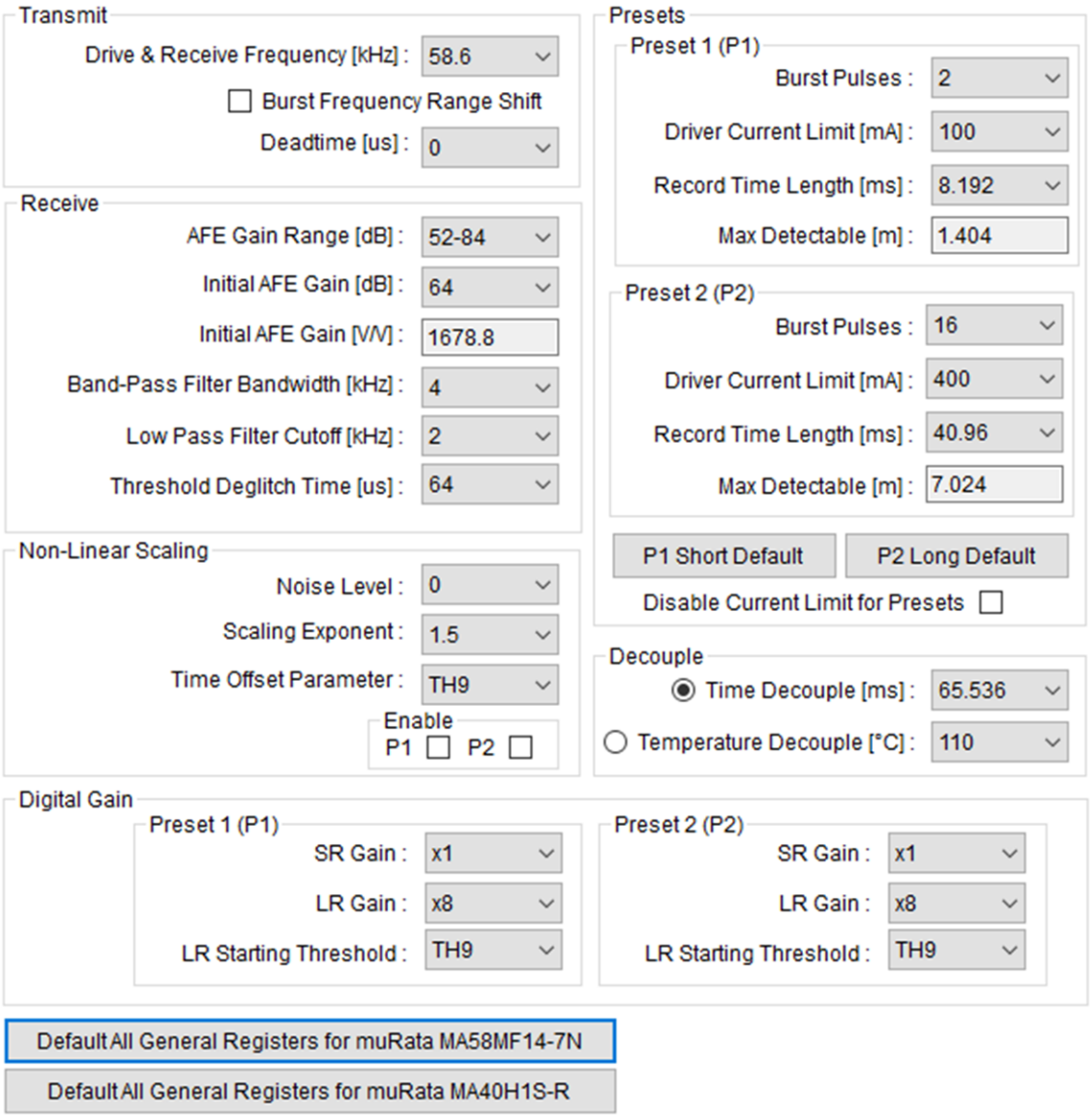



**Figure 10. General Settings Configuration Page**

The different sections on the *General* page are described as follows:

**Transmit —** Every transducer has a center frequency specification, and the driving frequency of the PGA460 must be set to the same value to effectively excite the transducer to generate the maximum sound pressure level. The PGA460-Q1 is compatible with transducers operating at a center frequency between 30-80kHz. The *Burst Frequency Range Shift* checkbox gives the user access to the high frequency range of 180 to 480 kHz. The dead time can be used for fine-tuning of the driver stage, and is only recommended for direct driven modes. The bandpass filter coefficients of the digital signal processing (DSP) are automatically calculated and updated when the frequency register is updated for the low-frequency range of 30 to 80 kHz. However, the high-frequency range will require the user to manually update the coefficients. The Utilities tab of the right panel includes a calculator to generate the coefficients.

**Receive —** The signal chain sequence of the analog front end (AFE) to the digital signal processor is represented from top-down selections of the Receive group. When the AFE Gain Range is shifted on the General page, the options on the Time Varying Gain page are also updated. The initial gain is set on the General page, but to set the entire Time Varying Gain range, go to the Time Varying Gain page. The band-pass filter bandwidth and low-pass filter cutoff frequencies are set in the Receive group. The threshold deglitch time is only applicable to the UART object timer and TCI-IO pin control, and is used to ignore any transients, minor noise, or small echoes that cross the threshold within the set deglitch time.

**Presets —** Two preset configurations can be saved to switch between two different use-cases for the same hardware configuration. A typical best practice is to allocate Preset 1 for short distance (between 30 cm to 1 m), and allocate Preset 2 for long distance (between 1 m to 7 m). The number of burst pulses and the driver current limit determines the drive strength of the transmitting signal. The driver current limit can be disabled, but is only recommended for high-frequency transducers or experimentation. The record time length determines how long the listen mode is active to capture and compute the ultrasonic data up to an equivalent distance.

**Non-Linear Scaling —** These settings are only recommended for applications where the noise floor is stable or repetitive. Nonlinear scaling can aid in setting the threshold for objects with weak echo amplitudes. The noise level determines which portion of the 8-bit data is truncated for each echo data point, the scaling exponent determines how large of a factor to multiply the existing data points by, and the time offset determines at which point on the record window the scaling is applied.

**Decouple —** Time decouple mode is intended to isolate the transducer from noise that potentially couples onto the primary windings of the transformer, which would be amplified on the secondary windings or transducer. Because the characteristics of a transducer can change across temperature, temperature decouple mode is intended to apply parallel capacitance to the transducer at a given temperature to retune the resonant frequency between the secondary transformer and transducer. Time and temperature decouple are only effective for the transformer driven mode. By default, the decouple feature is disabled when in time decouple mode and set to the maximum time delay.

**Digital Gain —** Digital gain is applied after the digital filtering stages of the DSP to determine which 8-bit segment of the 12-bit ADC output will be saved to the echo data dump registers or used for calculating the ultrasonic measurement results. Short range (SR) and long range (LR) controls are available in the event that a single preset is to be used to detect both short and long range objects (30 cm to 7 m). The short range gain applied as soon as the PGA460-Q1 begins recording data, and the long range gain is applied at the time equivalent of the starting threshold point 9-12.

The *Default All General Registers* button sets all general settings to TI recommended values, and can be used as a reference point when tuning these settings for a specific transducer.

### 3.5.1.2 Block Diagram

The block diagram representation of the PGA460-Q1 is a simplified view of the settings on the *General* page superimposed onto a visual equivalent of each device function. The block diagram perspective offers three control groups as shown in Figure 11.

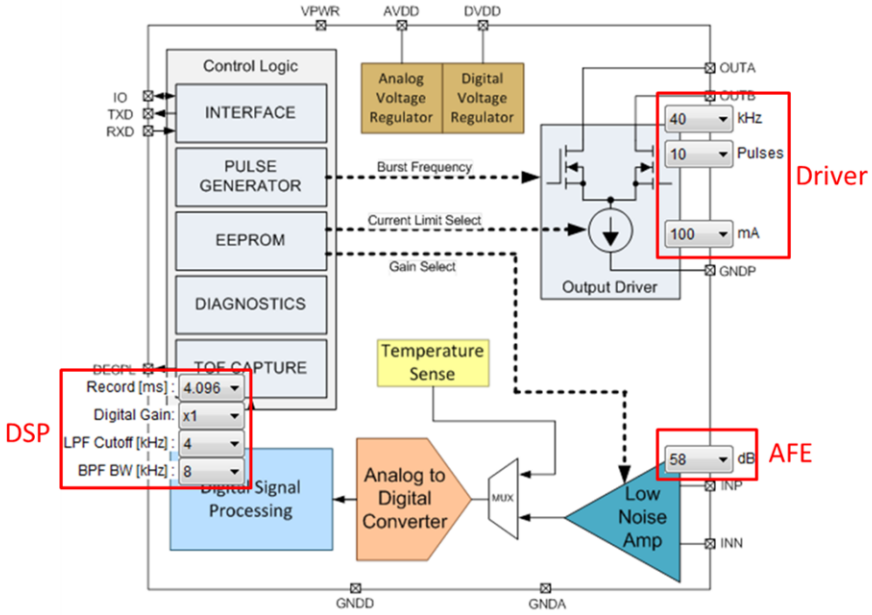



**Figure 11. Block Diagram**

These control groups are defined as follows:

**Driver —** The driving frequency, pulse count, and driving current limit are set with this group. This group is specific to the generation and transmission of an ultrasonic echo.

**AFE —** The gain selected on the block diagram view sets all levels of the time varying gain to the same gain level. This group is specific to amplifying the raw ultrasonic echo received.

**DSP —** The bandpass filter bandwidth, low-pass filter cutoff, short and long range digital gain, and record length are able to process the digitized ultrasonic echo received from the AFE.

Although the PGA460-Q1 has two presets, only Preset 1 is updated when configuring the device from the block-diagram control perspective. Preset 2 must be configured using the *General* page.

### 3.5.1.3 Time Varying Gain

The *Time Varying Gain* (TVG) page allows the user to configure the six gain timing deltas and levels that the programmable AFE applies to the received ultrasonic echo. Because the time varying gain is applied in the AFE and not the DSP block, both presets use the same TVG profile.

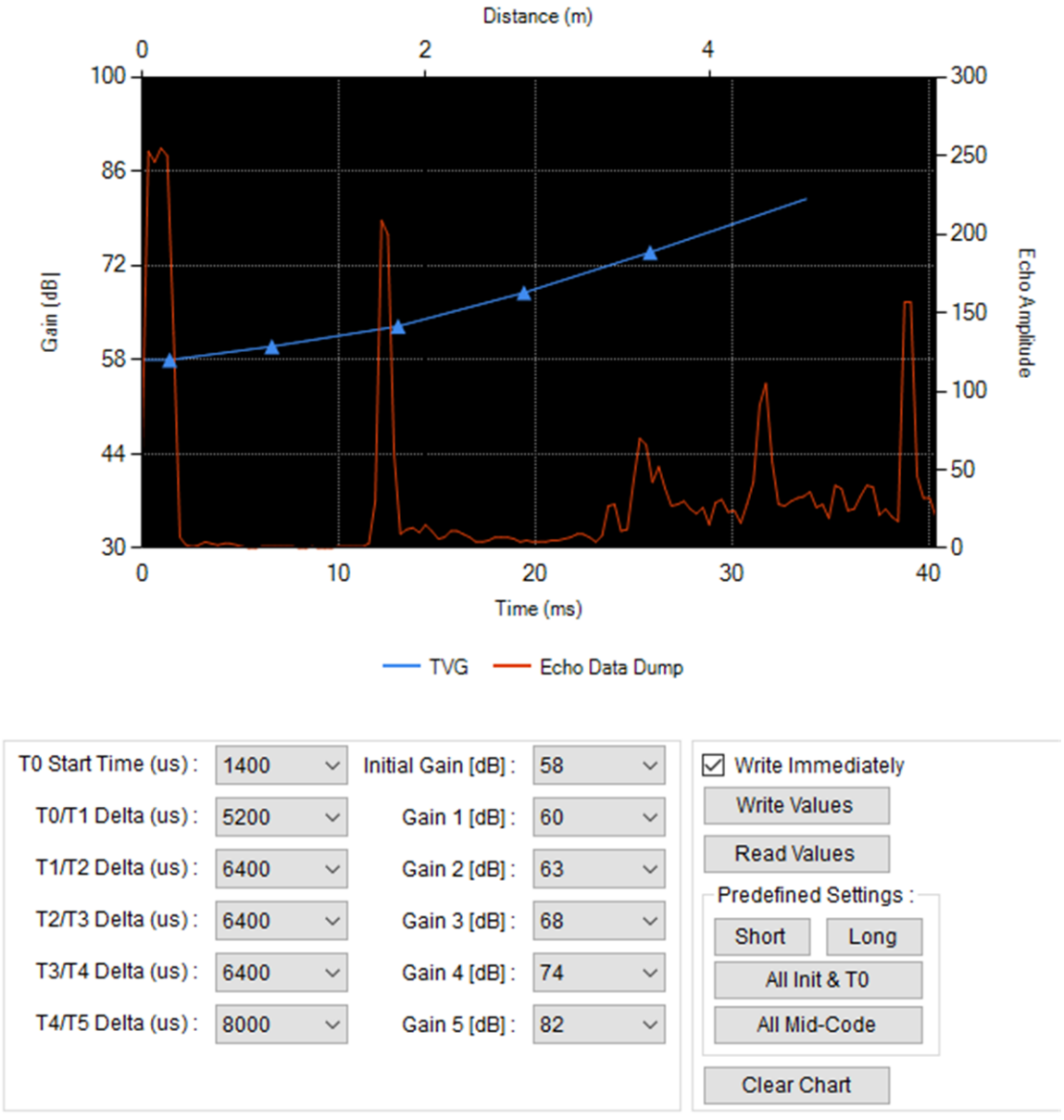



**Figure 12. Time Varying Gain Page**

The controls available on the *Time Varying Gain* page are as follows:

**T0 Start Time —** Expressed in terms of absolute time from the start of the record period.

**T*n*/T*n+1* Delta —** Expressed as a delta time between the absolute time of the previous TVG point and the absolute time value of the current TVG point.

**Initial Gain and Gain*n* —** Expressed in an absolute gain value in dB, and are unrelated from each other. The final gain assignment determined by the gain setting 5 will be kept constant until the end of the echo record time.

**Write Immediately —** Writes the updated time, level values, or both immediately after selection when checked.

**Write Values —** Manually writes all timing and level values.

**Read Values —** Manually reads all timing and level values. Updates the chart with the read values.

**Clear Chart —** Erases all data points on the TVG chart.

To suggest default or typical values, the Predefined Settings group allows the user to update the TVG with the best suited profile for initial testing, and as a reference to customize. This group is as follows:

**Short—** Writes generic TI recommended profile for object detection up to 1 m.

**Long—** Writes generic TI recommended profile for object detection beyond 1 m.

**All Init & T0—** Writes all timing values to T0 Start Time, and all level values to Initial Gain.

**All Mid-Code—** Write all timing and level values to the mid-code time and mid-code level for the selected AFE Gain Range.

**Load Chart—**A previously saved echo data dump plot can be loaded into the TVG page for offline or post time varying gain time and level configuration.

**Clear Chart —** Erases all data points on the TVG chart.

### 3.5.1.4 Threshold

The PGA460-Q1 threshold assignments are organized in two presets, Preset1 and Preset2. Both of these presets have an independent volatile SRAM memory map for threshold segment allocation. The PGA460-Q1 supports up to 12 threshold segments per preset defined by the threshold segment points (TSP). The threshold must be written to at least once after start-up to clear the threshold CRC error that is always flagged high on initialization. The threshold CRC error must be cleared before the PGA460-Q1 is allowed to execute a Burst & Listen or Listen-Only command.

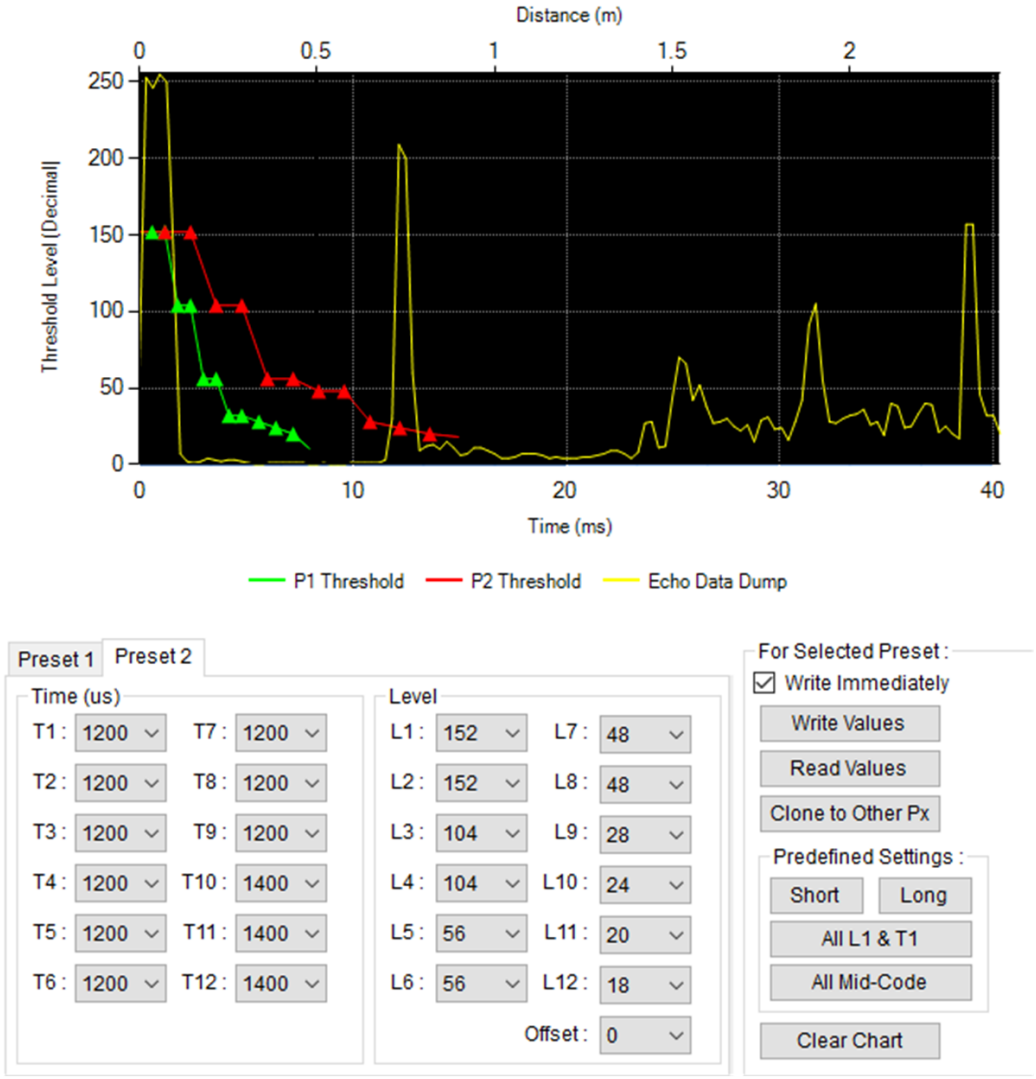



**Figure 13. Threshold Page**

The controls available on the threshold page are as follows:

**Time T*n* —** Only the Initial Segment Time (T1) parameter value is expressed in terms of absolute time, while all following TSP times are expressed as a delta time between the absolute time value of the previous TSP and the absolute time value of the current TSP.

**Level L*n* —** The level values of each threshold segment point are all expressed in an absolute LSB level value and are unrelated from each other.

