![Texas Instruments logo]

PGA460PSM-EVM With Ultrasonic Transducer User's Guide

The PGA460PSM-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 a transformer driven closed-top transducer when using the GUI.

NOTE: The PGA460PSM-EVM requires a separate master controller to enable full evaluation. Texas Instruments recommends pairing the PGA460PSM-EVM with the PGA460-Q1 EVM tools to enable full evaluation. To purchase and download the PGA460-Q1 EVM tools, go to the product folder: www.ti.com/tool/BOOSTXL-PGA460. This document assumes the MSP-EXP430F5529LP is used as the master controller.

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1   Introduction

The PGA460PSM-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. 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 PGA460-Q1 EVM's MSP430F5529 LaunchPad™ Development Kit (MSP-EXP430F5529LP) is used as an example 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.

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.

The PGA460PSM-EVM incorporates the minimum circuitry and components with the following features:

*   PGA460-Q1 ultrasonic sensor signal conditioner IC
*   Ultrasonic closed-top transducer
*   Center-tap push-pull transformer

Figure 1 shows the PGA460PSM-EVM architecture, identifying the key components and blocks previously listed.

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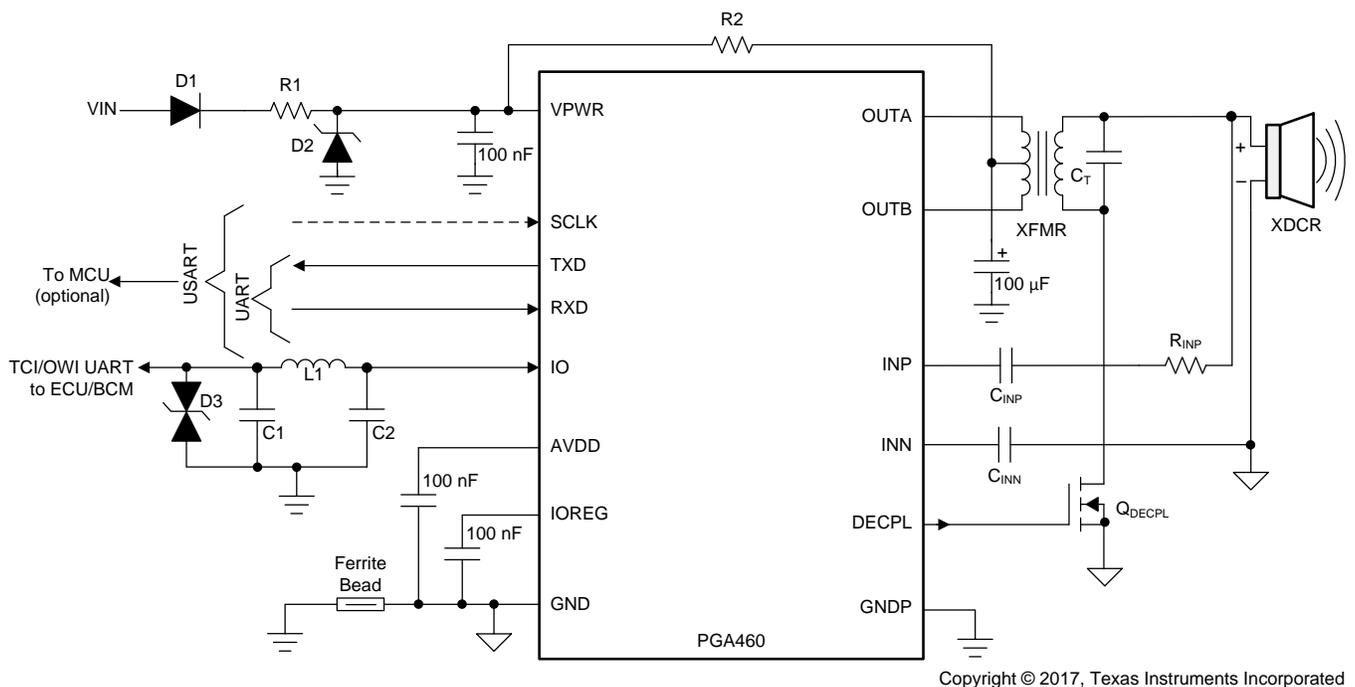
Figure 1. PGA460PSM-EVM Block Diagram

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.

