User's Guide
SLAU822A–December 2019–Revised April 2020

TUSS44x0 EVM for Ultrasonic Sensors User's Guide

The TUSS44x0 Evaluation Module (EVM) lets users evaluate the functionality of Texas Instrument's TUSS4440 and TUSS4470 ultrasonic sensor-signal conditioner and driver integrated circuits. The TUSS4440 and TUSS4470 devices are highly integrated transducer drive analog front-end devices for industrial ultrasonic applications. This user's guide describes both the hardware platform containing a sample TUSS4440 (BOOSTXL-TUSS4440) or TUSS4470 (BOOSTXL-TUSS4470) device, and the graphical user interface (GUI) software used to configure and operate the device. This EVM can be used to display the ultrasonic echo envelope and time-of-flight measurement results of the transducer when used with the GUI.

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Trademarks

1 Introduction

The BOOSTXL-TUSS44x0 EVM is a fully assembled evaluation module (EVM) designed for the combined evaluation of the TUSS44x0 ultrasonic-sensor signal conditioner IC and ultrasonic transducer.

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 and control the TUSS44x0 through SPI and GPIO interfaces.

NOTE: The BOOSTXL-TUSS44x0 requires an external master controller to evaluate the TUSS44x0. The TUSS44x0 is exclusively a slave device.

The MSP-EXP430F5529LP is controlled by commands received from the BOOSTXL-TUSS44x0 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 TUSS44x0 EVM allows alternative external master communication to the TUSS44x0.

The BOOSTXL-TUSS44x0 incorporates all required circuitry and components for operation with the following features:

- TUSS44x0 ultrasonic sensor signal conditioner IC
- Multiple test points for various analog and digital signals
- Ultrasonic sensing transducer for mono-static time-of-flight measurements

Figure 1 shows the TUSS44x0 EVM architecture, identifying the key components and blocks previously listed.