**Level Offset —** Because the resolution on the threshold level parameters is 8 LSBs, a threshold offset is defined to fine-adjust the threshold map. This threshold offset the 5-bit threshold parameters (1 through 8). Parameters 9 through 12 do not need an offset as they are already 8 bits.

**Write Immediately —** Writes the updated time, level values, or both immediately after selection when checked.

**Write Values —** Manually writes all timing and level values.

**Read Values —** Manually reads all timing and level values. Updates the chart with the read values.

**Clone to Other Px —** If the user requires both presets to be identical, all timing and level values of the selected preset will be updated and written to for the other preset tab.

**Load Chart—**A previously saved echo data dump plot can be loaded into the threshold page for offline or post threshold time and level configuration.

**Clear Chart —** Erases all data points on the threshold chart.

**Copy to USER_DATA1-16—** The selected preset threshold time and level information is copied to USER_DATA1-16. This allows the threshold settings to be saved to EEPROM as an alternative to using the Memory Map's grid save feature. By saving a copy of the threshold to EEPROM, the information will always be available locally to the device. Only one preset's threshold details can be saved because there are only 20 USER_DATA registers, but 16 registers worth of threshold information per preset.

**Copy from USER_DATA1-16—** If a copy of the threshold details were previously saved to the USER_DATA EEPROM space, then the GUI will read the values from the USER_DATA space, and write them to the selected preset threshold.

Th Predefined Settings group is as follows:

**Short —** Writes generic TI recommended profile for object detection up to 1m.

**Long —** Writes generic TI recommended profile for object detection beyond 1m.

**All Init & T0 —** Writes all timing values to Time T1, and all level values to Level L1.

**All Mid-Code —** Write all timing and level values to the mid-code.

Automatic thresholding is available for users who require assistance in mapping the threshold times and levels based on the echo data dump data. The Auto-Threshold tab configure is described as follows:

**Noise Floor Margin—**The threshold level is set to the maximum downsampled value per window, rounded up to a multiplier of 8 plus the value of the noise floor margin. For instance, if the threshold timing is set to 300us, and the maximum value from the first 300us of the echo data dump is a value of 197, the level will be rounded-up to 200 plus the noise floor margin value. The noise floor margin is also a multiplier of 8. If the maximum downsampled value in a window is >=248 and <255, the threhsold offset of +6 is applied. If the maximum downsampled value in a window is >=255, the threshold offset is maximized to +7 to ignore the saturated echo data dump data.

**Threshold Timing—**The echo data dump is partitioned up to 12 windows for independent downsampling of the maximum value per threshold timing interval. If the existing threshold time values are to be used, check the Use Existing Timing box to prevent setting the threshold times to the same value.

**Apply Up to Thr—**By default, the auto-threshold algorithm is applied to all 12 threshold points. However, it is possible to only apply the algorithm to recalculate the time and level for a given number of threshold points, starting from point 1 of 12.

**Run Auto-Thresholding—** Runs the auto-threshold routine for the echo data dump of preset 1 or 2. Runs a burst/listen command prior to applying auto-threhsold algorithm if the Get New Echo Data Dump box is checked.

**Get New Echo Data Dump—**When checked, a burst/listen command is sent, and the echo data dump results for the preset 1 or 2 threshold mapping will be refreshed. If not checked, the last auto-thresholding algorithm is applied to the last set of echo data dump values.

### 3.5.1.5 Diagnostics

The PGA460-Q1 AFE implements system diagnostics for proper transducer monitoring during the burst and decay stage of the echo recording process as means to measuring the maximum voltage achieved, the frequency of oscillation, and the rate of ringing-decay at the transducer node.

The PGA460-Q1 device can implement a low-power mode where the current consumption is reduced to preserve system power. In the event of low-power mode, the threshold is reset upon wake-up, and must be rewritten to clear the threshold CRC error.

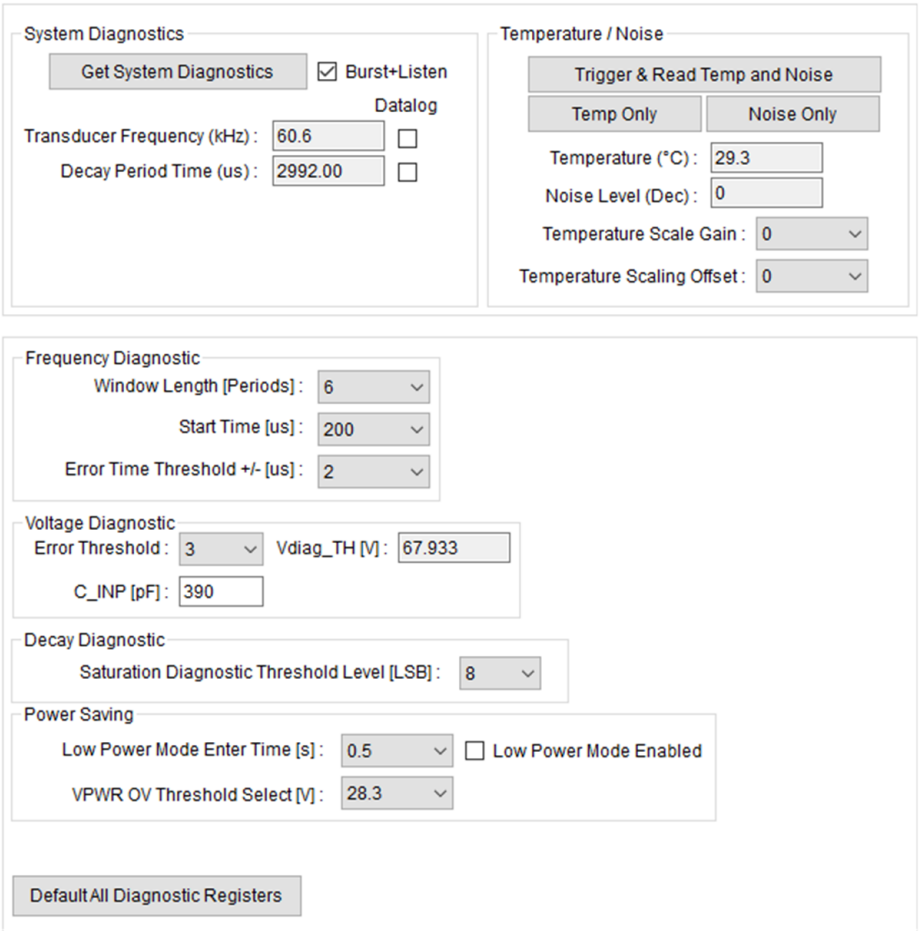



**Figure 14. Diagnostic Page**

The controls available on the *Diagnostic* page are as follows:

- System Diagnostics

  **Get System Diagnostics —** this button returns the results of the system diagnostics command based on the last burst-and-listen command issued.

  **Burst+Listen —** Selecting this option triggers a Burst and Listen command when clicking get system diagnostics to update the diagnostic values with the most recent results.

  **Datalog—** This option prints the checked system diagnostic values in the datalog viewer in the *Utilities* tab.

- Temperature / Noise

  **Temp Only —** The temperature digital data-path consists of a 16-sample averager and a scaling block. The 16-sample averager will average 16 temperature measurements arriving at a rate of 1 S/µs into one result to remove temperature measurement variations. The scaling block is used to adjust the gain and the offset parameter to better calibrate the temperature sensor. The temperature scale gain and offset are reserved for advanced calibration of the temperature sensor, and is only recommended for advanced users.

  **Noise Only —** During noise level measurement, the PGA460-Q1 device executes and returns the result of the *Receive Only (Preset 2)* command where no burst is performed; only a record interval is started and lasts 8.192 ms.

  **Tigger & Read Temp and Noise —** This button sequentially executes both the Temp Only and Noise Only commands.

- Frequency Diagnostic

  **Window Length Period —** The window length parameter sets the time width of the diagnostic window in terms of signal periods captured. The window length must be a non-zero value to enable the frequency diagnostic.

  **Start Time—** The start parameter defines the time when the frequency measurement starts relative to the end of burst time.

  **Error Time Threshold —** The value in this drop-down menu signifies that the measured transducer frequency is outside of the limits set by the threshold parameter. The result of this feature is reported in the status frames of the IO Time-Command or the UART interface.

- Voltage Diagnostic

  **Error Threshold—** A current corresponding to the voltage at the particular burst frequency is generated and comparted to a reference current. If the outputs exceeds the threshold limit, a comparator output, ILIM_CMP, on the digital core input goes high. If this output is detected high during the duration of the burst pulsing, it would imply a normal burst with the desired level of excitation voltage. If not, a corresponding error flag is set.

- Decay Diagnostic

  **Saturation Diagnostic Threshold Level —** The measurement starts at the same time when the burst stage is completed and the decay period is measured as long as the echo level is higher than a saturation threshold level defined in EEPROM by the SAT_TH parameter.

- Power Saving

  **Low Power Mode Enter Time —** Enter LPM mode after a period of inactivity.

  **Low Power Mode Enabled—** Enables the LPM timeout.

  **VPWR Over Voltage (OV) Threshold Select —** The input device supply on the VPWR pin defines an adjustable overvoltage level that keeps the device active while disabling the output driver. In this way, the output driver is not damaged over a certain voltage while controlling the power dissipated out of the device.

### 3.5.1.6 Test Modes

The *Test Modes* page contains the user controls required to both enable and route the PGA460-Q1 internal test modes and signals and to program or reload the EEPROM registers.

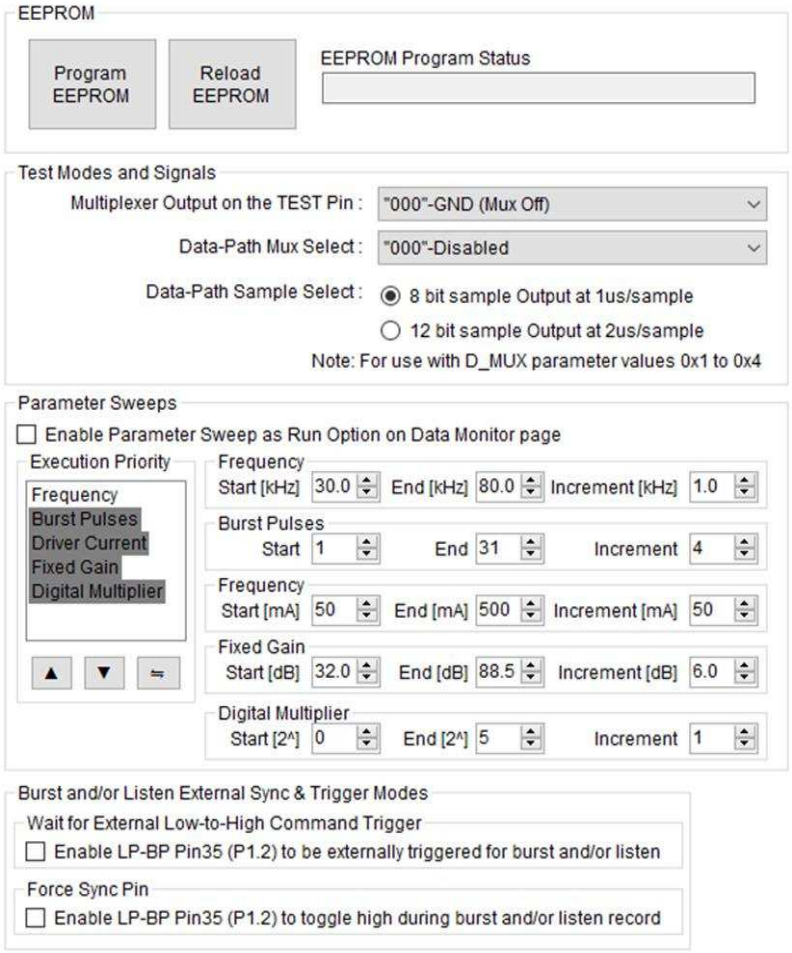



**Figure 15. Test Modes Page**

The internal signals on the TEST pin can be extracted by selecting a predefined signal through the internal test mux using the TEST_MUX register parameter. Table 4 lists the possible PGA460-Q1 internal signals that are output at the TEST pin.

**Table 4. Test Mux Signals**

| TEST_MUX Value | Signal Name | Type | Description |
|---|---|---|---|
| 0x00 | Hi-Z (Disabled) | Analog | The TEST pin is High Impedance |
| 0x01 | ASC Output | | Analog Signal Chain Output before ADC |
| 0x02 | "Reserved" | | |
| 0x03 | "Reserved" | | |
| 0x04 | 8MHz Clock | Digital | 8-MHz Clock Output from PGA460 for Synchronization when Synchronous Data Burst is used. |
| 0x05 | ADC Sample Clock | | 1-µs ADC sample Clock for Synchronization when Synchronous Data Burst is used. |
| 0x06 | "Reserved" | | |
| 0x07 | "Reserved" | | |

#### 3.5.1.6.1 Programming EEPROM

All of the write commands executed by the GUI write to shadow registers, not directly to the EEPROM. The shadow registers are referenced for all operations of the device. At start-up, the PGA460-Q1 device loads the shadow registers with the values stored in the EEPROM. If the PGA460-Q1 device is power cycled, the shadow registers are cleared and the shadow registers are reloaded with the EEPROM-based values.

To save the present values in the shadow registers to the EEPROM, click the *Program EEPROM* button to burn the values to the EEPROM. After the shadow registers have been burned to the EEPROM, the device keeps the most recently updated values prior to the power cycle.

To reload the EEPROM-based values to the shadow registers, click the *Reload EEPROM* button.

The threshold values are stored in RAM and cannot be burned to memory. The threshold values must be written to after every instance of the PGA460-Q1 power-cycle and start-up.

### 3.5.1.7 Parameter Sweeps

Optimizing device settings for a specific transducer for a particular range and target type will require sweeps of the various drive and receive settings. To help automate this process, the Parameter Sweeps block allows the user to sweep the range of interest for the driver and receive center frequency, burst pulse count, driver current limit, fixed time-varying gain, and digital gain multiplier. The execution priority of these settings can be set, and whether to omit a one or more parameters (grey highlight omits). Because the results are plotted and printed on the Data Monitor page, the data can be background exported such that the output file will be named with the specific parameter and value for identification. When the parameter sweep is completed, the device settings are reverted to what the values were prior to the sweep.

### 3.5.1.8 External Sync and Trigger

To synchronize the EVM-GUI with external devices or tools, the burst and/or listen command can be instructed to wait for an external low-to-high toggle on LP-BP pin 35, or toggle pin 35 high during the burst and/or listen command. If the PGA460-Q1 DECPL pin is not used for time or temperature decouple mode, it can be repurposed as a sync pin to indicate when the device is actively bursting and/or listening. When the DECPL pin is set to time decouple mode, and set to the equivalent value of the preset's record length timer, the DECPL pin will toggle high at the beginning of the burst, and toggle low when the record timer has expired.

### 3.5.2 Data Monitor

The *Data Monitor* page displays either the ultrasonic echo data dump, the ultrasonic measurement results, or both, depending on the preset configurations defined on the *General* page.

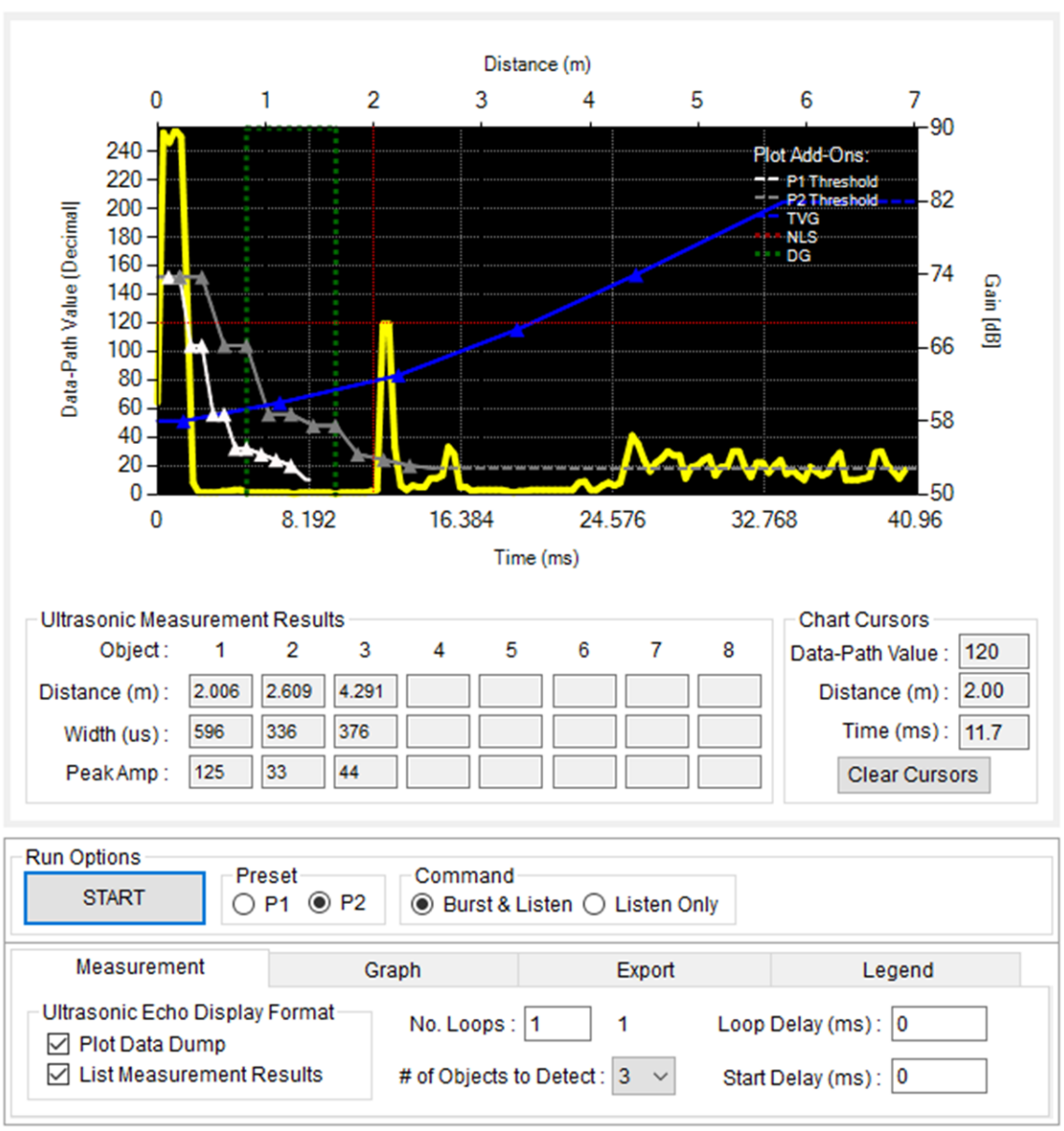



**Figure 16. Data Monitor Page—Working Example**

Before capturing ultrasonic echo information, ensure the following sequential checklist is reviewed:

- ❑ Point the transducer in the direction of the target, and minimize unwanted-reverberating reflections by clearing the transducers field-of-vision (FOV) from restricted spaces, clutter, or noisy test environments.
- ❑ Decide to initially use and configure either Preset 1 or Preset 2.
- ❑ Configure the Device Settings for the selected preset. As a minimum requirement, the user is responsible for setting the transducer specified frequency and record length. Set the record length to a value greater than the equivalent round-trip time to the target. For example, if your target is at 2m, the record length round trip time must be set to a minimum value of 12.288 ms (or 2.107 m). Use the *Time-of-Flight Converter* on the *Utilities* tab to determine what the minimum record time length must be for a target at any given distance.

When the hardware and device settings are configured, set the run options of the data monitor as shown in Figure 17.