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2   Setup and Operation

2.1   Required Equipment for Device Evaluation

The following elements are required for full evaluation of the PGA460PSM-EVM:

* MSP-EXP430F5529LP for USART (UART and SPI) communication
* 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) BOOSTXL-PGA460 BoosterPack (included with the purchase of the PGA460-F5529-BNDL) for One-Wire Interface communication
* (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 PGA460PSM-EVM offers four different interfaces to communicate to a master controller. These include: UART, SPI, OWU, and TCI.

2.2.2.1   UART and SPI for Logic Level Communication

UART and SPI are grouped in the USART communication mode of the PGA460-Q1, which are referenced to logic levels of 3.3 V or 5 V depending on the configuration of the TEST pin at start-up. The UART mode uses the TXD and TXD pins of the PGA460-Q1. The SPI mode uses the TXD, RXD, and SCLK pins of the PGA460-Q1. The SPI mode does not include a chip select pin because the PGA460-Q1 has a 3-bit address (UART_ADDR) in software. This enables an eight PGA460-Q1 device bus in both UART and SPI modes. The USART mode enables the PGA460PSM-EVM to connect directly to the MSP-EXP430F5529LP when the PGA460-Q1 digital interface is configured for 3.3-V operation (the PGA460-Q1 TEST pin is floating or grounded during device start-up).

To evaluate the PGA460-Q1 in USART mode, connect the following to the J2 connector of the PGA460PSM-EVM:

* J2-1: *PWR* to the positive terminal of a power supply at 6 V to 28 V
* J2-2: *GND* to the negative terminal of a power supply
* J2-3: *TXD* to the master controller's UART RXD pin (MSP-EXP430F5529LP P3.4) or SPI MISO pin (MSP-EXP430F5529LP P3.1)
* J2-4: *RXD* to the master controller's UART TXD pin (MSP-EXP430F5529LP P3.3) or SPI MOSI pin (MSP-EXP430F5529LP P3.0)
* J2-5: *SCLK* to the master controller's SPI CLK pin (MSP-EXP430F5529LP P3.2)

2.2.2.2 OWU and TCI for Battery Level Communication

One-Wire UART (OWU) and Time Command Interface (TCI) are grouped in the OWI communication mode of the PGA460-Q1, which are referenced to the VPWR level (6 V to 28 V) of the device. All OWI communication occurs at the PGA460-Q1 IO pin. OWU mode operates identically to UART mode, and allows for an eight PGA460-Q1 device bus. The IO_IF_SEL bit of the PGA460-Q1 determines which OWI mode is active. The factory default OWI mode is TCI; however, the IO_IF_SEL bit is not accessible through TCI mode. To change the OWI mode from TCI to OWU or vice-versa, use the IO-pin interface toggle pattern.
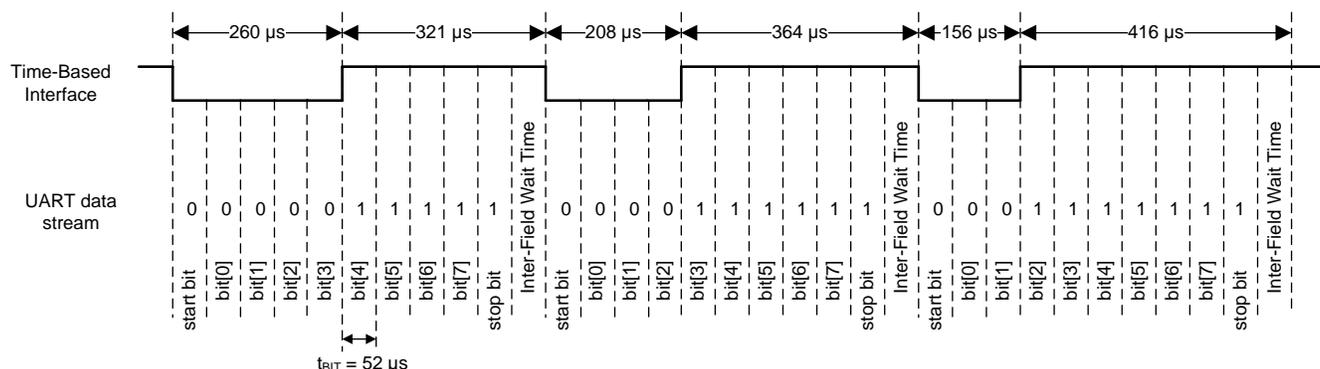
Figure 2. IO-Pin Interface Toggle Pattern