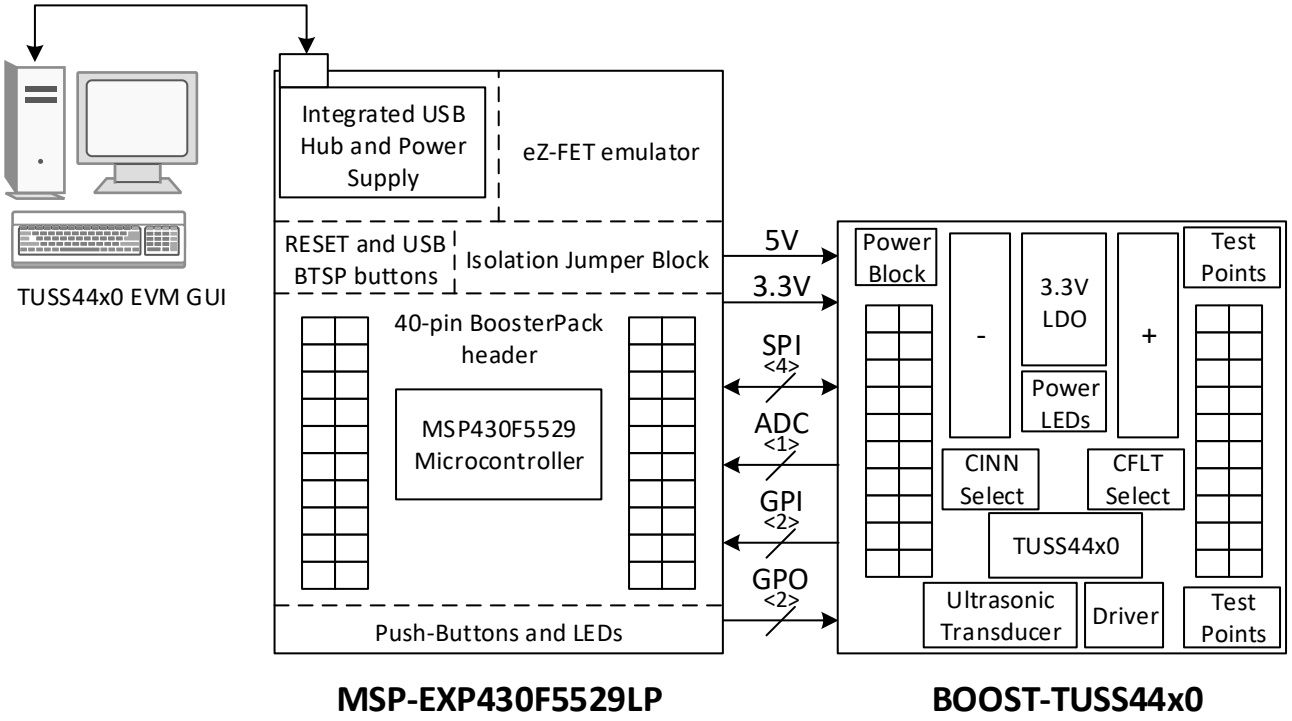


Figure 1. BOOSTXL-TUSS44x0 EVM Block Diagram

2 Setup and Operation

2.1 BOOSTXL-TUSS44x0 (Active EVM) Setup and Operation

2.1.1 Required Equipment for Device Evaluation

The following elements are required for proper operation and to receive consistent results as described in this document:

- BOOSTXL-TUSS4440 or BOOSTXL-TUSS4470 BoosterPack Plug-in Module
- MSP-EXP430F5529LP (included with the purchase of the TUSS44x0-F5529-BNDL)
- TUSS44x0 EVM GUI (TUSS Gen III EVM GUI) download from TUSS44x0 product page
- A computer running an operating system of Windows 7 or later, and .NET Framework 4.5
- Micro-USB to USB cable (included with the purchase of the TUSS44x0-F5529-BNDL)
- (Optional) A single power supply unit, battery, or AC/DC adapter to provide a voltage output from 5 V to 36 V and a current output up to 500 mA.

2.1.2 Initial EVM Setup

2.1.2.1 Setup Instructions

The user requires two separate boards from Texas Instruments to assemble the TUSS44x0 EVM, as shown in Figure 2.

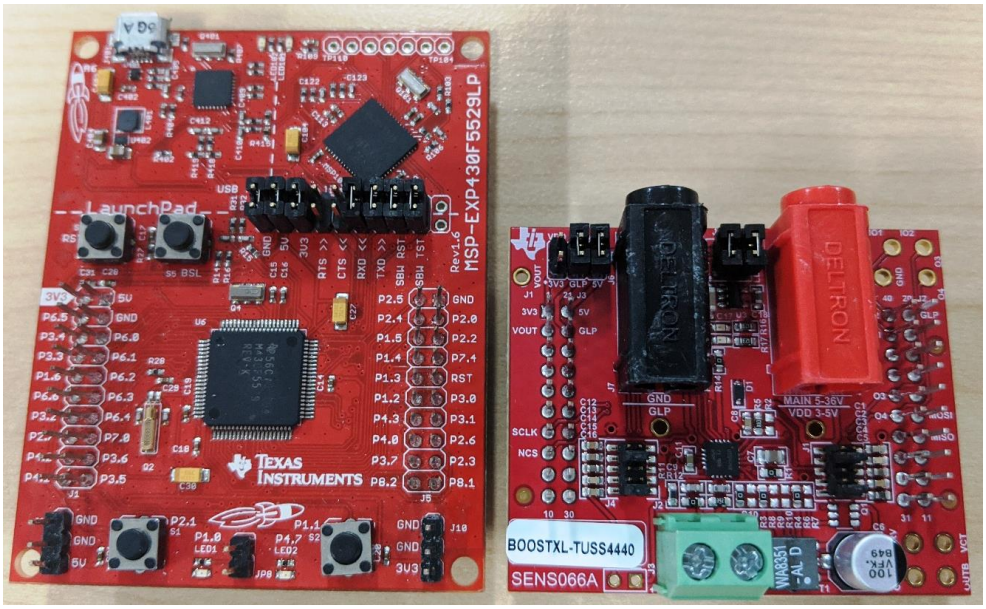


Figure 2. EVM Boards - Separated

To properly evaluate the TUSS44x0 EVM solution, connect and assemble the two boards as described in these steps:

1. Stack the BOOSTXL-TUSS44x0 board on top of the MSP-EXP430F5529LP. Pin 1 of the MSP-EXP430F5529LP must align with pin 1 of the BOOSTXL-TUSS44x0 LaunchPad-BoosterPack connector (J1).
2. Position the power mode jumper for the intended use-case (see Figure 3).
3. Connect the transducer to the terminal block at J2.
4. Set the CFLT shunt(s) at J1 and CINN shunts(s) at J4 to most closely equal (or rounded up to) the calculated capacitance values based on the transducer frequency.
5. Connect the micro-USB cable to a PC (see Section 2.1.2.2).
6. If using an external power supply, turn on the supply (see Section 2.1.2.2).

Figure 3 shows the assembled solution for the BOOSTXL-TUSS44x0 board configuration.

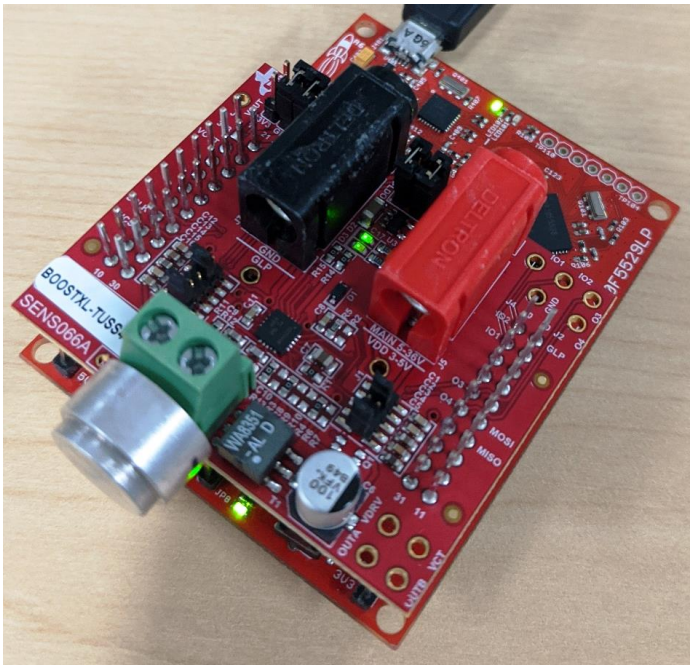


Figure 3. EVM Boards - Assembled

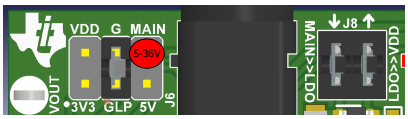
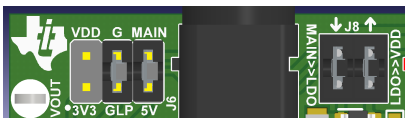
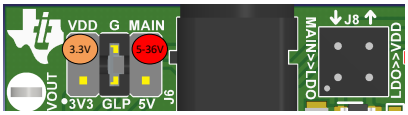
WARNING

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.

2.1.2.2 Power Mode Jumper Settings

The BOOSTXL-TUSS44x0 EVM has an alternative power mode selector jumper block (J6). 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 POSITIONS	DESCRIPTION	VISUAL REFERENCE
Standard (Default)	J6 Pin 1-2 Open J6 Pin 3-4 Short J6 Pin 5-6 Open J8 Pin 1-2 Short J8 Pin 3-4 Short	The MSP-EXP430F5529LP is powered by USB, and the TUSS44x0 driver voltage (VPWR) is powered by an external source at J6 Pin 6 (MAIN) or the red-banana jack connector J5. When the jumpers of J8 are installed, the MAIN to 3.3-V LDO rail from the on-board TPS7B6933 LDO supplies the TUSS44x0 voltage regulator input (VDD).	
USB Only (Out-of-Box)	J6 Pin 1-2 Open J6 Pin 3-4 Short J6 Pin 5-6 Short J8 Pin 1-2 Short J8 Pin 3-4 Short	The MSP-EXP430F5529LP and BOOSTXL-TUSS44x0 are powered by USB. This power mode uses the 5-V USB supply at the TUSS44x0 driver voltage with a recommended maximum current of 100 mA. When the jumpers of J8 are installed, the MAIN to 3.3-V LDO rail from the on-board TPS7B6933 LDO supplies the TUSS44x0 voltage regulator input (VDD).	
External Only	J6 Pin 1-2 Open J6 Pin 3-4 Short J6 Pin 5-6 Open J8 Pin 1-2 Open J8 Pin 3-4 Open	The BOOSTXL-TUSS44x0 driver voltage and voltage regulator input supplies come from two independent external sources: J6 Pin 6 or J5 (MAIN) and J6 Pin 2 (VDD). This options requires all jumpers at J8 to be removed to disable and disconnect the 3.3-V LDO input and output.	