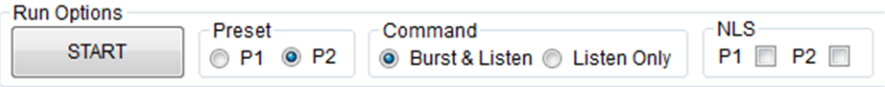



**Figure 17. Data Monitor—Run Options**

These settings are defined as follows:

**Preset —** Select Preset 1 (P1) or Preset 2 (P2).

**Command —** Select if a Burst & Listen command or Listen Only command will be issued.

### 3.5.2.1 Data Monitor Tabs

#### 3.5.2.1.1 Measurement

In addition to the *Run Options*, the *Measurement* tab determines how the data is either depicted, reported, or both (see Figure 18).

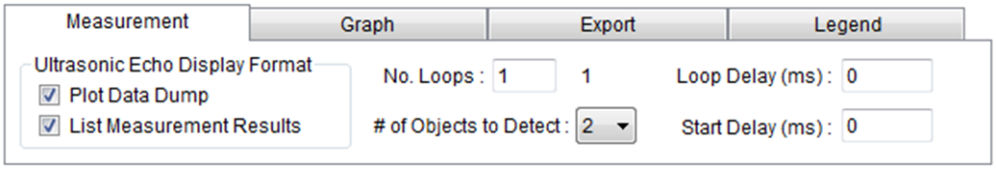



**Figure 18. Data Monitor—Measurement Tab**

These settings are defined as follows:

**Ultrasonic Echo Display Format —** Use this option to select if the ultrasonic echo should be displayed as a plot, listed as measurement results, or both options. If both the *Plot Data Dump* and *List Measurement Results* options are checked, a total of two independent and sequential run commands are issued in the background. The PGA460-Q1 device can only plot or calculate the ultrasonic measurement results, but not both for a single run command. For this reason, the plot and measurement results may not match 100% for every iteration.

**No. Loops —** The number of loops determines how many run commands are automatically issued to the PGA460-Q1 device by the GUI. To run an indefinite number of loops, set the value to 0.

**# of Objects to Detect —** The number of objects to detect is only required for the ultrasonic measurement results feature, and is used to calculate the distance, width, and peak amplitude based on when the threshold is crossed by the echo profile. The *Ultrasonic Measurement Results* table will only update the number of columns as a relation to the number of objects to detect. When the record time reaches the end of record defined by the record length parameter, but the number of objects to be detected is still not achieved, the undetected object locations are assigned a value of 0xFF. In case the number of objects to be detected is fulfilled before the end of record interval, the device interrupts the record cycle because the number of objects has already been detected and the device is ready to compute the ultrasonic measurement results.

**Loop Delay—** This field determines how much of a delay is added between multiple loop commands.

**Start Delay —** This field determines how much of a delay is added before the first command is issued.

#### 3.5.2.1.2 Graph

When using the chart of the data monitor to plot data, use the *Graph* tab to customize the display format (see Figure 19).

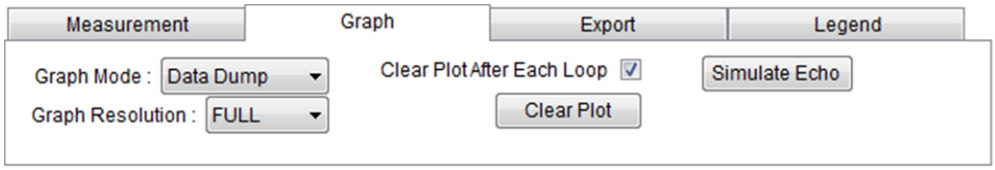



**Figure 19. Data Monitor—Graph Tab**

These settings are defined as follows:

**Graph Mode —** The default and recommend graph mode is a *data dump*, which is asynchronous USART based. Test modes are offered to route specific outputs of the digital signal processing block to the echo the data dump memory or UART timer. These DSP testmodes include: BPF, rectifier, and peakhold subblock outputs at synchronous USART rate of 8MHz. An alternative graph mode is *ADC* mode, which is an extension of the test mode to extract the output of the internal ADC at a synchrounous USART rate of 8 MHz. The ADC mode is recommend for advanced users and debug purposes only.

**Graph Resolution —** To plot all 128 bytes of the echo data dump, the FULL resolution is required. To reduce the graph resolution, and increase the update rate of the chart, ½ and ¼ resolution options are also available.

**Clear Plot After Each Loop —** When this box is checked, the plot always clears and updates with the most recent echo data dump extracted. When unchecked, the plot saves the history of previous echo data dump plots, and iteratively updates the plot with up to six different colors.

**Clear Plot —** Manually click this button to clear the chart of all echo data dump plots.

**Distance Decimal Places—**The threshold comparator is able to update the time-of-flight information for returning echoes crossing the threshold at a rate of 1us. This enables millimeter resolution when converted to a distance equivalent. Depending on the transducer frequency and accuracy requirement of the application, the user can select how many decimal places to show on the Ultrasonic Measurement Results table.

**Simulate Echo —** Clicking this button plots an example echo data dump profile based on the record length of the currently selected preset.

A cross-hair type cursor is available to allow the user the click anywhere on the chart to obtain the data-path value, distance (meters), and round-trip time (milliseconds).

#### 3.5.2.1.3 Export

To save the echo data dump and ultrasonic measurement results for post-review or analysis, the user has the option the export the data from the *Export* tab (see Figure 20).

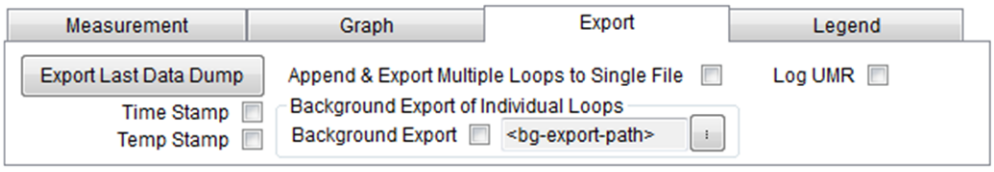



**Figure 20. Data Monitor—Export Tab**

These settings are defined as follows:

**Export Last Data Dump —** Click this button to export the most recent echo data dump plot as a text, CSV , or XML file.

**Time Stamp —** Use this option to append the date and time (down to the millisecond) for each loop of the exported text file.

**Temp Stamp —** Use this option to execute the temperature measurement command and append the temperature measurement result for each loop of the exported text file.

**Append Export Multiple Loops to Single File —** When this option is checked, multiple echo data-dump loop iterations are stored in temporary memory until the end of the loop count and then saved as a single text file.

**Background Export —** When this option is checked, the GUI automatically, and without prompts, saves individual text files for each loop to the user-specified directory.

**Log UMR —** Use this option to append the ultrasonic measurement results with a time stamp to the datalog monitor on the *Utilities* tab. The datalog can be saved as a text file.

**Save Chart Image—** Saves a .PNG screen capture image of the plot as shown on the Data Monitor page.

#### *3.5.2.1.4 Legend*

The echo data dump chart can be superimposed with plot add-ons to assist in the fine-tuning and visible representation of device features. By default, all plot add-ons are shown, but can be hidden to reduce clutter on the chart (see Figure 21).

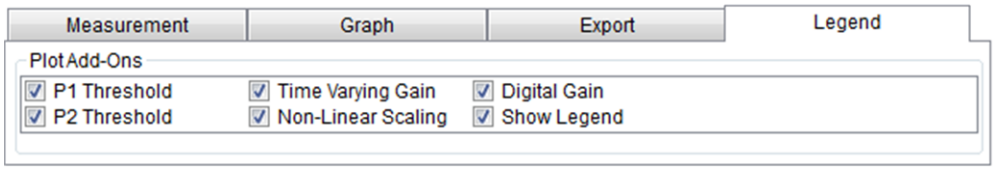



**Figure 21. Data Monitor—Legend**

The echo data dump chart can be superimposed with plot add-ons to assist in the fine-tuning and visible representation of device features. By default, all plot add-ons are shown, but can be hidden to reduce clutter on the chart.

### 3.5.3 Interface Mode

The PGA460-Q1 device offers three modes of communication to interface to a master controller. The three communication interfaces include asynchronous USART (or UART), one-wire UART, and TCI. A secondary communication interface is the synchronous USART mode, but is limited to executing a few commands, and is only recommended for advanced users or debugging. The UART interface was selected as the primary interface for the GUI because of the full-range of access, customization, and commonality of the serial communication format.

#### *3.5.3.1 Universal Asynchronous Receive/Transmit (UART)*

The PGA460-Q1 device includes a UART digital communication interface. The main function of the UART is to enable writes to and reads from all addresses available for UART access, including access to all user EEPROM register and RAM register memory locations on the PGA460-Q1 device. The UART digital communication is a master-slave communication link in which the PGA460-Q1 is a slave device only. The master device controls when data transmission begins and ends. The slave device does not transmit data back to the master until it is commanded to do so by the master.

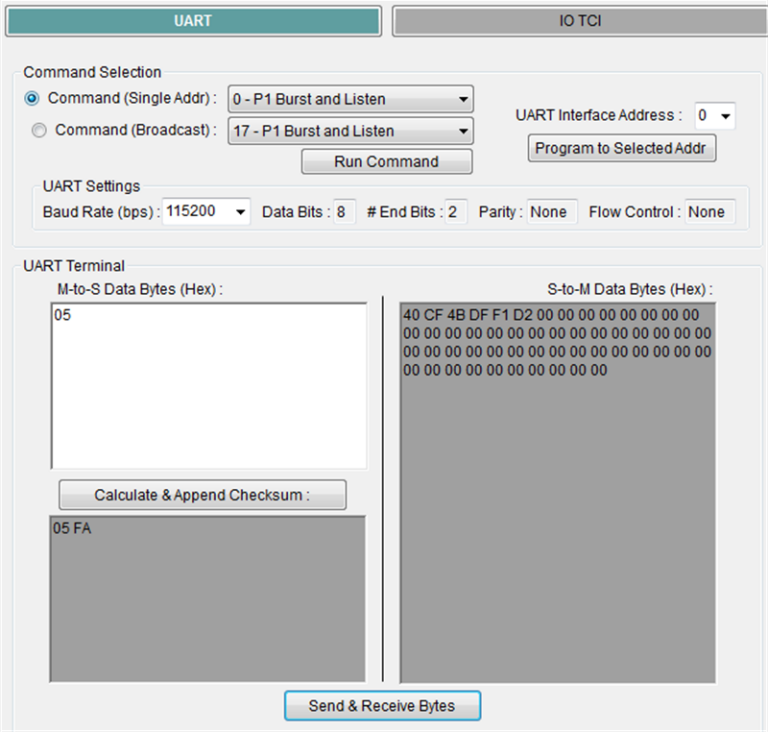



**Figure 22. Interface - UART Page**

The UART page contains elements to configure the PGA460-Q1 device address, select the baud rate of the master, and manually send and receive command data. The controls available on the *Diagnostic* page are as follows:

- Command Selection

  **Command (Single Addr) —** This option transmits the selected command to the specified UART interface address.

  **Command (Broadcast) —** This option transmits the selected command to all connected PGA460-Q1 devices simultaneously.

  **Command (Broadcast) —** This option executes the selected command from the single address or broadcast command selection, depending on which radio button is selected.

  **UART Interface Address —** This option is the PGA460-Q1 UART address that the master (GUI) attempts to communicate with.

  **Update Device to Selected Addr —** The address currently entered into the *UART Interface Address* drop-down menu is register-written to for the currently connected PGA460-Q1 device. This does not permanently save the new address into the UART_ADDR bit field. Use the EEPROM Program feature to overwrite the UART_ADDR in EEPROM memory.

- UART Settings

  **Baud Rate —** This drop-down menu includes a list of common serial communication rates that the PGA460-Q1 device is able to support. The master transmits and expects data to be returned by the PGA460-Q1 device at the selected rate.

- UART Terminal

  **M-to-S Data Bytes (Hex) [White] —** This text box is reserved for the user input for which the checksum is to be calculated for. The input string format requires each byte to be entered in hex and with a delimiter of either a space, comma, period, colon, or tab. The input is limited to 54 bytes. Do not include the 0x55 sync byte when attempting to calculate the checksum. An example of the input for command 1 with address 2 and three objects to detect is *41 03*.

**Calculate Append Checksum —** When clicked, the input of the white *M-to-S Data Bytes (Hex)* text box will be referred to as an input for the checksum calculator, and the result will be displayed in the grey *M-to-S Data Bytes (Hex)* text box.

**M-to-S Data Bytes (Hex) [Grey] —** This text box displays the output of the input string with the appending checksum. The hex string displayed in this box will be transmitted when the *Send & Receive Bytes* button is clicked.

**Send & Receive Bytes —** When this button is clicked, the hex string displayed in the *M-to-S Data Bytes (Hex)* text box will be transmitted to the PGA460-Q1 device. The 0x55 sync byte is automatically appended to the beginning of the hex string during the transmit routine. After the transmit routine, a read routine is executed to display the data returned by the PGA460-Q1 device. The output is limited to 54 bytes per click. For commands that return more than 54 bytes, clear the *M-to-S Data Bytes (Hex)* input, click the *Calculate Append Checksum* button, and click the *Send & Receive Bytes* button until all bytes have been read from the return buffer.

**S-to-M Data Bytes (Hex) —** This field displays the data returned from the PGA460-Q1 device after clicking the *Send & Receive Bytes* button. A maximum of 54 bytes can be displayed at a time.

### 3.5.3.2 Time Command Interface (TCI)

The time-command interface (TCI) is the communication interface connected on the IO pin. The default state for the IO pin when the interface is idle is HIGH (pulled-up to VPWR). The pin communication is bidirectional such that the PGA460 is actively driving the IO pin and providing a response by changing the state of the IO pin.

The GUI is primarily configured for UART evaluation. The TCI mode is offered as an alternative, but it does not grant access to all of the device or GUI features.

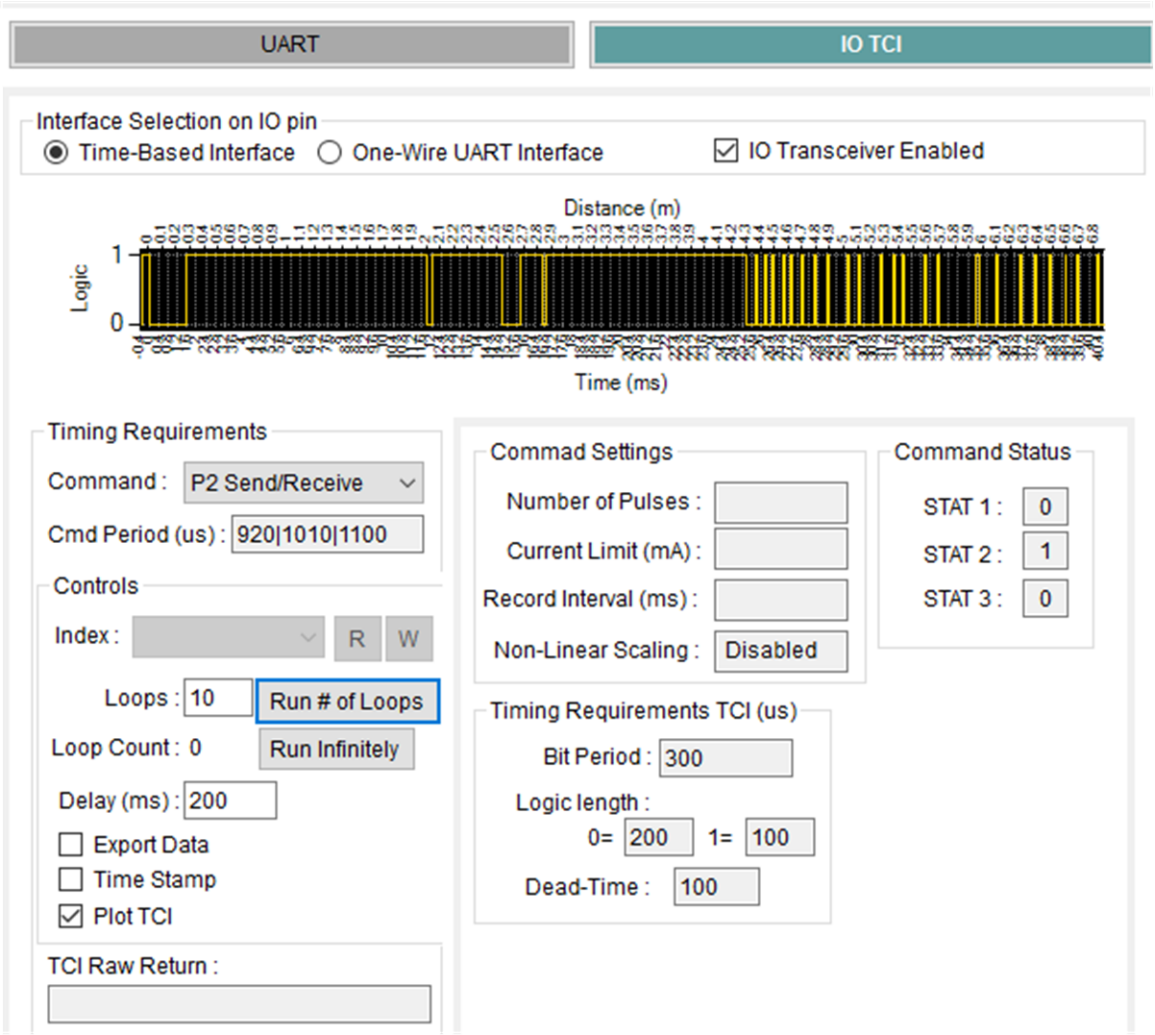



**Figure 23. Interface - TCI Page**

The *TCI* page can configure all of the user-space EEPROM and RAM register settings. The plot displayed the TCI pin status across time after a TCI command is issued. The display format is similarly to that of an oscilloscope capture, sampling every 12.5 µs. The controls and displays on the TCI page are as follows:

- Interface Selection on IO-pin

  **Time-Based Interface versus One-Wire UART Interface —** The IO pin shares two communication modes. Depending on the bit setting of IO_IF_SEL, the mode will be dedicated to time-based interface or one-wire UART. The one-wire UART Interface is not fully supported by the GUI to process the return data. Only data transmitted in one-wire UART mode is supported by the GUI.. If the *One-Wire UART Interface* radio button is selected, the user must power cycle the PGA460-Q1 device to re-enable GUI communication.

  **IO Transceiver Enabled —** When this box is checked, the IO pin can be used for communication.

**In-Sys IO Toggle —** The PGA460-Q1 device is factory programmed with the time-command interface enabled on the IO-pin. In a system where the end user uses the IO-pin in a one-wire UART mode, two possible options of enabling the one-wire UART interface on the IO-pin are available as follows. This button executes the IO-Pin Interface Toggle Pattern to switch between TCI and OWU as described in the second bullet.

- If access to the UART RXD and TXD pins is possible then the user can set the IO_IF_SEL bit to 1 in the EEPROM memory space and then execute an EEPROM program command to store the configuration for future use.
- If access to the RXD and TXD pins is not possible (assuming the end product has already been assembled) then the device can be toggled between interfaces by using the pattern on the IO-pin.

- Timing Requirements and Controls

**Command and Cmd Period —** These options allow the user to select which TCI command to send from the GUI master to the PGA460-Q1 slave device. Each command toggles the IO pin low for a given time as indicated in the *Cmd Period* text box in the form of minimum | nominal | maximum microseconds. Available commands include, *Preset 1 Burst & Listen*, *Preset 2 Burst & Listen*, *Preset 1 Listen Only*, *Preset 2 Listen Only*, *Device Configuration*, *Temperature Measurement*, and *Noise Measurement*.