To evaluate the PGA460-Q1 in OWI mode, connect the following to the J1 connector of the PGA460PSM-EVM:

- J2-1: *V* to the positive terminal of a power supply at 6 V to 28 V
- J2-2: *IO* to a OWI transceiver for battery level to logic level conversion for master controller connection. Use the BOOSTXL-PGA460 J6-2 (IO) connector for OWI communication through the MSP-EXP430F5529LP.
- J2-3: *G* to the negative terminal of a power supply

2.3 Transformer Driver Configuration

The PGA460PSM-EVM offers evaluation of a mono-static ultrasonic sensor transformer-based driver configuration. 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 is a fixed-type Wurth 750317161. 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, 40-kHz PUI Audio UTR-1440K-TT-R is paired with the transformer. The center-tap voltage should not exceed 15-V due to a voltage doubling effect during burst at the PGA460's OUTA and OUTB pins, which are limited to 30 V.

WARNING

The PGA460PSM-EVM 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.

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

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3 Evaluation

This section provides a detailed description on connecting the PGA460PSM-EVM devices to the PGA460-Q1 EVM to reuse the PGA460-Q1 EVM GUI or PGA460 Energia Library and Code Examples.

3.1 *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. The PGA460PSM-EVM is an example of a small form-factor solution. Other 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.

3.1.1 IO Transceiver Circuit

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

- **Software Modification**: Disable the onboard PGA460's IO pin transceiver before connecting the external module. To do so, set the IO_IF_SEL bit to 0 and the IO_DIS bit to 1 to immediately disable 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-Q1 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 crosstalk 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'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 3-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.
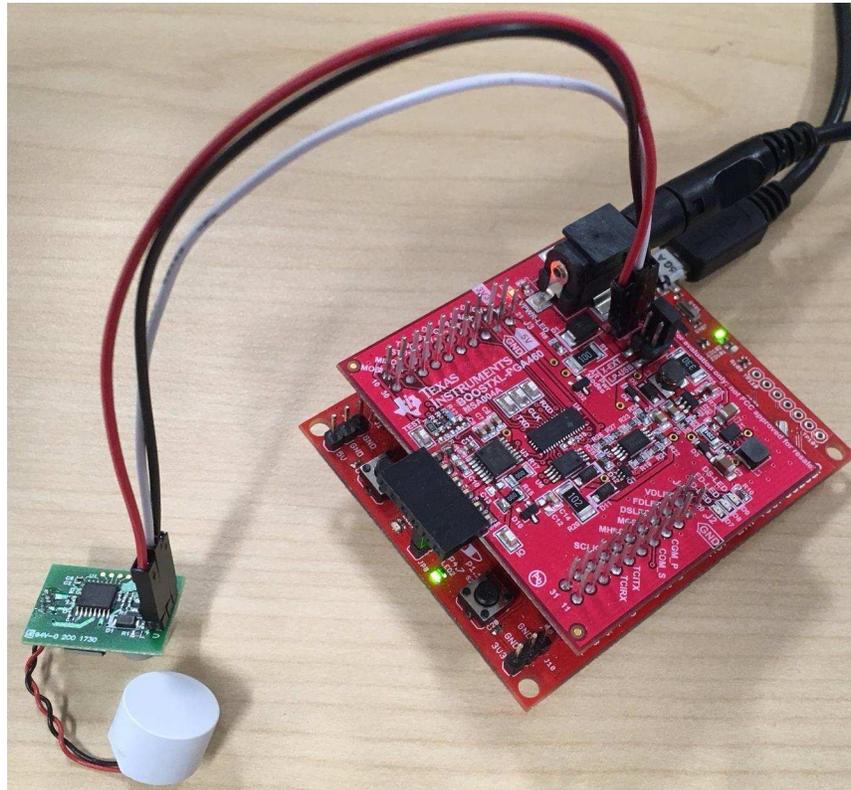
Figure 3. External OWI Evaluation Setup for PGA460PSM-EVM With Software Modification