MAIN is rated for a voltage range of 5 V to 36 V, and VDD is rated for a voltage of 3.3 V when paired with the MSP-EXP430F5529LP master. VDD can be increased to 5.0 V if paired with a different microcontroller master.

The LaunchPad MCU is known to create noise at the TUSS44x0 AFE. If the noise becomes too large in amplitude, especially for high-pass filter mode measurements, then TI recommends to make the LaunchPad ground and BoosterPack ground common at the external power supply (if applicable) by removing the shunt at J6 Pin 3-4. GLP is an abbreviation for Ground of LaunchPad. It can only be made common to the BoosterPack ground through jumper at J6 Pin 3-4. This shunt is required for the USB Only power mode of evaluation.

2.2 BOOST-TUSS44x0 (Discontinued EVM) Setup and Operation

2.2.1 Required Equipment for Device Evaluation

The following elements are required for proper operation and to receive consistent results as described in this document:

- BOOST-TUSS4440 or BOOST-TUSS4470 BoosterPack Plug-in Module
- MSP-EXP430F5529LP (included with the purchase of the TUSS44x0-F5529-BNDL)
- TUSS44x0 EVM GUI (TUSS Gen III EVM GUI) download from TUSS44x0 product page
- A computer running an operating system of Windows 7 or later, and .NET Framework 4.5
- Micro-USB to USB cable (included with the purchase of the TUSS44x0-F5529-BNDL)
- (Optional) A single power supply unit, battery, or AC/DC adapter to provide a voltage output from 5 V to 36 V and a current output up to 500 mA.

2.2.2 Initial EVM Setup

2.2.2.1 Setup Instructions

The user requires two separate boards from Texas Instruments to assemble the TUSS44x0 EVM, as shown in Figure 4.

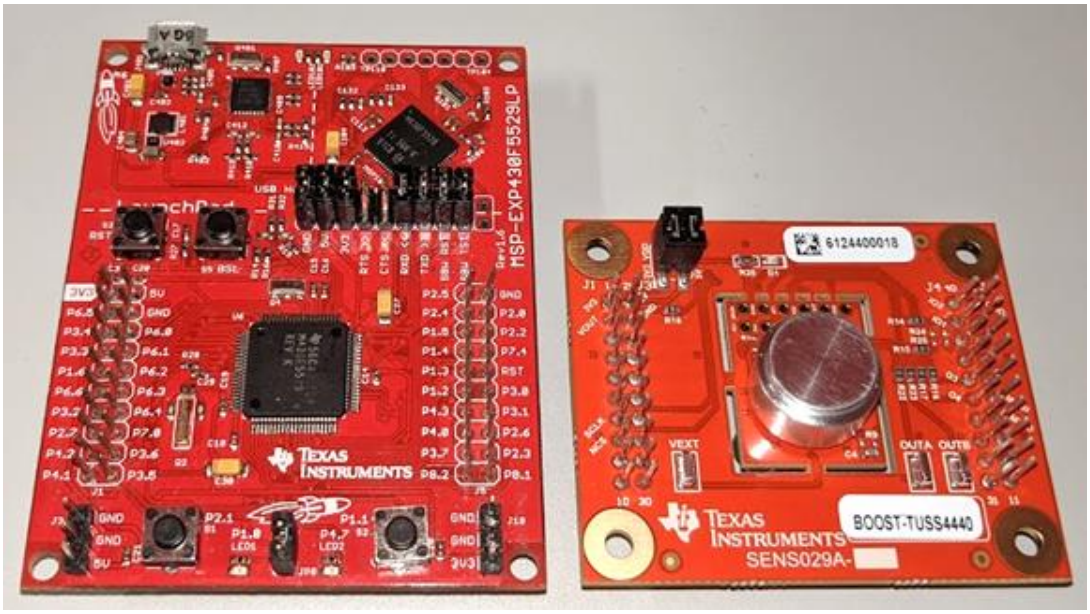


Figure 4. EVM Boards - Separated

To properly evaluate the TUSS44x0 EVM solution, connect and assemble the two boards as described in these steps:

1. Stack the BOOST-TUSS44x0 board on top of the MSP-EXP430F5529LP. Pin 1 of the MSP-EXP430F5529LP must align with pin 1 of the BOOST-TUSS44x0 LaunchPad-BoosterPack connector (J1).
2. Position the power mode jumper for the intended use-case (see Figure 5).
3. Connect the micro-USB cable to a PC (see Section 2.2.2.2).
4. If using an external power supply, turn on the supply (see Section 2.2.2.2).

Figure 5 shows the assembled solution for the BOOST-TUSS44x0 board configuration.

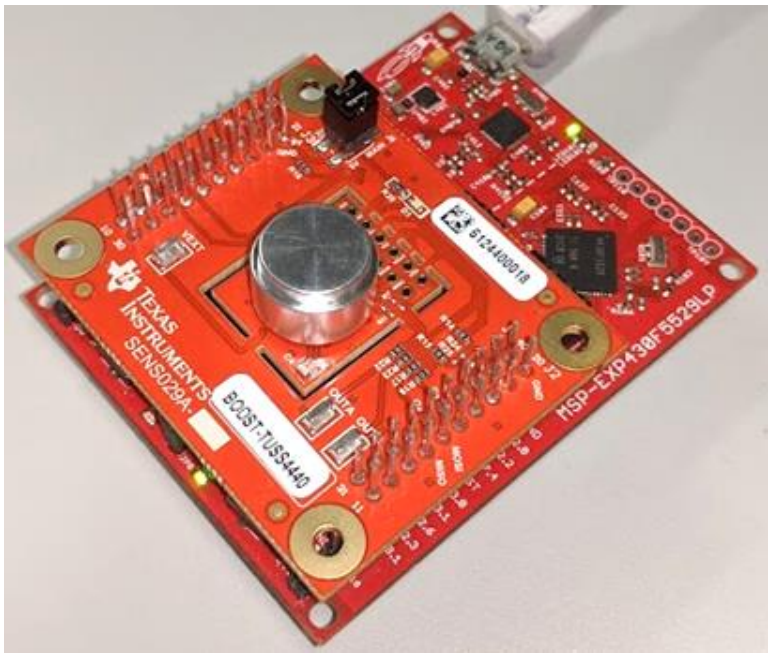


Figure 5. EVM Boards - Assembled

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.

2.2.2.2 Power Mode Jumper Settings

The BOOST-TUSS44x0 EVM has an alternative power mode selector jumper block (J6). Depending on the use-case, the assembled EVM can be powered from a variety of single or multiple power sources. Table 2 lists each power mode with the jumper position of the power mode selector block.