**Index —** This drop-down menu is only enabled when Command 4 (device configuration) is selected. For every selected index, the read (R) and write (W) options are enabled, and the detailed register settings are displayed in the center-right panel.

**R/W —** For the selected index, issue a read or write command. When issuing a write command, the values selected on the register configuration page of the associated index is referenced. The *General* page is not referenced for any of the R/W TCI commands. Only the *Threshold*, *Time-Varying Gain*, and *Memory Map* pages are referenced externally by the TCI Page.

- Other controls:

**Run Options —** To run a command, click either the *Run # of Loops* button or *Run Infinitely* button. When running a fixed number of loops, the process can only be stopped if the number of loops in the user input box is less than or equal to the current loop count. When running infinitely, the user must click the *Stop Loops* button to end the TCI command process. An n-millisecond delay can be added between each TCI command issued, but is 0 by default to run the commands sequentially as fast as possible.

**Export Options —** The plotted TCI is used as the data point reference when exporting TCI data. To export data check the *Export Data* box. Additionally, a time stamp can be added between each data point.

**TCI Raw Return—** This field is only applicable to TCI command 4. When a read command is issued, the TCI binary string of 0 and 1 is printed in this box. If the return prints *TCI Read Fail. Retry…*, an issue probably occurred in the TCI connection or configuration of the PGA460-Q1 device. The GUI automatically attempts the TCI command issued three times before reporting the failure.

**Command Settings —** These options are only applicable to TCI commands 0 to 3. For the selected preset, the number of pulses, current limit, and record interval are listed.

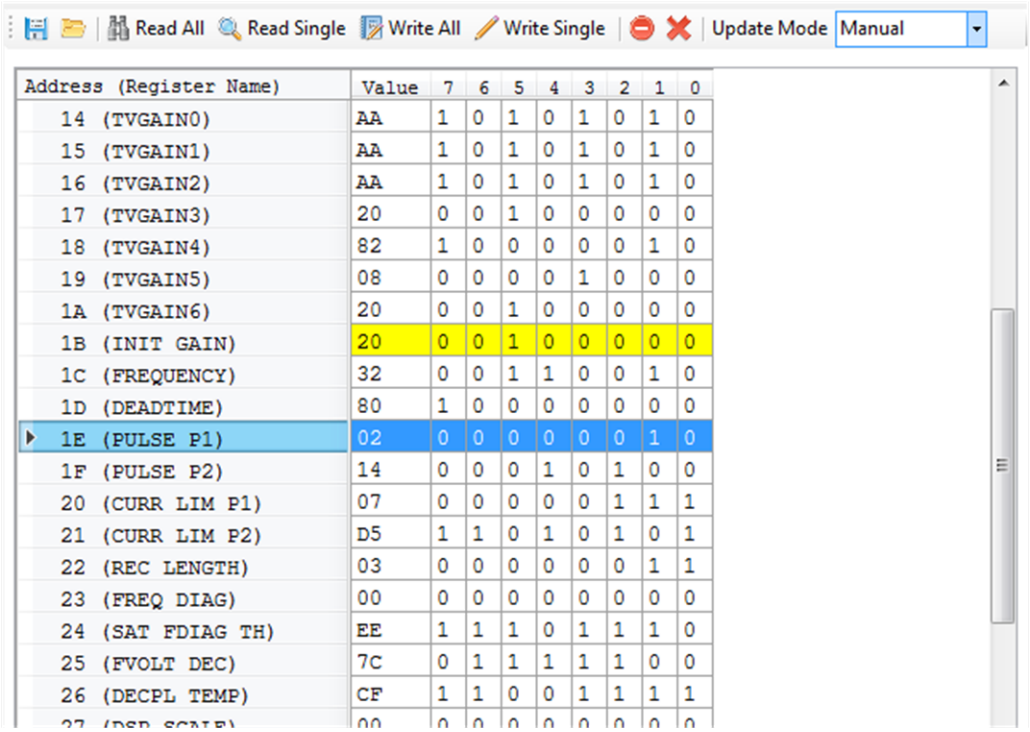
**Command Status —** These options are only applicable to TCI commands 0 to 3. If the preset *Burst & Listed* or *Listen Only* command is issued successfully, all STAT-n indicators read 0. If an error or fault exists, the STAT-n box reads 1. The command status fields are always provided for diagnostics and debug help.

**TCI Echo Results —** The time-of-flight to distance (meters) equivalent and echo width (microseconds) of return echoes are externally computed for up to four objects for comparison to the USART's Ultrasonic Measurement Results command. The results can be data-logged for post-processing and analysis to compare multiple burst and/or listen iterations.

For a detailed discussion on the timing parameters and commands of the TCI communication mode, refer to *PGA460-Q1 Ultrasonic Sensor-Signal Conditioner* (SLASEC8).

### 3.5.4 Memory Map

The memory map is used to read and write to all of the device registers. The memory map columns from left-to-right display the hex address and register name, the current 8-bit hex value of the register, and individual bit values.




| Address (Register Name) | Value | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|---|---|
| 14 (TVGAIN0) | AA | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 |
| 15 (TVGAIN1) | AA | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 |
| 16 (TVGAIN2) | AA | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 |
| 17 (TVGAIN3) | 20 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 18 (TVGAIN4) | 82 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 19 (TVGAIN5) | 08 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 1A (TVGAIN6) | 20 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 1B (INIT GAIN) | 20 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 1C (FREQUENCY) | 32 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 |
| 1D (DEADTIME) | 80 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1E (PULSE P1) | 02 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 1F (PULSE P2) | 14 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 |
| 20 (CURR LIM P1) | 07 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 |
| 21 (CURR LIM P2) | D5 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 1 |
| 22 (REC LENGTH) | 03 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 23 (FREQ DIAG) | 00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 24 (SAT FDIAG TH) | EE | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 |
| 25 (FVOLT DEC) | 7C | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 |
| 26 (DECPL TEMP) | CF | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 |

**Figure 24. Memory Map Page**

Table 5 defines the primary buttons at the top of the *Memory Map* page.

**Table 5. Memory Map Interactive Features**

| Function | Button | Description |
|---|---|---|
| Save Grid |  | Save the contents of the memory map grid to a text file. This option is useful for reusing predefined or previously configured register settings. |
| Load Grid |  | Load the compatible text file memory map grid, and update all *Device Setting* pages of the GUI. |
| Read All |  | Read all of the registers, and update all *Device Setting* pages of the GUI. |
| Read Single |  | Read the value of the currently selected register. |
| Write All |  | Write the current values listed in the table to all of the registers, including those that were not modified. Registers excluded from the *Write All* button include: EE_CNTRL, DEV_STAT0, DEV_STAT1 |
| Write Single |  | Write the value of the currently selected register. |
| Zero Grid |  | Set all register values to 0. |
| Deselect Grid |  | Remove all selections from the grid. |

To modify the values of the grid, the user can enter a hex value in the *Value* column or toggle the bit values in the bit-n column. To read and write the values, the user changes can be updated one of two modes:

**Immediate —** Whenever any of the memory map cells are changed, the GUI automatically writes to the modified register, and updates the associated pages *Device Setting* pages. This update mode is the default setting of the *Memory Map* page.

**Manual—** All changes applied to the grid are queued on the *Memory Map* page only. To update the PGA460-Q1 with the changes, the *Write All* or *Write Single* buttons must be clicked.

A row on the *Memory Map* page that is highlighted blue indicates a selected row. Only one row can be selected at a time. A row on the *Memory Map* page that is highlighted yellow indicates a queued modification to the grid, but a pending write to the PGA460-Q1 device. If multiple rows indicate queued changes are pending (multiple yellow rows), each row requires an individual *Write Single* click, or single *Write All* click.

For a selected row, the register details are listed in the *Register* tab of the right panel. For details about the *Register* tab, see Section 3.6.3.

## 3.6 PGA460-Q1 GUI Right Panel

The right panel of the GUI serves as a support panel to update the user of device faults, provide calculators and converters, log GUI activities, search register descriptions for keywords, and list the detailed description of a selected register of the *Memory Map* page. The right panel is not required to use the GUI. The option to collapse this panel is made available under the View settings in the menu. The right panel can also be resized manually.

### 3.6.1 Faults

The GUI monitors the device status by periodically reading back the device status registers. All status error bits must read 0 for the device to be in the normal or working state. If any of the status bits read 1, the a fault exists or the register map is corrupt and the device may not function properly.

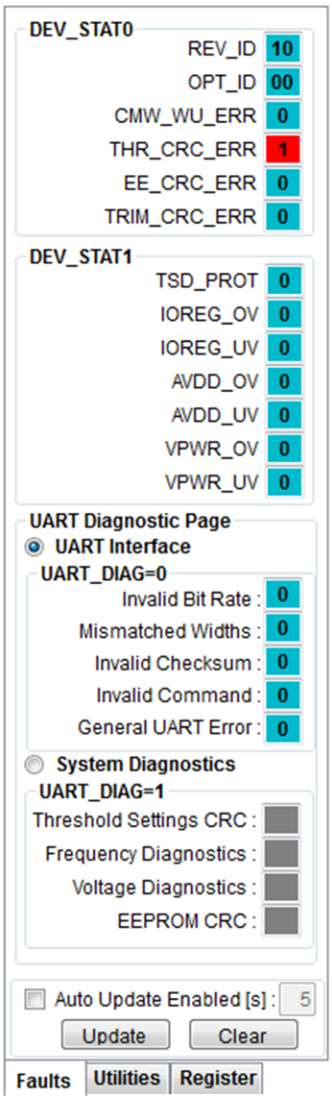



**Figure 25. Faults and Errors Tab**

Table 6 lists descriptions of the device error status bits.

**Table 6. Device Error Status Descriptions**

| Register Name | Field Name | Description |
|---|---|---|
| DEV_STAT0 | REV_ID | Device revision identification |
| | OPT_ID | Device option identification |
| | CMW_WU_ERR | 1 = Indicates that user tried to send a command before wake up sequence is done |
| | THR_CRC_ERR | Threshold settings CRC error status:<br>0 = No error<br>1 = Threshold CRC error |
| | EE_CRC_ERR | EEPROM CRC error status:<br>0 = No error<br>1 = EEPROM CRC error |
| | TRIM_CRC_ERR | Trim CRC error status:<br>0 = No error<br>1 = Trim CRC error |
| DEV_STAT1 | ILIM_OK | TBD |
| | TSD_PROT | Thermal shut-down protection:<br>0 = No Thermal shutdown has occurred<br>1 = Thermal shutdown action has occurred |
| | IOREG_OV | IOREG pin overvoltage status:<br>0 = No error<br>1 = IOREG overvoltage error |
| | IOREG_UV | IOREG pin undervoltage status:<br>0 = No error<br>1 = IOREG undervoltage error |
| | AVDD_OV | AVDD pin overvoltage status:<br>0 = No error<br>1 = AVDD overvoltage error |
| | AVDD_UV | AVDD pin undervoltage status:<br>0 = No error<br>1 = AVDD undervoltage error |
| | VPWR_OV | VPWR pin overvoltage status:<br>0 = No error<br>1 = VPWR overvoltage error |
| | VPWR_UV | VPWR pin undervoltage status:<br>VPWR UV measures 5.05 V<br>0 = No error<br>1 = VPWR undervoltage error |

The PGA460-Q1 device begins the response transmission with a diagnostic data field. This field contains UART communication error bits. If a particular bit is set to 1 then the associated communication error has occurred sometime between the last response operation and the current response operation. After a response operation is performed the communication error bits are cleared.

Table 7 lists descriptions of the diagnostic data error status bits.

**Table 7. PGA460-Q1 UART Diagnostic Data Description**

| Bit | UART_DIAG = 0 | UART_DIAG = 1 |
|---|---|---|
| Error status [0] | PGA460-Q1 Device Busy | |
| Error status [1] | Sync field bit rate too high (>115200 bps)<br>Sync field bit rate too low (>115200 bps) | Threshold settings CRC error |
| Error status [2] | Consecutive SYNC field bit widths do not match | Frequency diagnostics error |
| Error status [3] | Invalid checksum received from master (essentially a calculated slave checksum does not match the checksum transmitted by the master) | Voltage diagnostics error |
| Error status [4] | Invalid command sent from master | Logic 0 |
| Error status [5] | General communication error:<br>• SYNC filed stop bit too short<br>• Command filed incorrect stop bit (dominant when should be recessive)<br>• Command filed stop bit too short<br>• Data field incorrect stop bit (dominant when should be recessive)<br>• Data field stop bit too short<br>• Data field PGA460-Q1 transmit value overdriven to dominant value during stop bit transmission<br>• Data contention during PGA460-Q1 UART transmit | EEPROM CRC error or TRM CRC error |
| Error status [6] | Logic 1 | |
| Error status [7] | Logic 0 | |

After every UART command, the UART diagnostic bits are read. After every BURST and LISTEN command, LISTEN ONLY command, or register read or write, the error status bits of the device are updated.

### 3.6.2 Utilities

The *Utilities* tab offers additional tools to help the user search for and calculate values that pertain specifically to ultrasonic time-of-flight and the PGA460-Q1 device (see Figure 26).

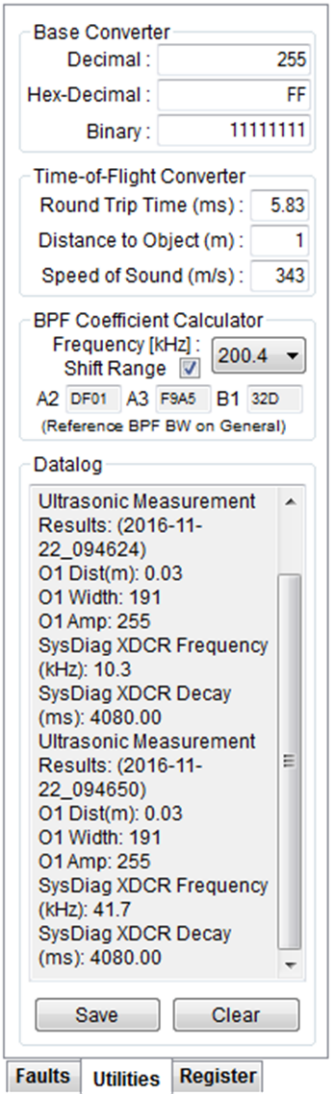



**Figure 26. Utilities Tab**

#### *3.6.2.1 Base Converter*

To convert between binary, decimal, or hexadecimal, the base converter allows the user to enter a value from one base and the GUI calculates the equivalent value for the other bases.

#### *3.6.2.2 Time-of-Flight Converter*

Because the PGA460-Q1 device is intended for use in time-of-flight calculations, the time-of-flight converter is used to compute a distance or round-trip time equivalent for the user input variable. Speed of sound is assumed to be 343 m/s at room temperature by default. The speed of sound can change across temperature and humidity.

#### 3.6.2.3 BPF Coefficient Calculator

The coefficient values of the band-pass filter (BPF) of the digital signal processing block are automatically calculated and updated by the PGA460-Q1 device for the low operating frequency range of 30 to 80 kHz. In the event the high-frequency range of 180 to 480 kHz is required, the PGA460-Q1 coefficient values must be updated manually to match the desired frequency and BPF width. Frequency and BPF bandwidth are the only variables that impact the coefficients. The calculator refers to the frequency selected form the drop-down menu of the calculator, but refers to the band-pass bandwidth set on the *General* page. If the BPF coefficients are updated manually for the high-frequency range, any change to the frequency or BPF width registers will reset the coefficients. Therefore, the coefficients must be updated after any change to these two registers. The GUI will automatically update the BPF coefficient values when the high-frequency mode is being evaluated. To force the BPF coefficient values as shown in the calculator, click the *Write Coefficients* button.

#### 3.6.2.4 Datalog

The *Datalog* can be used to record and track GUI activity, as well as print device information such as error status, diagnostic results, or ultrasonic measurement results. The contents of the *Datalog* section can be saved to a text file. The text file is saved with the term *datalog* and a date-time stamp in the "My Documents\ BOOSTXL-PGA460" directory.

### 3.6.3 Register

The *Register* tab is an expansion of the *Memory Map* page, and is only visible when the *Memory Map* page is selected (see Figure 27). If the *Register* tab is selected, the *Memory Map* page will load into the center panel.

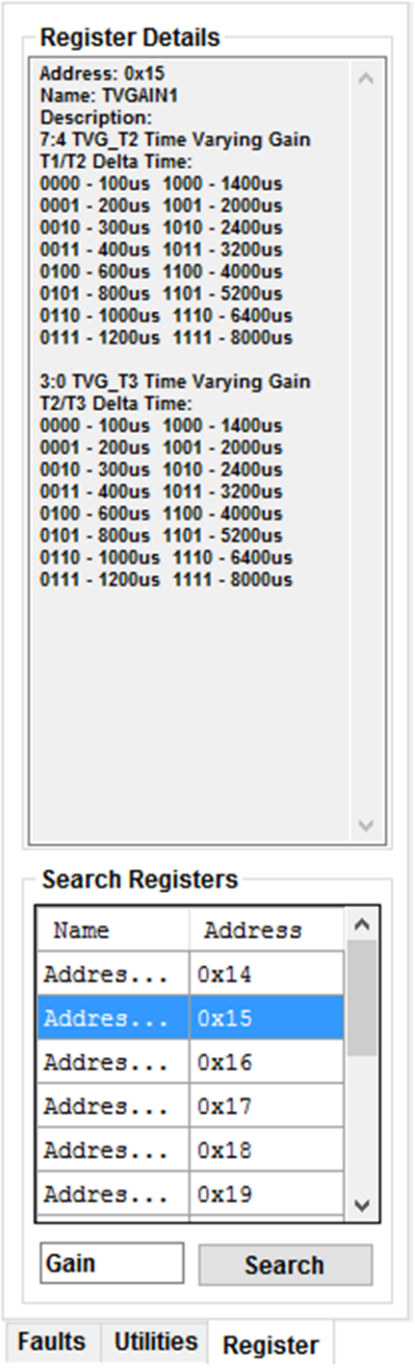



**Figure 27. Register Tab**

#### 3.6.3.1 Register Details

This tab displays the detailed register information for the selected memory-map register row. The operation, configurability, bit definitions, and related registers are described in this window. The Search Registers refers to the same detailed library that the *Details* window loads from.

#### 3.6.3.2 Register Search

The *Search Registers* function allows the user to type in a keyword which is then compared to a library of detailed register descriptions. The register address and full description containing the keyword will be listed as a result. Multiple registers may contain cross-references to the keyword and therefore multiple registers can be listed as results.

## 3.7 File Menu, Quick Access Menu, and Status Bar

### 3.7.1 File Menu

The *File* menu gives the user access to high-level GUI controls specific to the PC environment (see Figure 28). The different menu options are defined as follows:

- File

**Flash Program —** The user can manually force program the MSP-EXP430F5529LP by navigating to and selecting the appropriate batch file in the file explorer view.

**Power Budget Calculator —** The user can approximate the average power consumption of the PGA460-Q1 device by specifying the required device parameters, power modes, and command interval length.