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.

3.1.2 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 3.1.1. 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.
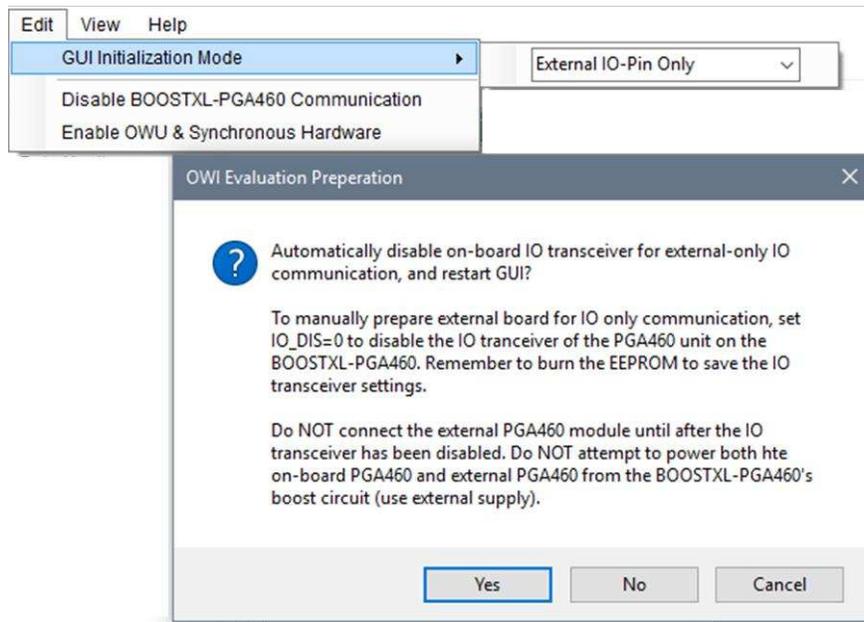
Figure 4. OWI Evaluation Page Preparation