Table 2. Power Mode Jumper Position

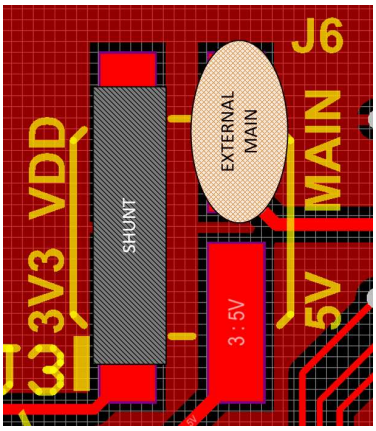
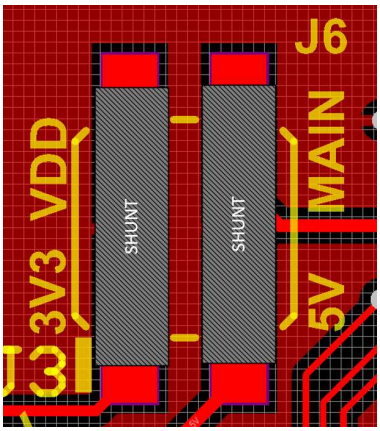
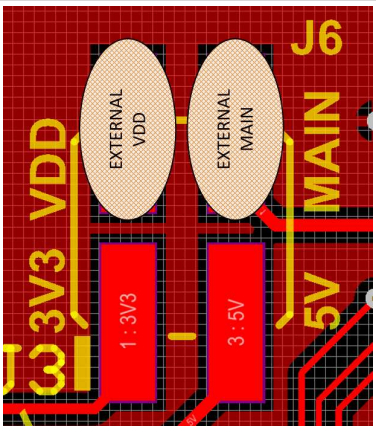
POWER MODE	JUMPER POSITIONS	DESCRIPTION	VISUAL REFERENCE
Standard (Default)	Pin 1-2 Short Pin3-4 Open	The MSP-EXP430F5529LP is powered by USB, and the TUSS44x0 driver voltage is powered by an external source at J6 Pin 4 (MAIN). The 3.3-V LDO rail from the LaunchPad™ Development Kit supplies the TUSS44x0 voltage regulator input.	
USB Only (Out-of-Box)	Pin 1-2 Short Pin 3-4 Short	The MSP-EXP430F5529LP and BOOST-TUSS44x0 are powered by USB. This power mode uses the 5-V USB supply at the TUSS44x0 driver voltage with a recommended maximum current of 100 mA. The 3.3-V LDO rail from the LaunchPad™ Development Kit supplies the TUSS44x0 voltage regulator input.	

Table 2. Power Mode Jumper Position (continued)

POWER MODE	JUMPER POSITIONS	DESCRIPTION	VISUAL REFERENCE
External Only	Pin 1-2 Open Pin 3-4 Open	The BOOST-TUSS44x0 driver voltage and voltage regulator input supplies come from two independent external sources: J6 Pin 4 (MAIN) and J6 Pin 2 (VDD). TI recommends full evaluation and development of the TUSS44x0 be performed in this mode for best results.	

MAIN is rated for a voltage range of 5 V to 36 V, and VDD is rated for a voltage of 3.3 V when paired with the MSP-EXP430F5529LP master. VDD can be increased to 5.0 V if paired with a different microcontroller master.

2.3 Installing the Graphical User Interface Software

Before the TUSS44x0 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 TUSS44x0 EVM GUI, go to www.ti.com/product/TUSS44x0-EVM

2.4 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 MSPEXP430F5529LP illuminates, and all available green LEDs on the BoosterPack illuminate.

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 *TUSS Generation III EVM GUI* application. Run the latest version of the *TUSS Generation III EVM GUI-x.x.x.x.exe* file. If the user must move the .exe file from the original install location, the Microsoft.VisualBasic.PowerPacks.Vs.dll files must be moved with the .exe to the same directory, or the GUI will fail to load.

3.2 Flash Program MSP-EXP430F5529LP

If the MSP-EXP430F5529LP has not been flash programmed with the required TUSS44x0 EVM batch (.bat) firmware, the GUI automatically prompts the user to do this at start-up, or after the MSP-EXP430F5529LP is plugged in to the USB port.

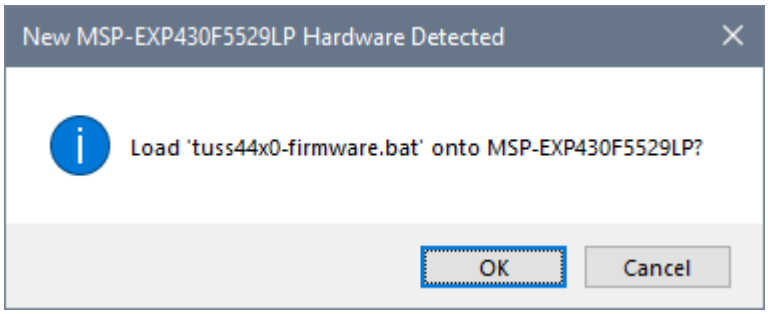


Figure 6. Automatic Prompt to Flash Program MSP-EXP430F5529LP

The GUI installs the *tuss44x0-firmware.bat* file to the *My Documents* folder under the *Texas Instruments* > *TUSS Generation III* > *TUSS44x0* > *UNIFLASH* 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 *tuss44x0-firmware.bat* in the default installation will be selected in the background and run.