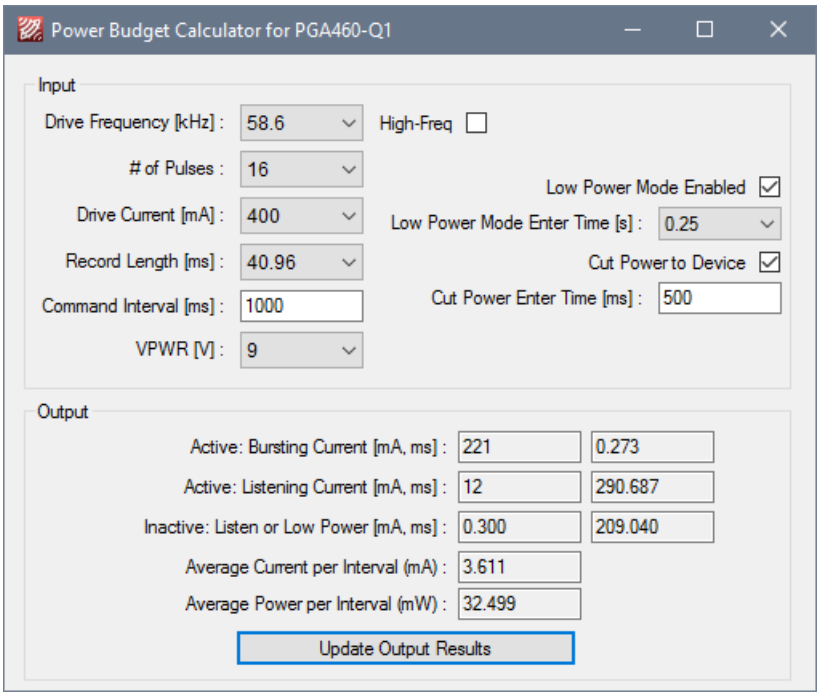



**Figure 28. Power Budget Calculator for PGA460-Q1**

**Data Plotter—** Echo data dumps exported from the Data Monitor page can be loaded into the Plotter for post-analysis, overlap, comparison, and averaging.

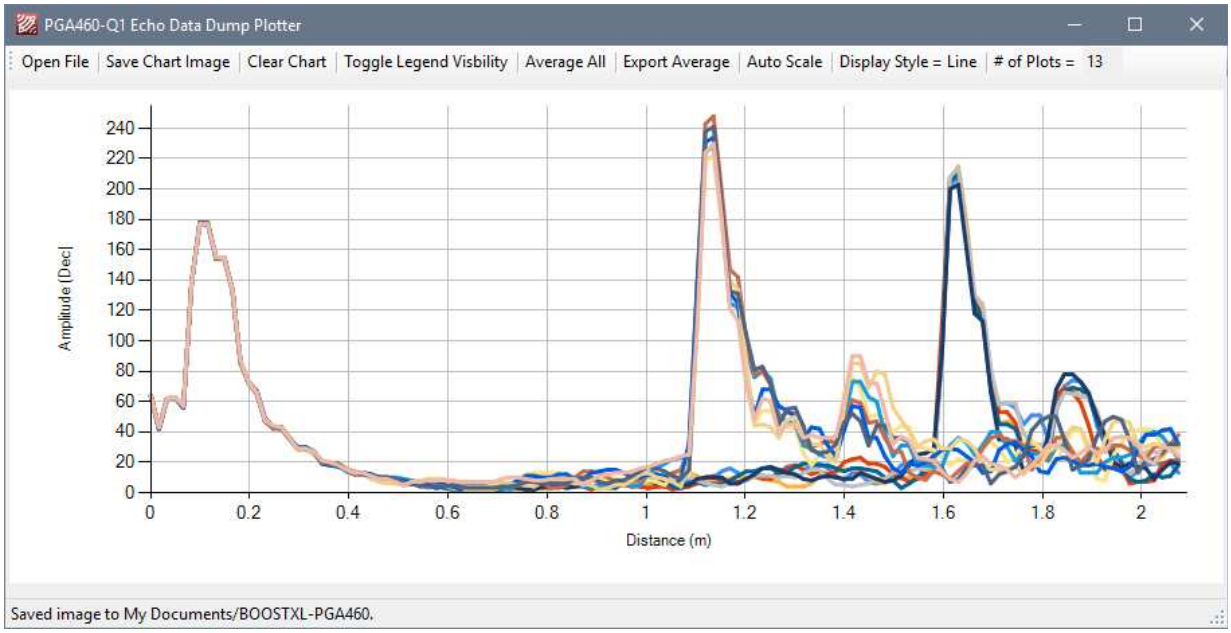



**Figure 29. Echo Data Dump Plotter for PGA460-Q1**

**Scripting—** The scripting tool is a text based method of controlling and automating all GUI functions. This can be helpful for running time consuming or looped measurements. The script input will run each instruction as sequentially listed in the Script INPUT window, and print the success state of command execution in the Script STATUS window. Refer to the HELP button in the Scripting window for a complete listing of the available commands.

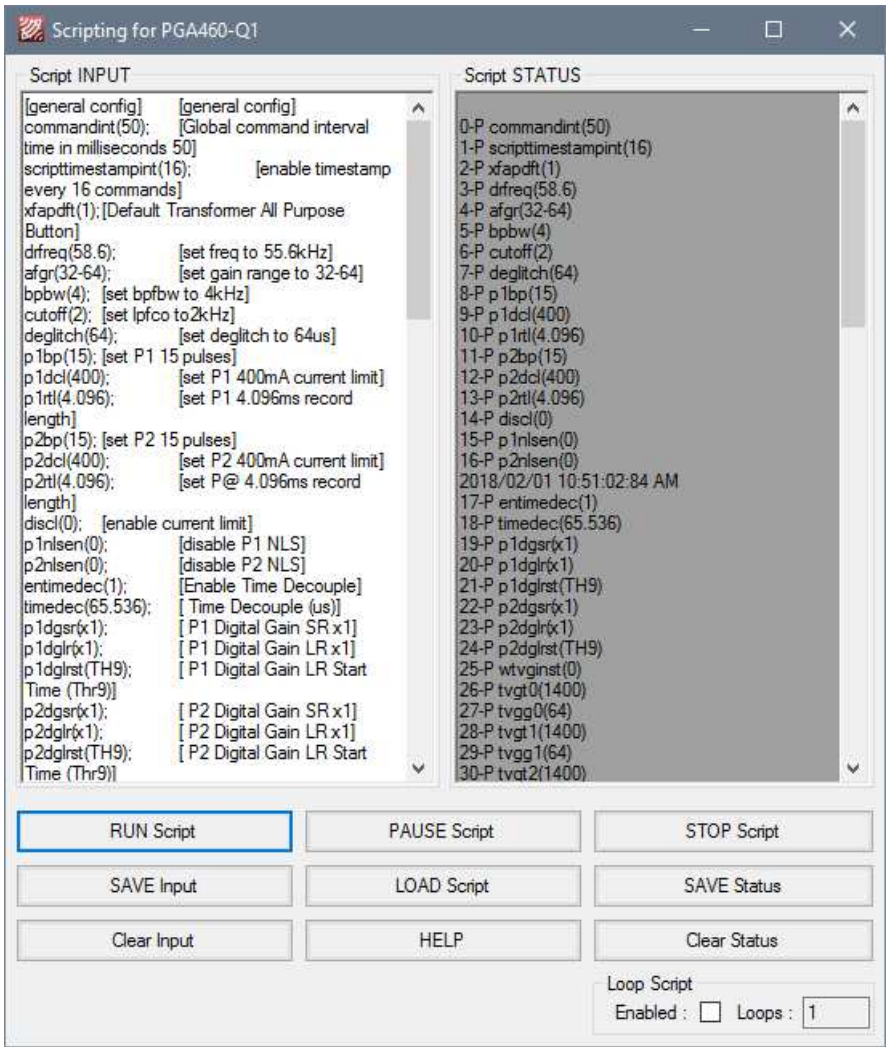



**Figure 30. Scripting for PGA460-Q1**

**Matching Daughtercard—** To optimize the passive component selection in parallel to the transducer, an EVM hardware extension called the BOOSTXL-PGA460-MATCHING daughtercard has been designed to sweep through typically tuning capacitor and damping resistor values to match the transducer to the driver (transformer or bridge). This feature will not work without the BOOSTXL-PGA460-MATCHING daughtercard hardware, which is available as a Design File on the PGA460-Q1 product page. The MATCHING daughtercard uses the LaunchPad's standard I2C port available on LP-BP pins 9 (P4.2) and 10 (P4.1) for SCL and SDA respectively. Connect the I2C port of the MATCHING daughtercard to the I2C pins on the BOOSTXL-PGA460 motherboard. On the motherboard, SCL is labeled as "MISO" and SDA is labeled as "MOSI" because the SPI port is shared with the I2C port. This is the only additional hardware connection required to operate the MATCHING daughtercard.

The tuning capacitor can be swept from 100pF up to 4800pF, and the damping resistor can be

swept from 100Ω up to 100kΩ. When the matching feature is enabled, the sweep will refer to the passive combinations in the queue, and sequentially execute a burst and/or listen command per combination. To continuously force a specific matching combination, select the values from the matching selection columns, and check the Force box. Custom ranges can be selected to auto populate the queue depending on the set step resolution.

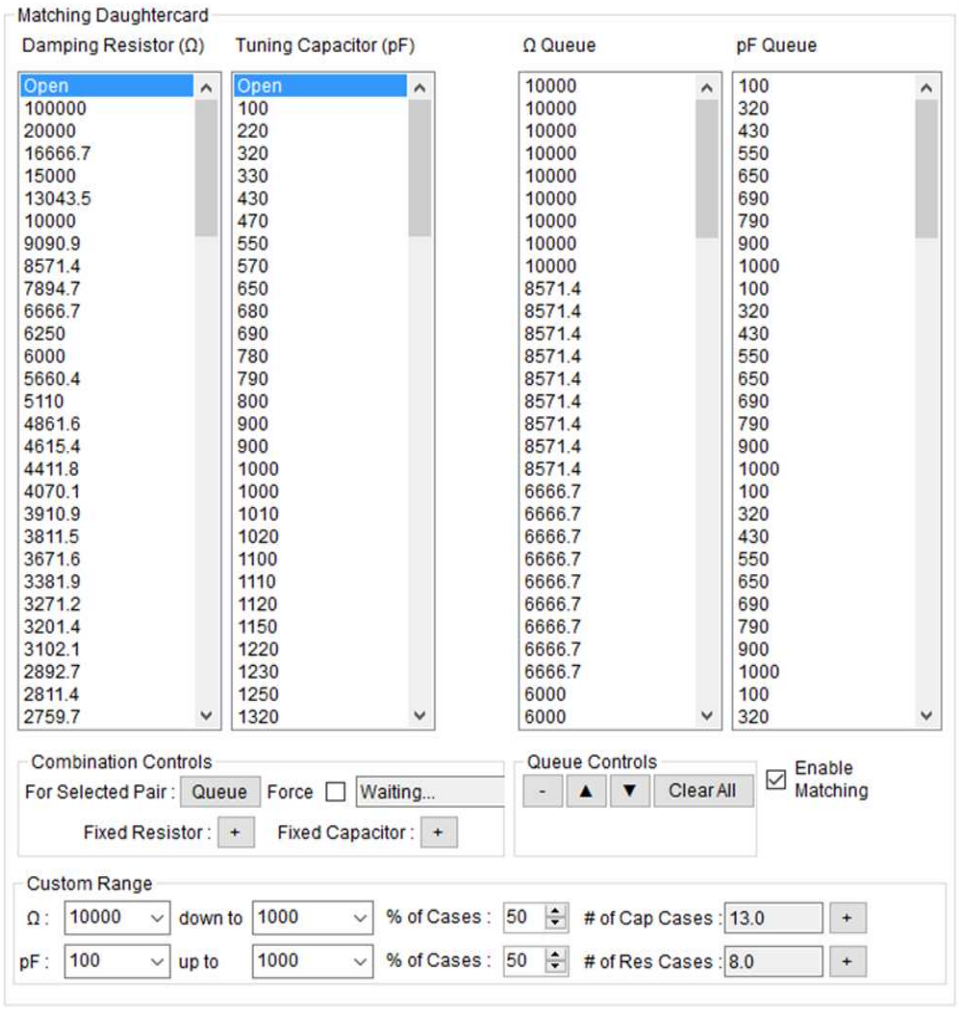



**Figure 31. Matching Daugthercard**

**High-Frequency BPF Coefficients—** The complete listing of high-frequency range (180k-480kHz) bandpass filter coefficient values is tabulated based on the bandpass filter bandwidth of 2, 4, 6, or 8kHz. These are the same values calculated by the BPF Coefficient Calculator.

**Exit —** This option disconnects the USB2ANY I/F from the GUI so that the I/F can be used by another instance of the GUI, or other program.

- Edit

**GUI Initialization Mode —** When the *BOOSTXL-PGA460 (Standard)* mode is selected, the GUI will initialize with the expectation of communicating to the PGA460-Q1 through UART. When the External IO-Pin Only mode is selected, the GUI will initialize with the expectation that an external module is connected to the BOOSTXL-PGA460 motherboard using IO-TCI and IO-OWU communication only. The onboard PGA460-Q1's IO transceiver should be disabled in this mode to prevent cross-talk or data collision between the onboard and external PGA460-Q1 devices.

**PGA460-Q1 EVM Communication —** Use this option to disable or enable communication to the PGA460-Q1 onboard the PGA460-Q1 EVM. All communication interfaces are routed through an electronically controlled switch on the PGA460-Q1 EVM. When disabled, the communication transmit commands from the master remain MSP-EXP430F5529LP active, but the PGA460-Q1 will not receive the command.

**OWU & Synchronous Hardware —** When disabled (default), the MSP-EXP430F5529LP UART port is routed through the TS3L501ERUAR to the PGA460-Q1 UART TXD and RXD pins, the PGA460-Q1 SCLK pin is grounded, and the SPI port is routed to the OWI Transceiver circuit for IO-TCI communication. When enabled, the MSP-EXP430F5529LP UART port is routed to the OWI Transceiver circuit for IO-OWU communication, and the SPI port is routed to the PGA460-Q1 USART TXD, RXD, and SCLK pins.

- View

  **Right Panel —** The support tabs in the right panel can be made visible or hidden.

- Help

  **Datasheet —** This option includes a hyperlink to the online-PDF version of the data sheet. If no internet access is detected, the data sheet will load from the install directory.

  **Collateral —** This option includes a hyperlink to the online product page for the PGA460-Q1.

  **About —** This option includes details regarding the revision history of the GUI and assembly information.

  **Check for Updates —** This option includes a hyperlink to the online software development page of the PGA460-Q1. This option also checks if the GUI version online matches that of the running GUI.

### 3.7.2 Quick Access Menu

The Quick Access menu refresh application option is defined as follows:

**Refresh Application —** To refresh the GUI in the event of an error, or hardware change, click the *Refresh Application* button to ensure the proper settings are populated into all GUI fields.

### 3.7.3 Status Bar

The status bar updates the user of all activity and status changes of the EVM hardware. If the hardware is connected, the status bar will include a virtual green LED to indicate that the EVM is operating correctly, and that a PGA460-Q1 device is detected. If the virtual LED turns red, either the EVM hardware has disconnected, or a PGA460-Q1 device was not detected.

# 4 External PGA460-Q1 Evaluation

This section provides a detailed description on connecting external PGA460-Q1 devices to the PGA460-Q1 EVM to reuse the PGA460-Q1 EVM GUI.

## *4.1 External PGA460-Q1 Module Compatibility and Connections for IO Communication*

When the user has completely evaluated the PGA460-Q1 EVM and GUI, the next step typically involves evaluation of custom hardware. Instead of using the BOOSTXL-PGA460, the user may build a custom small or system form factor module with the intention of continuing device evaluation using only the PGA460-Q1 GUI. Examples of small form factor PGA460-Q1 reference designs are available on www.ti.com. By detaching the BOOSTXL-PGA460 from the PGA460-Q1 EVM, the MSP-EXP430F5529LP can still be used as the master controller and interface to the PGA460-Q1 GUI through logic level USART. However, if the supply-voltage TCI or OWU interfaces are to be routed to the external PGA460-Q1 module, the BOOSTXL-PGA460 motherboard is required, and additional register modifications must be made to the onboard PGA460-Q1 device.

### 4.1.1 IO Transceiver Circuit

The PGA460 device onboard the BOOSTXL-PGA460 is always connected to the One-Wire Interface (OWI) IO transceiver circuit. To prevent cross-talk or data collision between the onboard and external PGA460-Q1 devices, the user has two options:

- **Software Modification**: Disable the onboard PGA460-Q1's IO pin transceiver before connecting the external module. To do so, the IO_IF_SEL bit must be set to 0, and then the IO_DIS bit must be set to 1, which immediately disables the IO pin transceiver. After applying these register modifications, communication to the onboard PGA460-Q1 is only possible through the RXD, TXD, and SCLK pins. To ensure the IO transceiver of the onboard PGA460 remains disabled upon power-cycle, EEPROM program the device to save IO transceiver settings. Now the BOOSTXL-PGA460's J6 connector block containing VPWR, IO, and GND can be used to connect a three-pin external module. As an additional precaution to eliminate any potential cross-talk or data collision between the onboard and external PGA460-Q1 devices in OWU mode, set different UART_ADDR values. TI recommends that the onboard PGA460-Q1's UART_ADDR be set to a value of 0x7, to allow the external PGA460-Q1 to use the default factory address of 0x0.
- **Hardware Modification**: De-solder the R15 0-Ω short which typically connects the OWI transceiver to the onboard PGA460-Q1 device's IO pin. Now the BOOSTXL-PGA460's J6 connector block containing VPWR, IO, and GND can be used to connect a three-pin external module. This hardware-only modification is required for IO-TCI communication. However, when using IO-OWU, different UART_ADDR address values can be used to differentiate between the onboard and external PGA460-Q1 devices.

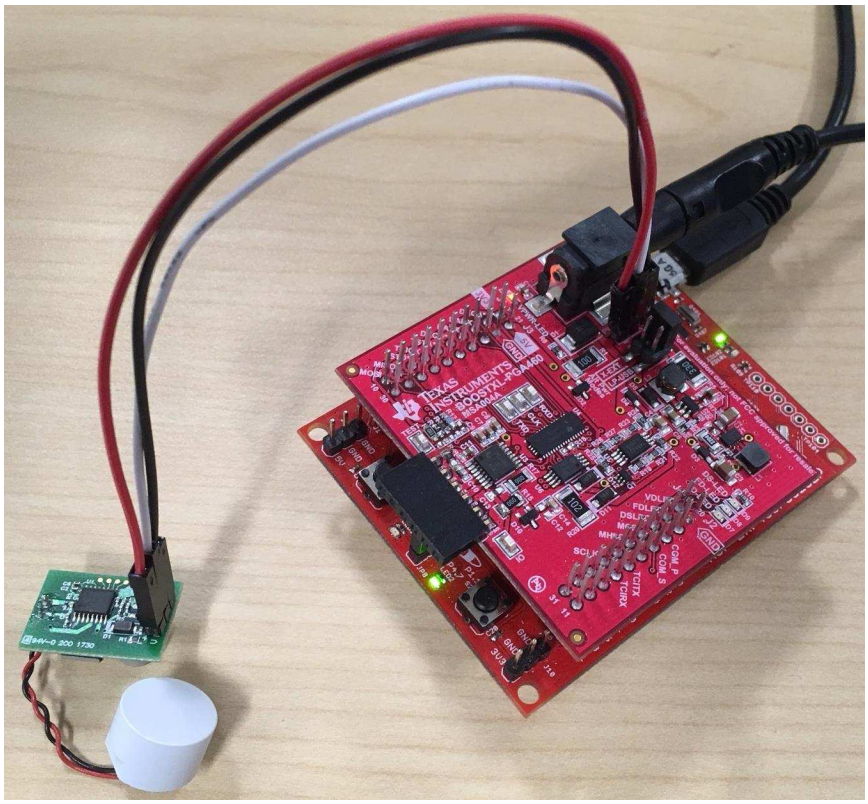


**Figure 32. External OWI Evaluation Setup for PGA460Q1USFF-XF Module With Software Modification**

Alternatively to using the BOOSTXL-PGA460's One-Wire Interface transceiver circuit, an external OWI transceiver circuit can be connected to the MSP-EXP430F5529LP. The discrete OWI transceiver circuit on the BOOSTXL-PGA460 allows OWU to operate up to 115.2kBaud. For solutions that only use TCI or OWU at 19.2kBaud or less, the SN65HVDA100-Q1 LIN Physical Interface can be used as an integrated OWI transceiver solution.