When the *GUI Initialization Mode* is set, the GUI will always start in that mode until the initialization mode is changed from the Edit drop-down menu. 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.
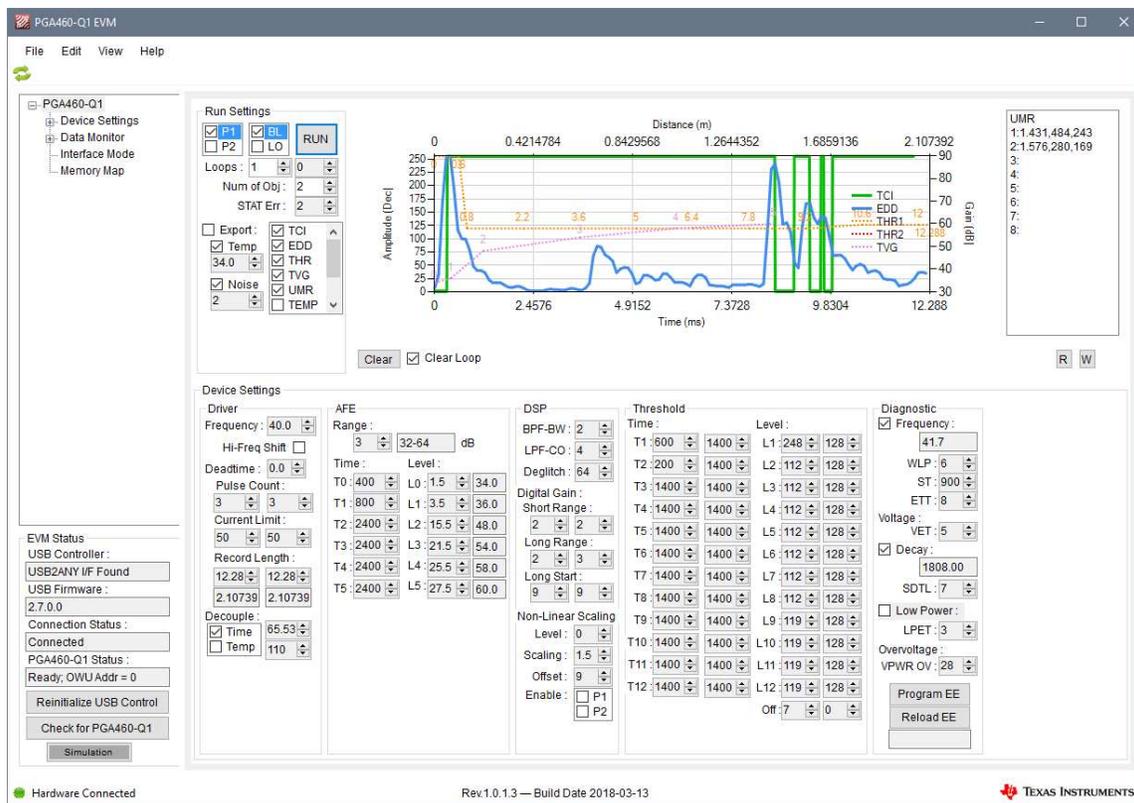
Figure 5. One-Wire Evaluation Page—Working Example

The OWI Evaluation settings are defined as follows:

Run Settings — Similar 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 that 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 will be 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.

For a complete explanation of the PGA460-Q1 GUI software and its capabilities, refer to the *PGA460-Q1 Ultrasonic Signal Conditioner EVM With Transducer User's Guide* (SLAU659).

3.2 Master Controller Firmware Development

To enable custom firmware development for a master controller, such as the MSP430F5529, an Energia open-source library of PGA460-Q1 example code is available.

GetDistance.ino— Single Device Basic Demo

The GetDistance.ino sketch is intended to demonstrate the basic time of flight capture routine when using a single PGA460-Q1 device. This demo continuously runs a burst-and-listen command and reads back the ultrasonic measurement results to report the time-of-flight converted to distance, echo peak amplitude, and echo width. All interfaces are supported.

BusDemo.ino— Multiple Device Basic Demo

The BusDemo.ino uses the approach of the GetDistance.ino sketch to burst-and-listen and read back the ultrasonic measurement results, but cycles this routine through the independent PGA460-Q1 device addresses. By connecting multiple PGA460-Q1 devices to a UART, SPI, or OWU bus, the time-of-flight converted to distance is extracted in a serial order. Up to eight PGA460-Q1 devices can be connected to a single bus due to the 3-bit UART_ADDR of the PGA460-Q1 device. The UART_ADDR of each PGA460-Q1 device must be preprogrammed prior to bus installation because the PGA460-Q1 does not support auto-addressing or daisy-chain addressing.

Triangulation.ino— Position Tracking Demo

The Triangulation.ino uses a UART, SPI, or OWU bus interface to compute and track an object's location using at least two PGA460-Q1 devices and the law of cosines. One PGA460-Q1 device must be hardware-configured to burst-and-listen, while the other PGA460-Q1 must be hardware-configured to listen-only (driver is floating). The PGA460's broadcast commands ensure the transmitter and receiver transducer elements are all synchronized for accurate triangulation.

AutosetThreshold.ino— Automatic Threshold Demo

The AutosetThreshold.ino collects the echo data dump data for a no-object burst-and-listen command, and automatically wraps the threshold times and levels based on down-sampled maximums. The user can specify the noise margin between the maximum down-sampled noise value, the spacing between each threshold time index, an automatic maximum level, and the number of echo data dump loops to collect and average.

4 Schematic, Bill of Materials, and Layout

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

4.1 Schematics
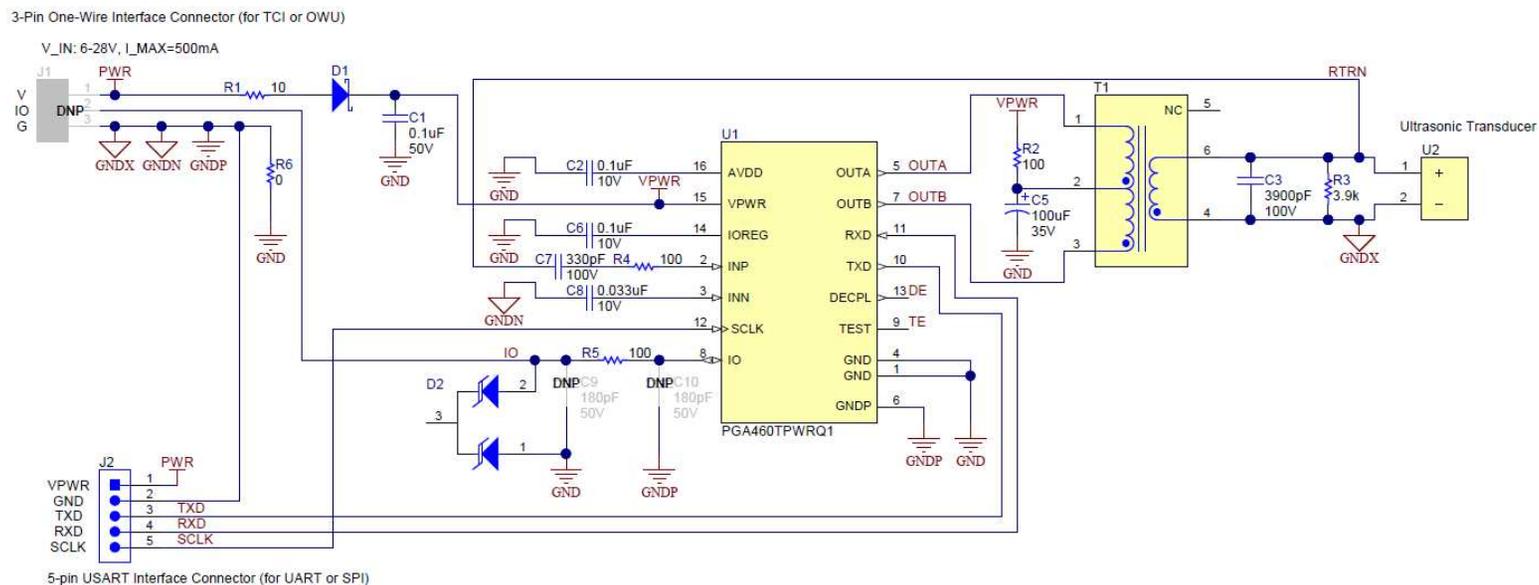
Figure 6. PGA460PSM-EVM Schematic

4.2 Bill of Materials

Table 1 lists the bill of materials (BOM) for the PGA460PSM-EVM.