### 4.1.2 One-Wire Evaluation Page

When using the BOOSTXL-PGA460 OWI transceiver for evaluation of an external module, the PGA460-Q1 EVM GUI can be enabled to display a page specific to external OWI evaluation. This OWI Evaluation page uses the in-system IO-pin interface selection toggle pattern to constantly switch between TCI and OWU modes to maximize the speed of OWI evaluation. TCI mode is used strictly for real-time IO toggle-response object detection, while OWU is used for all other register read and write features. Considering that TCI communicates at a speed equivalent to 3.3kBaud, OWU operating at 115.2kBaud is more suitable for register read and write commands. The benefit of using the OWI Evaluation page is that all device settings are made available on a single page to prevent the need to switch between multiple pages. This advanced condensed view of all device settings assumes the user is familiar with the features, thus details are limited to conserve space on the page.

To enable the OWI Evaluation page, navigate to the top of the GUI's menu bar. From the Edit drop-down, the *GUI Initialization Mode* will be set to *BOOSTXL-PGA460 (Standard)* by default. Change this selection to *External IO-Pin Only*. The GUI will then prompt the user to automatically apply the onboard IO transceiver software modifications described in section Section 4.1.1. If you have not applied any onboard IO transceiver modifications, follow the GUI's instructions, and click Yes. If you have applied the appropriate modifications, click No. Once all register changes and hardware connections are ready, the GUI will automatically restart or be manually restarted to reveal and initialize to the OWI Evaluation page.

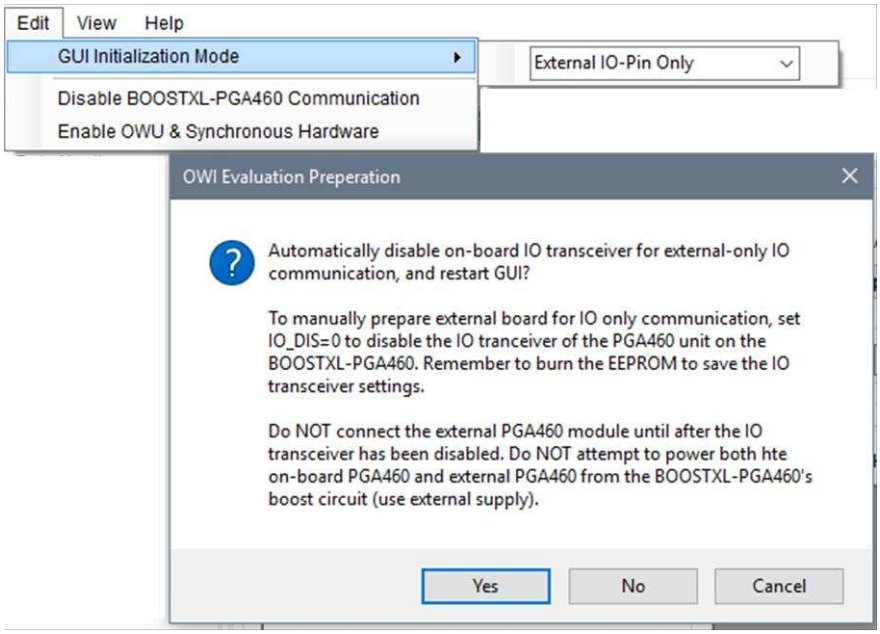



**Figure 33. OWI Evaluation Page Preparation**

Once the *GUI Initialization Mode* is set, the GUI will always start in that mode until the initialization mode is changed from the Edit menu drop-down. Thus, to revert to the standard UART mode of initialization and evaluation, TI recommends reverting the *GUI Initialization Mode* to *BOOSTXL-PGA460 (Standard)*. Ensure to restart the GUI after changing the initialization mode.

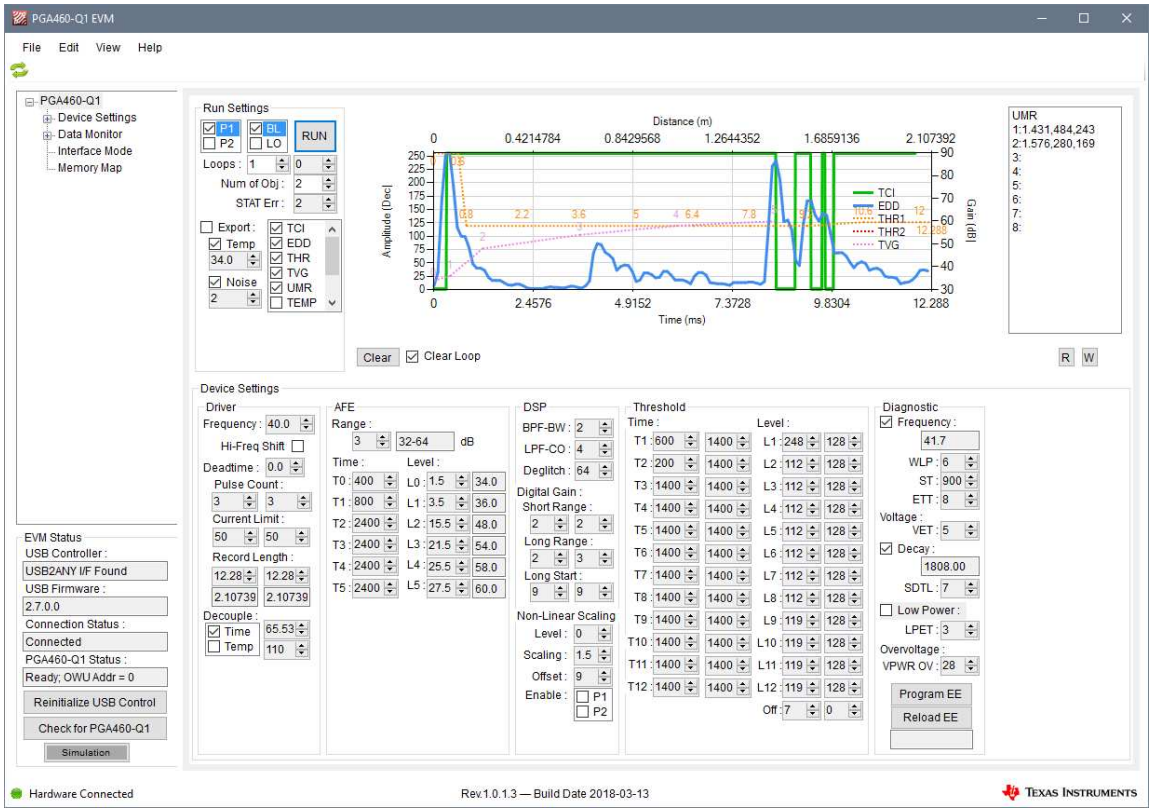



**Figure 34. One-Wire Evaluation Page—Working Example**

The OWI Evaluation settings are defined as follows:

**Run Settings —** Similarly to the Data Monitor page, this box allows you to define which preset and burst/listen type is to be run. In addition, the number of loops (1-1000) and the number of objects for the Ultrasonic Measurement Results can be defined. When the TCI mode is enabled, the STAT error will be updated here. Each item in the check box corresponds to a run type. The default run mode will obtain the TCI response, the Echo Data Dump response, and the Ultrasonic Measurement Results in a single loop. This means three independent burst/listen commands are run to obtain each set of data points. In addition to ultrasonic echo activity, the threshold and time varying gain profiles are mapped to the OWI chart by default. Items can be checked or unchecked based on the information to be displayed. When the export box is checked, each data point associated with the checked item in the check box list will be saved to a single XML file for post-processing. A separate TXT file is created and saved from the Utilities-Datalog box for UMR, TEMP, NOISE, FREQ, and DECAY because these data points are not included on the OWI chart. The exported files are automatically saved to the *"My Documents > BOOSTXL-PGA460"* path. When the Temp and Noise boxes are checked, the PGA460-Q1 will run independent temperature or noise measurements per item.

**OWI Chart —** The data points for TCI, EDD, THR, and/or TVG are plotted and overlapped on this chart based on their checked state in the Run Settings. Each loop will automatically clear, unless the Clear Loop box is unchecked. To clear the chart manually, click the Clear button. When UMR is enabled from the Run Settings, the UMR results list box will appear to the right of the OWI chart.

**Device Settings —** All device settings for the Driver, Analog Front End (AFE), Digital Signal Processing (DSP), Thresholding, and Diagnostic are made available here. Whenever a value is manually updated, the control will highlight yellow to indicate the value has changed, and is queued to update on the next run command. The register settings are not written to until the run command is sent from the Run Settings.

**Memory Map—** All register settings can be manually read and written to using the R and W buttons below the OWI Chart. When the Read (R) button is clicked, the Device Settings section is updated with the latest values read from the PGA460-Q1. When the Write (W) button is clicked, only the Device Settings highlighted in yellow will be updated; otherwise, there has been no change to the value since the last read. From the Memory Map page, the grid can be loaded with a previously saved memory map TXT file. Once the grid has been updated with the TXT file import, the user must click the Write All button to apply the updated Device Settings to the externally connected OWI device. The OWI device settings can also be saved to a TXT file for later use.

# 5 Schematic, Bill of Materials, and Layout

This section provides a detailed description of the schematic, bill of materials (BOM), and layout.

## 5.1 Schematics

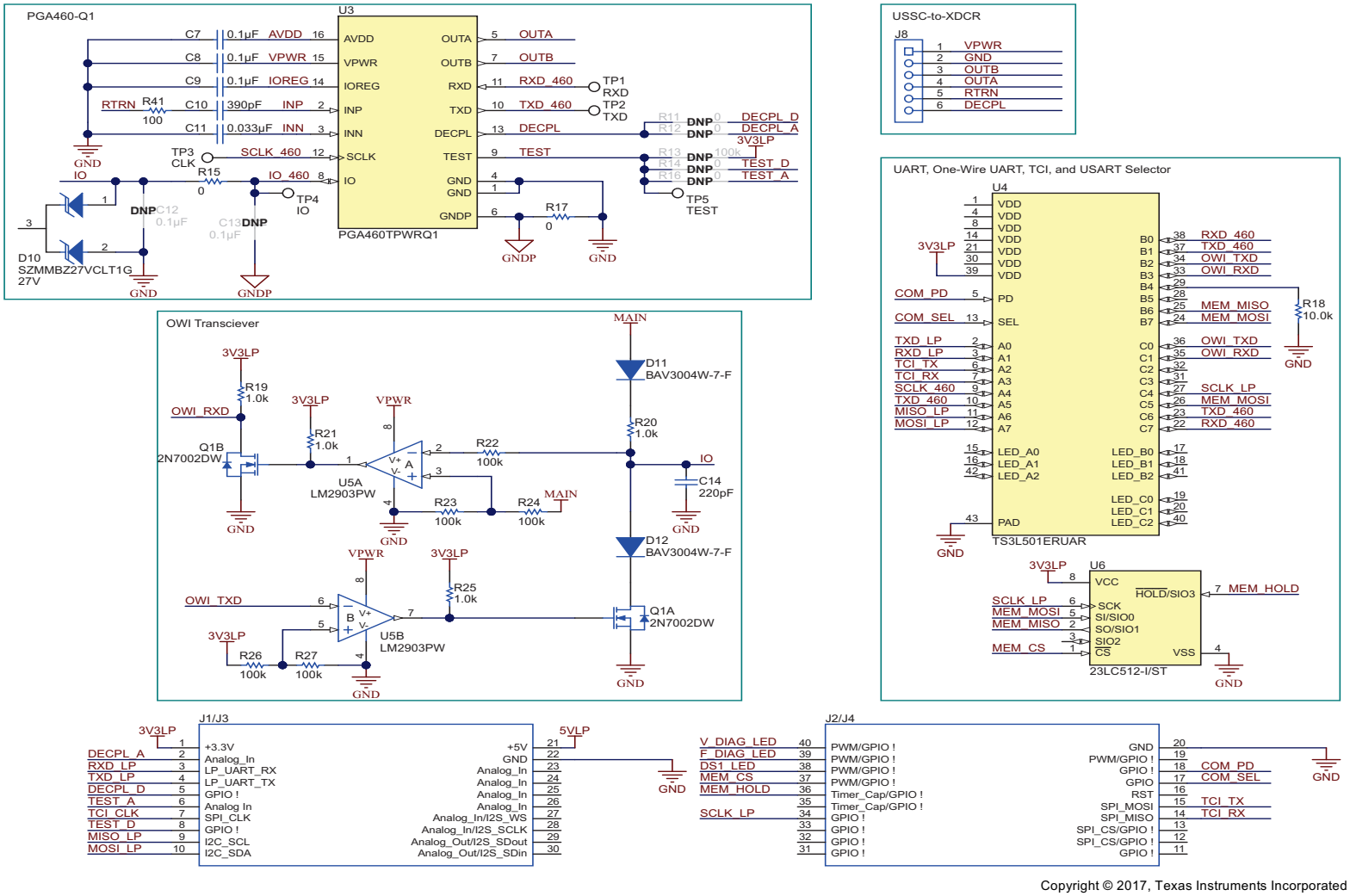



**Figure 35. PGA460-Q1 EVM Schematic – USSC**

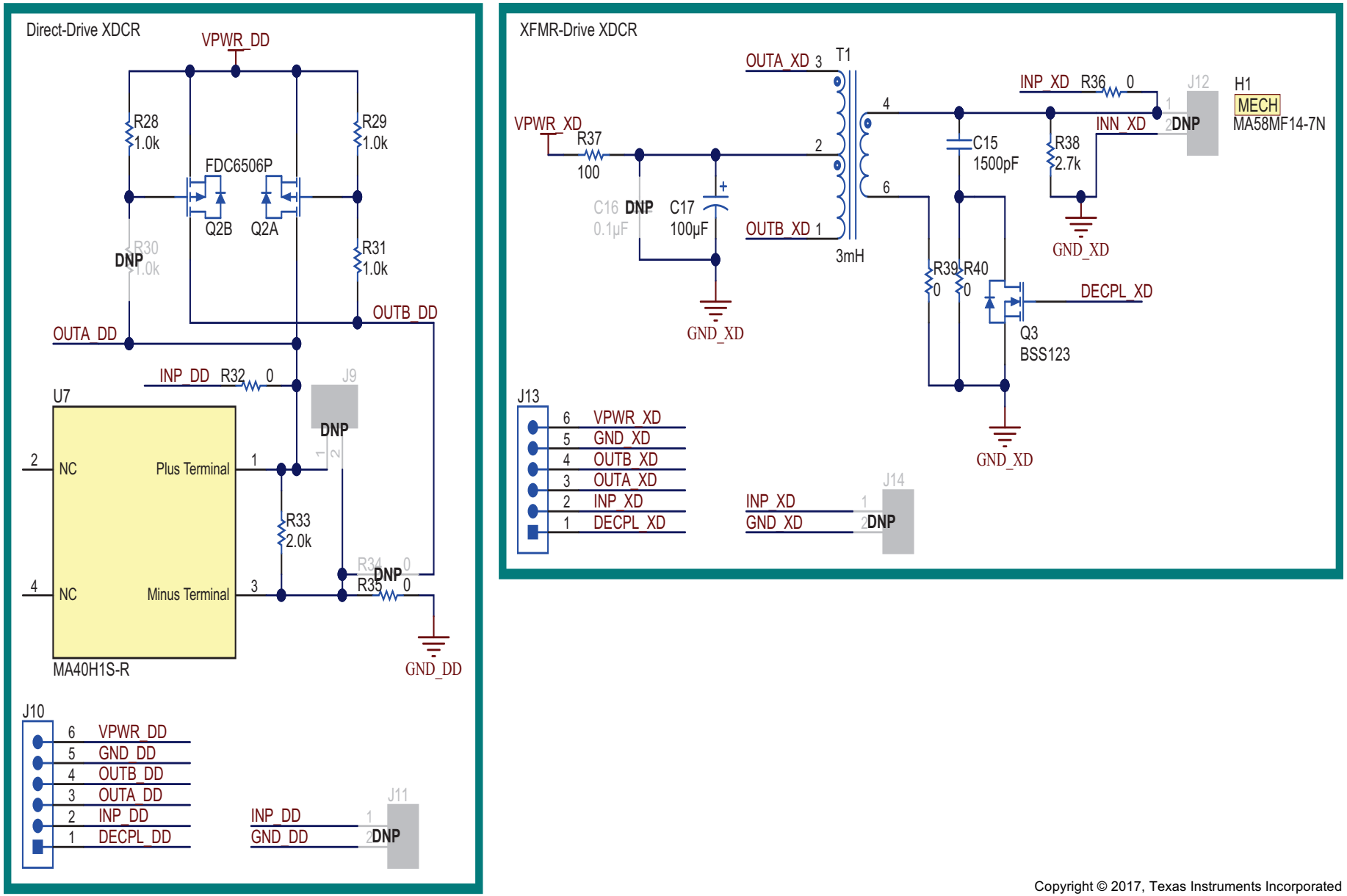





**Figure 36. PGA460-Q1 EVM Schematic – Driver and Transducer**

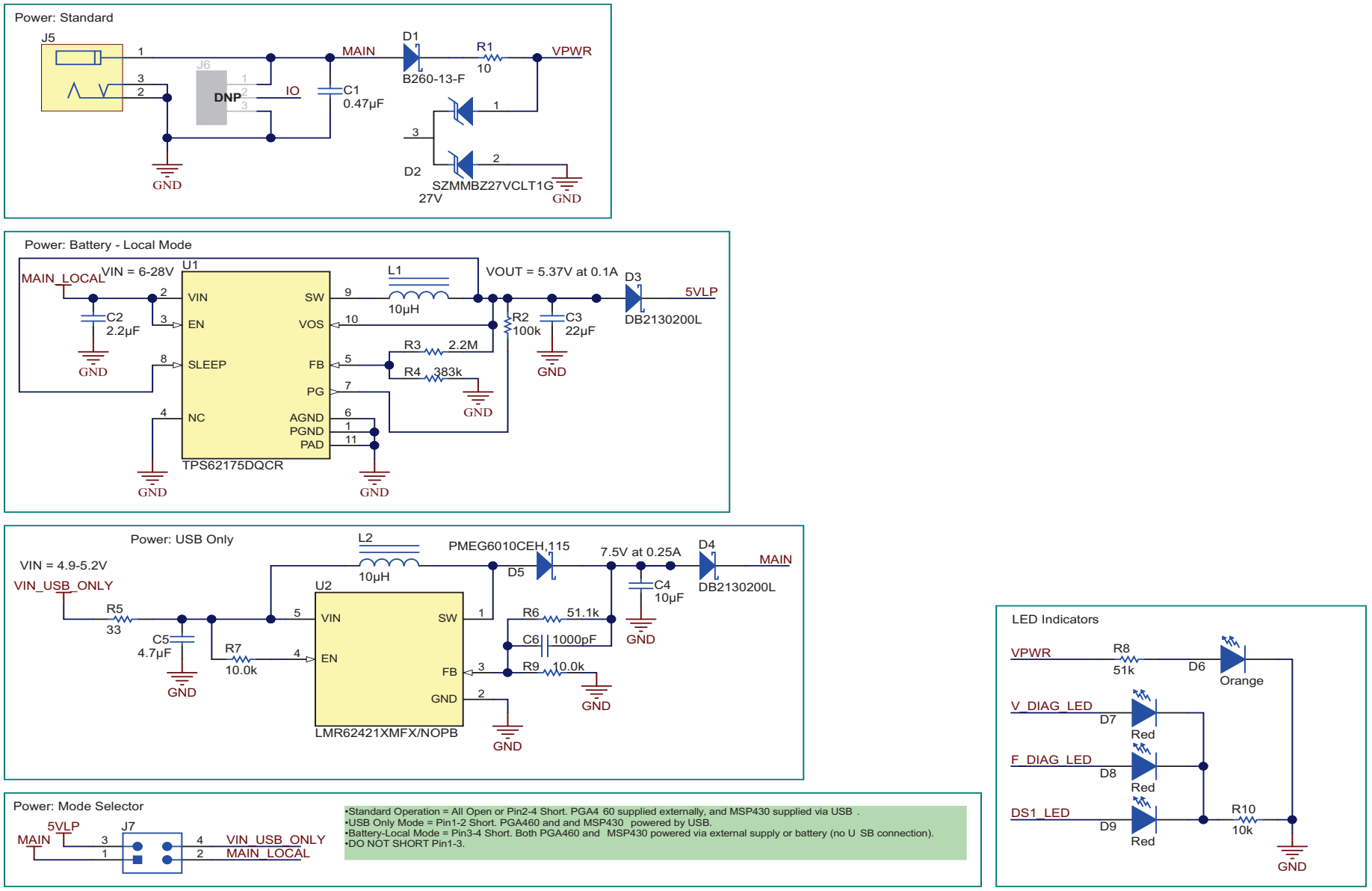





**Figure 37. PGA460-Q1 EVM Schematic - Power**

## 5.2 Bill of Materials

Table 8 lists the bill of materials (BOM) for the PGA460-Q1 EVM.

**Table 8. Bill of Materials**

| Designator | Quantity | Value | Description | Package | Part Number | Manufacturer |
|---|---|---|---|---|---|---|
| C1 | 1 | 0.47uF | CAP, CERM, 0.47 µF, 50 V, +/- 10%, X5R, 0603 | 0603 | C1608X5R1H474K080AB | TDK |
| C2 | 1 | 2.2uF | CAP, CERM, 2.2 µF, 50 V, +/- 10%, X7R, 1206 | 1206 | GRM31CR71H225KA88L | MuRata |
| C3 | 1 | 22uF | CAP, CERM, 22 µF, 10 V, +/- 10%, X5R, 1206 | 1206 | GRM31CR61A226KE19L | MuRata |
| C4 | 1 | 10uF | CAP, CERM, 10 µF, 16 V, +/- 10%, X5R, 0805 | 0805 | GRM21BR61C106KE15L | MuRata |
| C5 | 1 | 4.7uF | CAP, CERM, 4.7 µF, 10 V, +/- 20%, X5R, 0603 | 0603 | GRM188R61A475MAAJ | MuRata |
| C6 | 1 | 1000pF | CAP, CERM, 1000 pF, 50 V, +/- 10%, X7R, 0805 | 0805 | CC0805KRX7R9BB102 | Yageo America |
| C7, C8, C9 | 3 | 0.1uF | CAP, CERM, 0.1 µF, 50 V, +/- 10%, X7R, 0603 | 0603 | C1608X7R1H104K080AA | TDK |
| C10 | 1 | 390pF | CAP, CERM, 390 pF, 100 V, +/- 5%, C0G/NP0, 0603 | 0603 | GRM1885C2A391JA01D | MuRata |
| C11 | 1 | 0.033uF | CAP, CERM, 0.033 µF, 50 V, +/- 10%, X7R, 0603 | 0603 | GRM188R71H333KA61D | MuRata |
| C14 | 1 | 220pF | CAP, CERM, 220 pF, 50 V, +/- 10%, X7R, 0603 | 0603 | C0603C221K5RACTU | Kemet |
| C15 | 1 | 1500pF | CAP, CERM, 1500 pF, 100 V, +/- 5%, C0G/NP0, 0805 | 0805 | GRM2165C2A152JA01D | MuRata |
| C17 | 1 | 100uF | CAP, AL, 100 µF, 35 V, +/- 20%, SMD | F80 | EMVA350ADA101MF80G | Chemi-Con |
| D1 | 1 | 60V | Diode, Schottky, 60 V, 2 A, SMB | SMB | B260-13-F | Diodes Inc. |
| D2, D10 | 2 | 27V | Diode, TVS, Uni, 27 V, 40 W, SOT-23 | SOT-23 | SZMMBZ27VCLT1G | ON Semiconductor |
| D3, D4 | 2 | 30V | Diode, Schottky, 30 V, 1 A, SOD-323F | SOD-323F | DB2130200L | Panasonic |
| D5 | 1 | 60V | Diode, Schottky, 60 V, 1 A, SOD-123F | SOD-123F | PMEG6010CEH,115 | NXP Semiconductor |
| D6 | 1 | Orange | LED, Orange, SMD | LED_0603 | LTST-C191KFKT | Lite-On |
| D7, D8, D9 | 3 | Red | LED, Red, SMD | LED_0603 | LTST-C191KRKT | Lite-On |
| D11, D12 | 2 | 350V | Diode, Switching, 350 V, 0.225 A, SOD-123 | SOD-123 | BAV3004W-7-F | Diodes Inc. |
| FID4, FID5, FID6 | 3 | | Fiducial mark. There is nothing to buy or mount. | Fiducial | N/A | N/A |
| H1 | 1 | | Ultrasonic Transducer | | MA58MF14-7N | MuRata |
| J1/J3, J2/J4 | 2 | | Receptacle, 2.54mm, 10x2, Tin, TH | 10x2 Receptacle | SSQ-110-03-T-D | Samtec |
| J5 | 1 | | Power Jack, 2.5mm, R/A, SMT | 14.5x11x9mm | RASM712PX | Switchcraft |
| J7 | 1 | | Header, 2.54mm, 2x2, Gold, SMT | Header, 2.54mm, 2x2, SMT | 0015912040 | Molex |
| J8 | 1 | | Receptacle, 2.54mm, 6x1, Gold, R/A, Black, TH | Receptacle, 2.54mm, 6x1, R/A, TH | PPPC061LGBN-RC | Sullins Connector Solutions |
| J10, J13 | 2 | | Header, 2.54mm, 6x1, Gold, TH | Header, 2.54mm, 6x1, TH | PBC06SAAN | Sullins Connector Solutions |
| L1 | 1 | 10uH | Inductor, Shielded Drum Core, Ferrite, 10 µH, 1.15 A, 0.16 ohm, SMD | Inductor, 4.2x1.65x4.2mm | LQH44PN100MP0L | MuRata |
| L2 | 1 | 10uH | Inductor, Drum Core, Ferrite, 10 µH, 1.15 A, 0.18 ohm, SMD | 4.5x3.2x4mm | SDR0403-100ML | Bourns |
| Q1 | 1 | 60V | MOSFET, N-CH, 60 V, 0.115 A, SOT-363 | SOT-363 | 2N7002DW | Fairchild Semiconductor |
| Q2 | 1 | -30V | MOSFET, P-CH, -30 V, -1.8 A, superSOT-6 | superSOT-6 | FDC6506P | Fairchild Semiconductor |
| Q3 | 1 | 100V | MOSFET, N-CH, 100 V, 0.17 A, SOT-23 | SOT-23 | BSS123 | Fairchild Semiconductor |
| R1 | 1 | 10 | RES, 10, 5%, 0.75 W, 2010 | 2010 | CRCW201010R0JNEF | Vishay-Dale |
| R2 | 1 | 100k | RES, 100 k, 1%, 0.063 W, 0402 | 0402 | CRCW0402100KFKED | Vishay-Dale |
| R3 | 1 | 2.2Meg | RES, 2.2 M, 1%, 0.25 W, 1206 | 1206 | RC1206FR-072M2L | Yageo America |

**Table 8. Bill of Materials (continued)**

| Designator | Quantity | Value | Description | Package | Part Number | Manufacturer |
|---|---|---|---|---|---|---|
| R4 | 1 | 383k | RES, 383 k, 1%, 0.063 W, 0402 | 0402 | CRCW0402383KFKED | Vishay-Dale |
| R5 | 1 | 33 | RES, 33, 5%, 0.75 W, AEC-Q200 Grade 0, 2010 | 2010 | CRCW201033R0JNEF | Vishay-Dale |
| R6 | 1 | 51.1k | RES, 51.1 k, 1%, 0.063 W, 0402 | 0402 | CRCW040251K1FKED | Vishay-Dale |
| R7, R9, R18 | 3 | 10.0k | RES, 10.0 k, 1%, 0.063 W, 0402 | 0402 | CRCW040210K0FKED | Vishay-Dale |
| R8 | 1 | 51k | RES, 51 k, 5%, 0.1 W, 0603 | 0603 | RC0603JR-0751KL | Yageo America |
| R10 | 1 | 10k | RES, 10 k, 5%, 0.1 W, 0603 | 0603 | RC0603JR-0710KL | Yageo America |
| R15, R17, R32, R35, R36, R39, R40 | 7 | 0 | RES, 0, 5%, 0.25 W, 1206 | 1206 | CRCW12060000Z0EA | Vishay-Dale |
| R19, R21, R25, R28, R29, R31 | 6 | 1.0k | RES, 1.0 k, 5%, 0.1 W, 0603 | 0603 | CRCW06031K00JNEA | Vishay-Dale |
| R20 | 1 | 1.0k | RES, 1.0 k, 5%, 0.75 W, AEC-Q200 Grade 0, 2010 | 2010 | CRCW20101K00JNEF | Vishay-Dale |
| R22, R23, R24, R26, R27 | 5 | 100k | RES, 100 k, 5%, 0.1 W, 0603 | 0603 | CRCW0603100KJNEA | Vishay-Dale |
| R33 | 1 | 2.0k | RES, 2.0 k, 5%, 0.063 W, 0402 | 0402 | CRCW04022K00JNED | Vishay-Dale |
| R37 | 1 | 100 | RES, 100, 5%, 0.125 W, 0805 | 0805 | CRCW0805100RJNEA | Vishay-Dale |
| R38 | 1 | 2.7k | RES, 2.7 k, 5%, 0.25 W, 1206 | 1206 | CRCW12062K70JNEA | Vishay-Dale |
| R41 | 1 | 100 | RES, 100, 1%, 0.1 W, 0603 | 0603 | CRCW0603100RFKEA | Vishay-Dale |
| SH-J1 | 1 | | Shunt, 2.54mm, Gold, Black | Shunt, 2.54mm, Black | 60900213421 | Wurth Elektronik |
| T1 | 1 | 3mH | Transformer, 3 mH, SMT | 8.8x7.6mm | B78416A2232A003 | TDK |
| TP1, TP2, TP3, TP4, TP5 | 5 | | Test Point, Miniature, SMT | Testpoint_Keystone_Miniature | 5015 | Keystone |
| U1 | 1 | | 28V, 0.5A Step-Down Converter with Sleep Mode, DQC0010A | DQC0010A | TPS62175DQCR | Texas Instruments |
| U2 | 1 | | SIMPLE SWITCHER 24Vout, 2.1A Step-Up Voltage Regulator in SOT-23, DBV0005A | DBV0005A | LMR62421XMFX/NOPB | Texas Instruments |
| U3 | 1 | | PGA460TPWRQ1, PW0016A | PW0016A | PGA460TPWRQ1 | Texas Instruments |
| U4 | 1 | | 16-BIT TO 8-BIT MULTIPLEXER/DEMULTIPLEXER GIGABIT ETHERNET LAN SWITCH WITH POWER DOWN MODE, RUA0042A | RUA0042A | TS3L501ERUAR | Texas Instruments |
| U5 | 1 | | Dual Comparator, PW0008A | PW0008A | LM2903PW | Texas Instruments |
| U6 | 1 | | 512Kbit SPI Serial SRAM with SDI and SQI Interface, | TSSOP-8 | 23LC512-I/ST | Microchip |
| U7 | 1 | | Ultrasonic Transducer, 6 VPP, 40 kHz, 4500 pF, -20 to 60 degC, SMD, 4-Pin Body 5.2 x 5.2 mm | 4-Pin SMD Package, Body 5.2 x 5.2 mm, Height 1.2 mm | MA40H1S-R | MuRata |
| C12, C13, C16 | 0 | 0.1uF | CAP, CERM, 0.1 µF, 50 V, +/- 10%, X7R, 0603 | 0603 | C1608X7R1H104K080AA | TDK |
| FID1, FID2, FID3 | 0 | | Fiducial mark. There is nothing to buy or mount. | Fiducial | N/A | N/A |
| J6 | 0 | | Header, 2.54 mm, 3x1, Tin, TH | Header, 2.54 mm, 3x1, TH | TSW-103-07-T-S | Samtec |
| J9, J11, J12, J14 | 0 | | Header, 100mil, 2x1, Tin, TH | Header, 2 PIN, 100mil, Tin | PEC02SAAN | Sullins Connector Solutions |
| R11, R12, R14, R16 | 0 | 0 | RES, 0, 5%, 0.063 W, 0402 | 0402 | CRCW04020000Z0ED | Vishay-Dale |
| R13 | 0 | 100k | RES, 100 k, 5%, 0.063 W, 0402 | 0402 | CRCW0402100KJNED | Vishay-Dale |
| R30 | 0 | 1.0k | RES, 1.0 k, 5%, 0.1 W, 0603 | 0603 | CRCW06031K00JNEA | Vishay-Dale |
| R34 | 0 | 0 | RES, 0, 5%, 0.25 W, 1206 | 1206 | CRCW12060000Z0EA | Vishay-Dale |

## 5.3 Board Layout and Component Placement

Figure 38, Figure 39, Figure 40, and Figure 41 show the board layout and component placement.

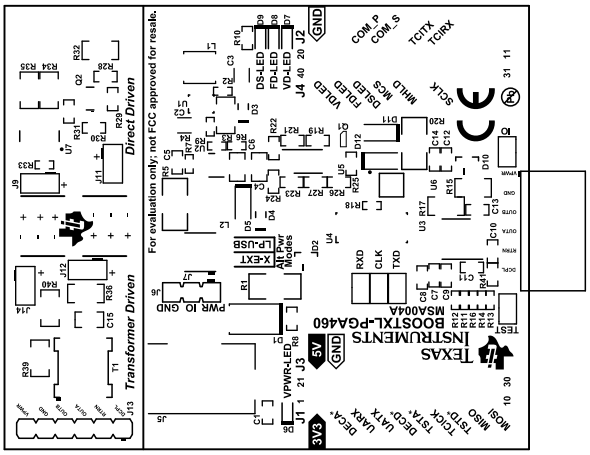



**Figure 38. Component Placement – Top Overview**

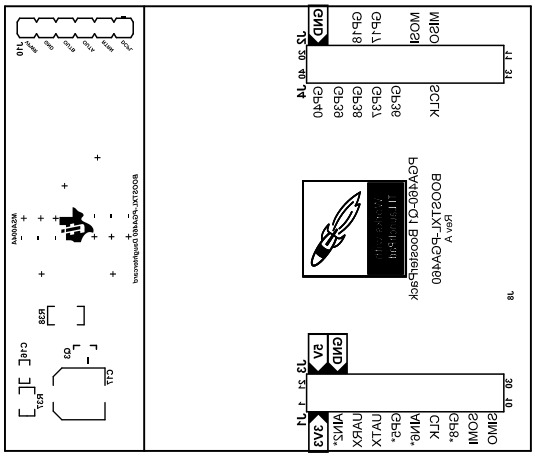



**Figure 39. Component Placement – Bottom Overview**

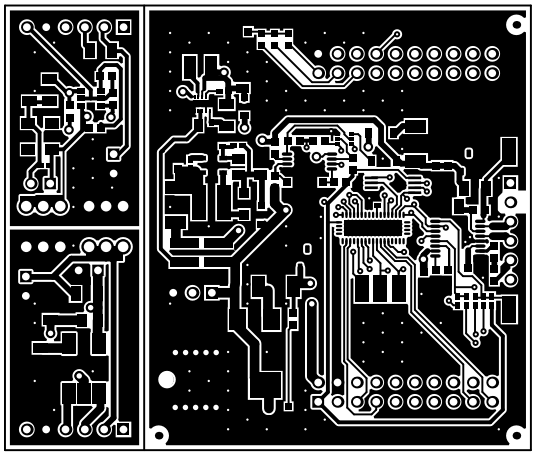


**Figure 40. Layout – Top**

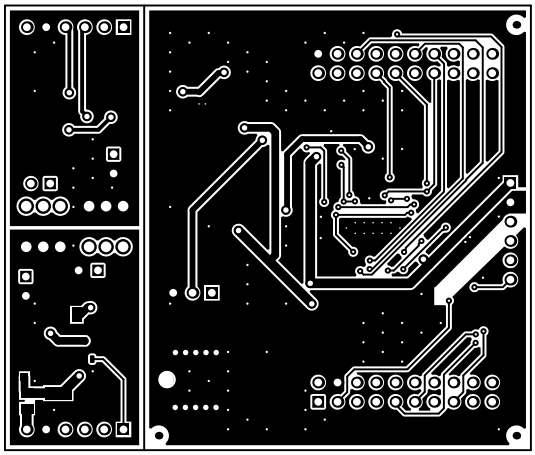


**Figure 41. Layout – Bottom**

# 6 References

For additional reference, refer to

- *LMx93, LM2903 Dual Differential Comparators*
- *LMR62421 SIMPLE SWITCHER® 24Vout, 2.1A Step-Up Voltage Regulator in SOT-23*
- *MSP430F5529 LaunchPad™ Development Kit (MSP-EXP430F5529LP)*
- *TPS6217x 28-V, 0.5-A Step-Down Converter With Sleep Mode*
- *TS3L501E 8-Channel SPDT/16-Bit to 8-Bit Multiplexer and Demultiplexer Ethernet LAN Switch With Power-Down Mode*
- *PGA460-Q1 Ultrasonic Sensor-Signal Conditioner*
- *SN65HVDA100-Q1 LIN Physical Interface* (SLIS128)

# Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

**Changes from A Revision (February 2017) to B Revision** **Page**

- Added content to the *Power Mode Jumper Position* table ..... 8
- Added content to the *Flash Program MSP-EXP430F5529LP* section ..... 11
- Added *Load Chart* and *Clear Chart* definitions ..... 19
- Added content to the *Threshold* section ..... 21
- Added *Parameter Sweeps* section ..... 25
- Added *External Sync and Trigger* section ..... 25
- Changed the *Program to Selected Addr* command to *Update Device to Selected Addr* ..... 30
- Added *In-Sys IO Toggle* and *TCI Echo Results* control definitions ..... 33
- Added content to the *BPF Coefficient Calculator* section ..... 40
- Added the *Datalog* directory path ..... 40
- Added new definitions to the *File Menu* section ..... 42
- Added *External PGA460-Q1 Evaluation* section ..... 47
- Added *SN65HVDA100-Q1 LIN Physical Interface* (SLIS128) app note to *References* ..... 56

**Changes from Original (February 2017) to A Revision** **Page**

- Clarified the warning about the transformer generating a driving voltage of 50 $V_{RMS}$ or more in the *Transformer Driven* section ..... 9

# STANDARD TERMS FOR EVALUATION MODULES

1. *Delivery:* TI delivers TI evaluation boards, kits, or modules, including any accompanying demonstration software, components, and/or documentation which may be provided together or separately (collectively, an “EVM” or “EVMs”) to the User (“User”) in accordance with the terms set forth herein. User's acceptance of the EVM is expressly subject to the following terms.