Table 1. Bill of Materials

Designator	Quantity	Value	Description	Package	Part Number	Manufacturer
C1	1	0.1uF	CAP, CERM, 0.1 uF, 50 V, +/-10%, X7R, AEC-Q200 Grade 1, 0402	0402	CGA2B3X7R1H104K050BB	TDK
C2, C6	2	0.1uF	CAP, CERM, 0.1 uF, 10 V, +/-10%, X7R, 0402	0402	CL05B104KP5NNNC	Samsung Electro-Mechanics
C3	1	3900pF	CAP, CERM, 3900 pF, 100 V, +/-5%, C0G/NP0, AEC-Q200 Grade 1, 0603	0603	CGA3E1C0G2A392J080AC	TDK
C5	1	100uF	CAP, AL, 100 uF, 35 V, +/- 20%, 0.34 ohm, AEC-Q200 Grade 2, SMD	SMT Radial D8	EEE-FK1V101XP	Panasonic
C7	1	330pF	CAP, CERM, 330 pF, 100 V, +/-5%, C0G/NP0, 0402	0402	C1005C0G2A331J050BE	TDK
C8	1	0.033uF	CAP, CERM, 0.033 uF, 10 V, +/-10%, X7R, 0402	0402	GRM155R71A333KA01D	MuRata
C9, C10	0	180pF	CAP, CERM, 180 pF, 50 V, +/- 5%, C0G/NP0, 0402	0402	GRM1555C1H181JA01D	MuRata
D1	1	40V	Diode, Schottky, 40 V, 1 A, AEC-Q101, SOD-123F	SOD-123F	SS14FL	Fairchild Semiconductor
D2	1	27V	Diode, TVS, Uni, 27 V, 38 Vc, SOT-23	SOT-23	MMBZ27VCL-7-F	Diodes Inc.
J1	0		Header, 100mil, 3x1, Gold, TH	3x1 Header	TSW-103-07-G-S	Samtec
J2	1		Header, 100mil, 5x1, Gold, TH	5x1 Header	TSW-105-07-G-S	Samtec
R1	1	10	RES, 10, 5%, 0.25 W, AEC-Q200 Grade 0, 0603	0603	CRCW060310R0JNEAHP	Vishay-Dale
R2, R4, R5	3	100	RES, 100, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW0603100RFKEA	Vishay-Dale
R3	1	3.9k	RES, 3.9 k, 5%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW06033K90JNEA	Vishay-Dale
R6	1	0	RES, 0, 0%, 0.2 W, AEC-Q200 Grade 0, 0402	0402	CRCW04020000Z0EDHP	Vishay-Dale
T1	1	3mH	Transformer, 3000 uH, SMD	8.26x6.6mm	750317161	Wurth Elektronik
U1	1		PGA460TPWRQ1, PW0016A (TSSOP-16)	PW0016A	PGA460TPWRQ1	Texas Instruments
U2	1		Ultrasonic Xmr/Receiver, TH	Dia 14.4mm	UTR-1440K-TT-R	PUI Audio

4.3 Board Layout and Component Placement

Figure 7 and Figure 8 show the board layout and component placement.