   1.1 EVMs are intended solely for product or software developers for use in a research and development setting to facilitate feasibility evaluation, experimentation, or scientific analysis of TI semiconductors products. EVMs have no direct function and are not finished products. EVMs shall not be directly or indirectly assembled as a part or subassembly in any finished product. For clarification, any software or software tools provided with the EVM (“Software”) shall not be subject to the terms and conditions set forth herein but rather shall be subject to the applicable terms that accompany such Software

   1.2 EVMs are not intended for consumer or household use. EVMs may not be sold, sublicensed, leased, rented, loaned, assigned, or otherwise distributed for commercial purposes by Users, in whole or in part, or used in any finished product or production system.

2 *Limited Warranty and Related Remedies/Disclaimers*:

   2.1 These terms do not apply to Software. The warranty, if any, for Software is covered in the applicable Software License Agreement.

   2.2 TI warrants that the TI EVM will conform to TI's published specifications for ninety (90) days after the date TI delivers such EVM to User. Notwithstanding the foregoing, TI shall not be liable for a nonconforming EVM if (a) the nonconformity was caused by neglect, misuse or mistreatment by an entity other than TI, including improper installation or testing, or for any EVMs that have been altered or modified in any way by an entity other than TI, (b) the nonconformity resulted from User's design, specifications or instructions for such EVMs or improper system design, or (c) User has not paid on time. Testing and other quality control techniques are used to the extent TI deems necessary. TI does not test all parameters of each EVM. User's claims against TI under this Section 2 are void if User fails to notify TI of any apparent defects in the EVMs within ten (10) business days after delivery, or of any hidden defects with ten (10) business days after the defect has been detected.

   2.3 TI's sole liability shall be at its option to repair or replace EVMs that fail to conform to the warranty set forth above, or credit User's account for such EVM. TI's liability under this warranty shall be limited to EVMs that are returned during the warranty period to the address designated by TI and that are determined by TI not to conform to such warranty. If TI elects to repair or replace such EVM, TI shall have a reasonable time to repair such EVM or provide replacements. Repaired EVMs shall be warranted for the remainder of the original warranty period. Replaced EVMs shall be warranted for a new full ninety (90) day warranty period.

3 *Regulatory Notices:*

   3.1 *United States*

      3.1.1 *Notice applicable to EVMs not FCC-Approved:*

      **FCC NOTICE:** This kit is designed to allow product developers to evaluate electronic components, circuitry, or software associated with the kit to determine whether to incorporate such items in a finished product and software developers to write software applications for use with the end product. This kit is not a finished product and when assembled may not be resold or otherwise marketed unless all required FCC equipment authorizations are first obtained. Operation is subject to the condition that this product not cause harmful interference to licensed radio stations and that this product accept harmful interference. Unless the assembled kit is designed to operate under part 15, part 18 or part 95 of this chapter, the operator of the kit must operate under the authority of an FCC license holder or must secure an experimental authorization under part 5 of this chapter.

      3.1.2 *For EVMs annotated as FCC – FEDERAL COMMUNICATIONS COMMISSION Part 15 Compliant:*

      **CAUTION**

      This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

      Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

      **FCC Interference Statement for Class A EVM devices**

      *NOTE: This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.*

**FCC Interference Statement for Class B EVM devices**

*NOTE: This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:*

- *Reorient or relocate the receiving antenna.*
- *Increase the separation between the equipment and receiver.*
- *Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.*
- *Consult the dealer or an experienced radio/TV technician for help.*

3.2 *Canada*

3.2.1 *For EVMs issued with an Industry Canada Certificate of Conformance to RSS-210 or RSS-247*

**Concerning EVMs Including Radio Transmitters:**

This device complies with Industry Canada license-exempt RSSs. Operation is subject to the following two conditions:

(1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

**Concernant les EVMs avec appareils radio:**

Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes: (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

**Concerning EVMs Including Detachable Antennas:**

Under Industry Canada regulations, this radio transmitter may only operate using an antenna of a type and maximum (or lesser) gain approved for the transmitter by Industry Canada. To reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the equivalent isotropically radiated power (e.i.r.p.) is not more than that necessary for successful communication. This radio transmitter has been approved by Industry Canada to operate with the antenna types listed in the user guide with the maximum permissible gain and required antenna impedance for each antenna type indicated. Antenna types not included in this list, having a gain greater than the maximum gain indicated for that type, are strictly prohibited for use with this device.

**Concernant les EVMs avec antennes détachables**

Conformément à la réglementation d'Industrie Canada, le présent émetteur radio peut fonctionner avec une antenne d'un type et d'un gain maximal (ou inférieur) approuvé pour l'émetteur par Industrie Canada. Dans le but de réduire les risques de brouillage radioélectrique à l'intention des autres utilisateurs, il faut choisir le type d'antenne et son gain de sorte que la puissance isotrope rayonnée équivalente (p.i.r.e.) ne dépasse pas l'intensité nécessaire à l'établissement d'une communication satisfaisante. Le présent émetteur radio a été approuvé par Industrie Canada pour fonctionner avec les types d'antenne énumérés dans le manuel d'usage et ayant un gain admissible maximal et l'impédance requise pour chaque type d'antenne. Les types d'antenne non inclus dans cette liste, ou dont le gain est supérieur au gain maximal indiqué, sont strictement interdits pour l'exploitation de l'émetteur

3.3 *Japan*

3.3.1 *Notice for EVMs delivered in Japan:* Please see http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_01.page 日本国内に輸入される評価用キット、ボードについては、次のところをご覧ください。
http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_01.page

3.3.2 *Notice for Users of EVMs Considered "Radio Frequency Products" in Japan:* EVMs entering Japan may not be certified by TI as conforming to Technical Regulations of Radio Law of Japan.

If User uses EVMs in Japan, not certified to Technical Regulations of Radio Law of Japan, User is required to follow the instructions set forth by Radio Law of Japan, which includes, but is not limited to, the instructions below with respect to EVMs (which for the avoidance of doubt are stated strictly for convenience and should be verified by User):

1. Use EVMs in a shielded room or any other test facility as defined in the notification #173 issued by Ministry of Internal Affairs and Communications on March 28, 2006, based on Sub-section 1.1 of Article 6 of the Ministry's Rule for Enforcement of Radio Law of Japan,
2. Use EVMs only after User obtains the license of Test Radio Station as provided in Radio Law of Japan with respect to EVMs, or
3. Use of EVMs only after User obtains the Technical Regulations Conformity Certification as provided in Radio Law of Japan with respect to EVMs. Also, do not transfer EVMs, unless User gives the same notice above to the transferee. Please note that if User does not follow the instructions above, User will be subject to penalties of Radio Law of Japan.

【無線電波を送信する製品の開発キットをお使いになる際の注意事項】 開発キットの中には技術基準適合証明を受けていないものがあります。 技術適合証明を受けていないもののご使用に際しては、電波法遵守のため、以下のいずれかの措置を取っていただく必要がありますのでご注意ください。

1. 電波法施行規則第6条第1項第1号に基づく平成18年3月28日総務省告示第173号で定められた電波暗室等の試験設備でご使用いただく。
2. 実験局の免許を取得後ご使用いただく。
3. 技術基準適合証明を取得後ご使用いただく。

なお、本製品は、上記の「ご使用にあたっての注意」を譲渡先、移転先に通知しない限り、譲渡、移転できないものとします。

上記を遵守頂けない場合は、電波法の罰則が適用される可能性があることをご留意ください。 日本テキサス・インスツルメンツ株式会社

東京都新宿区西新宿６丁目２４番１号

西新宿三井ビル

3.3.3 *Notice for EVMs for Power Line Communication:* Please see http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_02.page

電力線搬送波通信についての開発キットをお使いになる際の注意事項については、次のところをご覧ください。http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_02.page

3.4 *European Union*

3.4.1 *For EVMs subject to EU Directive 2014/30/EU (Electromagnetic Compatibility Directive)*:

This is a class A product intended for use in environments other than domestic environments that are connected to a low-voltage power-supply network that supplies buildings used for domestic purposes. In a domestic environment this product may cause radio interference in which case the user may be required to take adequate measures.

4 *EVM Use Restrictions and Warnings:*

4.1 EVMS ARE NOT FOR USE IN FUNCTIONAL SAFETY AND/OR SAFETY CRITICAL EVALUATIONS, INCLUDING BUT NOT LIMITED TO EVALUATIONS OF LIFE SUPPORT APPLICATIONS.

4.2 User must read and apply the user guide and other available documentation provided by TI regarding the EVM prior to handling or using the EVM, including without limitation any warning or restriction notices. The notices contain important safety information related to, for example, temperatures and voltages.

4.3 *Safety-Related Warnings and Restrictions:*

4.3.1 User shall operate the EVM within TI's recommended specifications and environmental considerations stated in the user guide, other available documentation provided by TI, and any other applicable requirements and employ reasonable and customary safeguards. Exceeding the specified performance ratings and specifications (including but not limited to input and output voltage, current, power, and environmental ranges) for the EVM may cause personal injury or death, or property damage. If there are questions concerning performance ratings and specifications, User should contact a TI field representative prior to connecting interface electronics including input power and intended loads. Any loads applied outside of the specified output range may also result in unintended and/or inaccurate operation and/or possible permanent damage to the EVM and/or interface electronics. Please consult the EVM user guide prior to connecting any load to the EVM output. If there is uncertainty as to the load specification, please contact a TI field representative. During normal operation, even with the inputs and outputs kept within the specified allowable ranges, some circuit components may have elevated case temperatures. These components include but are not limited to linear regulators, switching transistors, pass transistors, current sense resistors, and heat sinks, which can be identified using the information in the associated documentation. When working with the EVM, please be aware that the EVM may become very warm.

4.3.2 EVMs are intended solely for use by technically qualified, professional electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems, and subsystems. User assumes all responsibility and liability for proper and safe handling and use of the EVM by User or its employees, affiliates, contractors or designees. User assumes all responsibility and liability to ensure that any interfaces (electronic and/or mechanical) between the EVM and any human body are designed with suitable isolation and means to safely limit accessible leakage currents to minimize the risk of electrical shock hazard. User assumes all responsibility and liability for any improper or unsafe handling or use of the EVM by User or its employees, affiliates, contractors or designees.

4.4 User assumes all responsibility and liability to determine whether the EVM is subject to any applicable international, federal, state, or local laws and regulations related to User's handling and use of the EVM and, if applicable, User assumes all responsibility and liability for compliance in all respects with such laws and regulations. User assumes all responsibility and liability for proper disposal and recycling of the EVM consistent with all applicable international, federal, state, and local requirements.

5. *Accuracy of Information:* To the extent TI provides information on the availability and function of EVMs, TI attempts to be as accurate as possible. However, TI does not warrant the accuracy of EVM descriptions, EVM availability or other information on its websites as accurate, complete, reliable, current, or error-free.

6. *Disclaimers:*

   6.1 EXCEPT AS SET FORTH ABOVE, EVMS AND ANY MATERIALS PROVIDED WITH THE EVM (INCLUDING, BUT NOT LIMITED TO, REFERENCE DESIGNS AND THE DESIGN OF THE EVM ITSELF) ARE PROVIDED "AS IS" AND "WITH ALL FAULTS." TI DISCLAIMS ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, REGARDING SUCH ITEMS, INCLUDING BUT NOT LIMITED TO ANY EPIDEMIC FAILURE WARRANTY OR IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF ANY THIRD PARTY PATENTS, COPYRIGHTS, TRADE SECRETS OR OTHER INTELLECTUAL PROPERTY RIGHTS.

   6.2 EXCEPT FOR THE LIMITED RIGHT TO USE THE EVM SET FORTH HEREIN, NOTHING IN THESE TERMS SHALL BE CONSTRUED AS GRANTING OR CONFERRING ANY RIGHTS BY LICENSE, PATENT, OR ANY OTHER INDUSTRIAL OR INTELLECTUAL PROPERTY RIGHT OF TI, ITS SUPPLIERS/LICENSORS OR ANY OTHER THIRD PARTY, TO USE THE EVM IN ANY FINISHED END-USER OR READY-TO-USE FINAL PRODUCT, OR FOR ANY INVENTION, DISCOVERY OR IMPROVEMENT, REGARDLESS OF WHEN MADE, CONCEIVED OR ACQUIRED.

7. *USER'S INDEMNITY OBLIGATIONS AND REPRESENTATIONS.* USER WILL DEFEND, INDEMNIFY AND HOLD TI, ITS LICENSORS AND THEIR REPRESENTATIVES HARMLESS FROM AND AGAINST ANY AND ALL CLAIMS, DAMAGES, LOSSES, EXPENSES, COSTS AND LIABILITIES (COLLECTIVELY, "CLAIMS") ARISING OUT OF OR IN CONNECTION WITH ANY HANDLING OR USE OF THE EVM THAT IS NOT IN ACCORDANCE WITH THESE TERMS. THIS OBLIGATION SHALL APPLY WHETHER CLAIMS ARISE UNDER STATUTE, REGULATION, OR THE LAW OF TORT, CONTRACT OR ANY OTHER LEGAL THEORY, AND EVEN IF THE EVM FAILS TO PERFORM AS DESCRIBED OR EXPECTED.

8. *Limitations on Damages and Liability:*

   8.1 *General Limitations*. IN NO EVENT SHALL TI BE LIABLE FOR ANY SPECIAL, COLLATERAL, INDIRECT, PUNITIVE, INCIDENTAL, CONSEQUENTIAL, OR EXEMPLARY DAMAGES IN CONNECTION WITH OR ARISING OUT OF THESE TERMS OR THE USE OF THE EVMS , REGARDLESS OF WHETHER TI HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES. EXCLUDED DAMAGES INCLUDE, BUT ARE NOT LIMITED TO, COST OF REMOVAL OR REINSTALLATION, ANCILLARY COSTS TO THE PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES, RETESTING, OUTSIDE COMPUTER TIME, LABOR COSTS, LOSS OF GOODWILL, LOSS OF PROFITS, LOSS OF SAVINGS, LOSS OF USE, LOSS OF DATA, OR BUSINESS INTERRUPTION. NO CLAIM, SUIT OR ACTION SHALL BE BROUGHT AGAINST TI MORE THAN TWELVE (12) MONTHS AFTER THE EVENT THAT GAVE RISE TO THE CAUSE OF ACTION HAS OCCURRED.

   8.2 *Specific Limitations.* IN NO EVENT SHALL TI'S AGGREGATE LIABILITY FROM ANY USE OF AN EVM PROVIDED HEREUNDER, INCLUDING FROM ANY WARRANTY, INDEMITY OR OTHER OBLIGATION ARISING OUT OF OR IN CONNECTION WITH THESE TERMS, , EXCEED THE TOTAL AMOUNT PAID TO TI BY USER FOR THE PARTICULAR EVM(S) AT ISSUE DURING THE PRIOR TWELVE (12) MONTHS WITH RESPECT TO WHICH LOSSES OR DAMAGES ARE CLAIMED. THE EXISTENCE OF MORE THAN ONE CLAIM SHALL NOT ENLARGE OR EXTEND THIS LIMIT.

9. *Return Policy.* Except as otherwise provided, TI does not offer any refunds, returns, or exchanges. Furthermore, no return of EVM(s) will be accepted if the package has been opened and no return of the EVM(s) will be accepted if they are damaged or otherwise not in a resalable condition. If User feels it has been incorrectly charged for the EVM(s) it ordered or that delivery violates the applicable order, User should contact TI. All refunds will be made in full within thirty (30) working days from the return of the components(s), excluding any postage or packaging costs.

10. *Governing Law:* These terms and conditions shall be governed by and interpreted in accordance with the laws of the State of Texas, without reference to conflict-of-laws principles. User agrees that non-exclusive jurisdiction for any dispute arising out of or relating to these terms and conditions lies within courts located in the State of Texas and consents to venue in Dallas County, Texas. Notwithstanding the foregoing, any judgment may be enforced in any United States or foreign court, and TI may seek injunctive relief in any United States or foreign court.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265

## IMPORTANT NOTICE FOR TI DESIGN INFORMATION AND RESOURCES

Texas Instruments Incorporated ('TI") technical, application or other design advice, services or information, including, but not limited to, reference designs and materials relating to evaluation modules, (collectively, "TI Resources") are intended to assist designers who are developing applications that incorporate TI products; by downloading, accessing or using any particular TI Resource in any way, you (individually or, if you are acting on behalf of a company, your company) agree to use it solely for this purpose and subject to the terms of this Notice.

TI's provision of TI Resources does not expand or otherwise alter TI's applicable published warranties or warranty disclaimers for TI products, and no additional obligations or liabilities arise from TI providing such TI Resources. TI reserves the right to make corrections, enhancements, improvements and other changes to its TI Resources.

You understand and agree that you remain responsible for using your independent analysis, evaluation and judgment in designing your applications and that you have full and exclusive responsibility to assure the safety of your applications and compliance of your applications (and of all TI products used in or for your applications) with all applicable regulations, laws and other applicable requirements. You represent that, with respect to your applications, you have all the necessary expertise to create and implement safeguards that (1) anticipate dangerous consequences of failures, (2) monitor failures and their consequences, and (3) lessen the likelihood of failures that might cause harm and take appropriate actions. You agree that prior to using or distributing any applications that include TI products, you will thoroughly test such applications and the functionality of such TI products as used in such applications. TI has not conducted any testing other than that specifically described in the published documentation for a particular TI Resource.

You are authorized to use, copy and modify any individual TI Resource only in connection with the development of applications that include the TI product(s) identified in such TI Resource. NO OTHER LICENSE, EXPRESS OR IMPLIED, BY ESTOPPEL OR OTHERWISE TO ANY OTHER TI INTELLECTUAL PROPERTY RIGHT, AND NO LICENSE TO ANY TECHNOLOGY OR INTELLECTUAL PROPERTY RIGHT OF TI OR ANY THIRD PARTY IS GRANTED HEREIN, including but not limited to any patent right, copyright, mask work right, or other intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information regarding or referencing third-party products or services does not constitute a license to use such products or services, or a warranty or endorsement thereof. Use of TI Resources may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

TI RESOURCES ARE PROVIDED "AS IS" AND WITH ALL FAULTS. TI DISCLAIMS ALL OTHER WARRANTIES OR REPRESENTATIONS, EXPRESS OR IMPLIED, REGARDING TI RESOURCES OR USE THEREOF, INCLUDING BUT NOT LIMITED TO ACCURACY OR COMPLETENESS, TITLE, ANY EPIDEMIC FAILURE WARRANTY AND ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, AND NON-INFRINGEMENT OF ANY THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

TI SHALL NOT BE LIABLE FOR AND SHALL NOT DEFEND OR INDEMNIFY YOU AGAINST ANY CLAIM, INCLUDING BUT NOT LIMITED TO ANY INFRINGEMENT CLAIM THAT RELATES TO OR IS BASED ON ANY COMBINATION OF PRODUCTS EVEN IF DESCRIBED IN TI RESOURCES OR OTHERWISE. IN NO EVENT SHALL TI BE LIABLE FOR ANY ACTUAL, DIRECT, SPECIAL, COLLATERAL, INDIRECT, PUNITIVE, INCIDENTAL, CONSEQUENTIAL OR EXEMPLARY DAMAGES IN CONNECTION WITH OR ARISING OUT OF TI RESOURCES OR USE THEREOF, AND REGARDLESS OF WHETHER TI HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES.

You agree to fully indemnify TI and its representatives against any damages, costs, losses, and/or liabilities arising out of your non-compliance with the terms and provisions of this Notice.

This Notice applies to TI Resources. Additional terms apply to the use and purchase of certain types of materials, TI products and services. These include; without limitation, TI's standard terms for semiconductor products http://www.ti.com/sc/docs/stdterms.htm), evaluation modules, and samples (http://www.ti.com/sc/docs/sampterms.htm).

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265