Figure 7. Layout and Component Placement – Top Overview

Figure 8. Layout and Component Placement – Bottom Overview
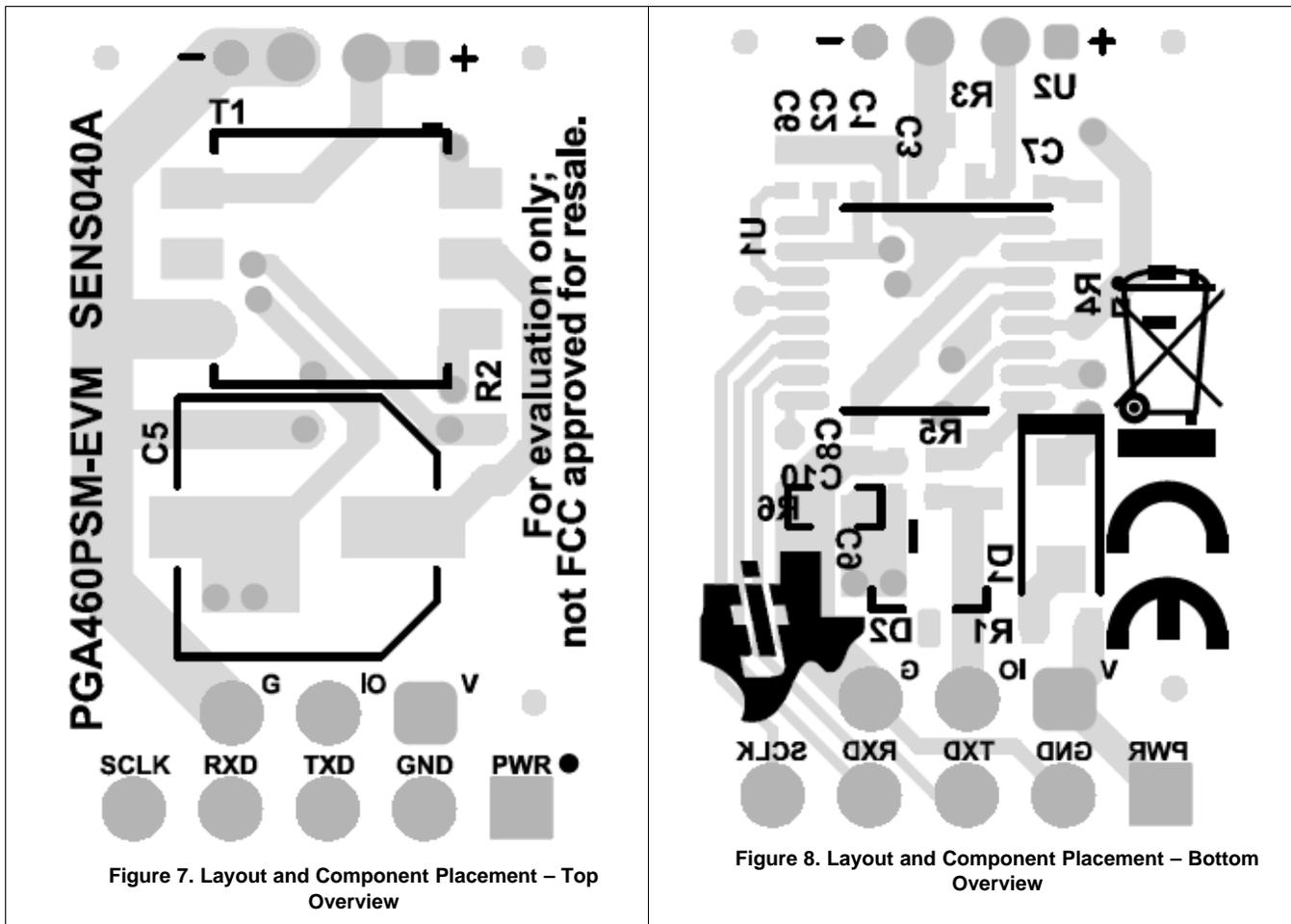
5 References

For additional references, see the following:

- Texas Instruments, *PGA460-Q1 Automotive Ultrasonic Signal Processor and Transducer Driver data sheet* (SLASEC8)
- Texas Instruments, *MSP430F5529 LaunchPad™ Development Kit (MSP-EXP430F5529LP) user's guide* (SLAU533)
- *PGA460-Q1 EVM GUI*
- *PGA460 Energia Library and Code Example*

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.

WARNING

Evaluation Kits 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 shall operate the Evaluation Kit within TI's recommended guidelines and any applicable legal or environmental requirements as well as reasonable and customary safeguards. Failure to set up and/or operate the Evaluation Kit within TI's recommended guidelines may result in personal injury or death or property damage. Proper set up entails following TI's instructions for electrical ratings of interface circuits such as input, output and electrical loads.

NOTE:
EXPOSURE TO ELECTROSTATIC DISCHARGE (ESD) MAY CAUSE DEGREDATION OR FAILURE OF THE EVALUATION KIT; TI RECOMMENDS STORAGE OF THE EVALUATION KIT IN A PROTECTIVE ESD BAG.

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.