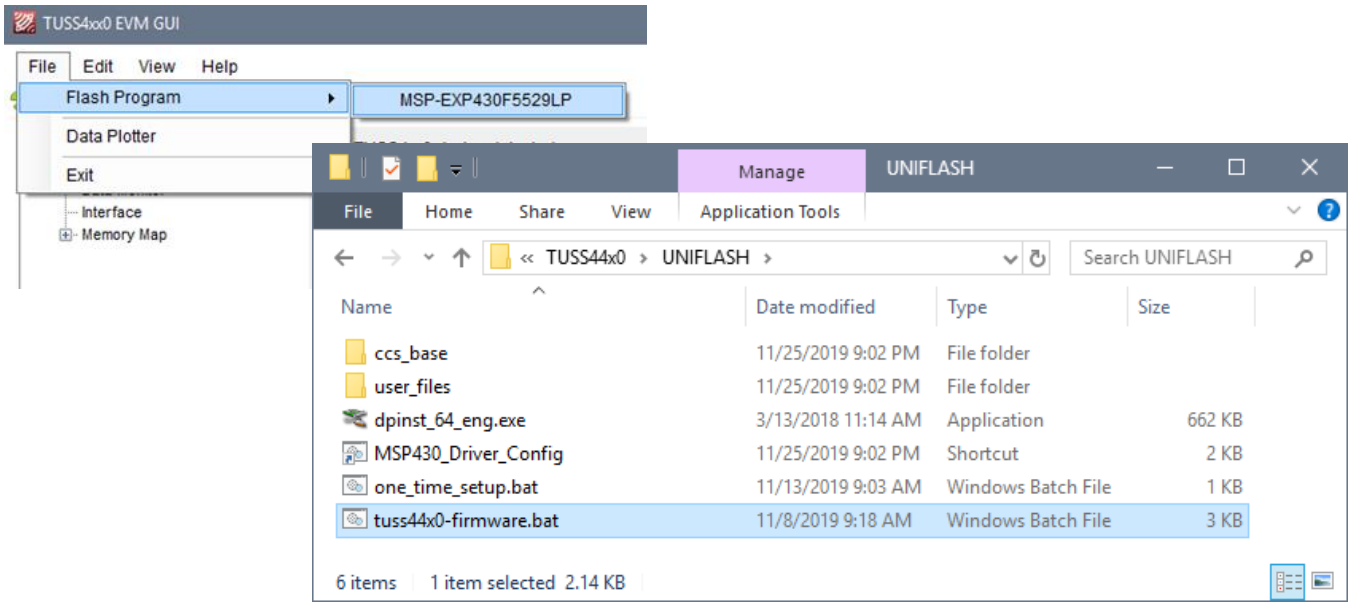


Figure 7. Manually Flash Program MSP-EXP430F5529LP

The MSP-EXP430F5529LP must be flash programmed only once, typically when first connecting to 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 TUSS44x0 EVM (although these drivers should have been previously installed by the TUSS44x0 EVM GUI install wizard).

The *tuss44x0-firmware.bat* in *My Documents* is only compatible with a 64-bit operating system. For a 32-bit version of the *tuss44x0-firmware.bat* file, navigate to the install path of the TUSS44x0 EVM GUI, and unzip *tuss44x0_fw_installer_32bit.zip*. Run the *one_time_setup.bat* file in this unzipped directory.

3.3 TUSS44x0 GUI Start-Up Screen

The TUSS44x0 GUI enables users to quickly assess whether the EVM hardware is operational, explore the TUSS44x0 device features, and modify the register configuration for optimal performance.

Figure 8 shows the default starting screen of the TUSS44x0 GUI. If the EVM is connected properly, the screen should display the following EVM Status indicators in the bottom left corner of the GUI:

- Controller: MSP-EXP430F5529LP
- Firmware: 03000000 or later
- Status: COMx
- Device:TUSS4440 or TUSS4470

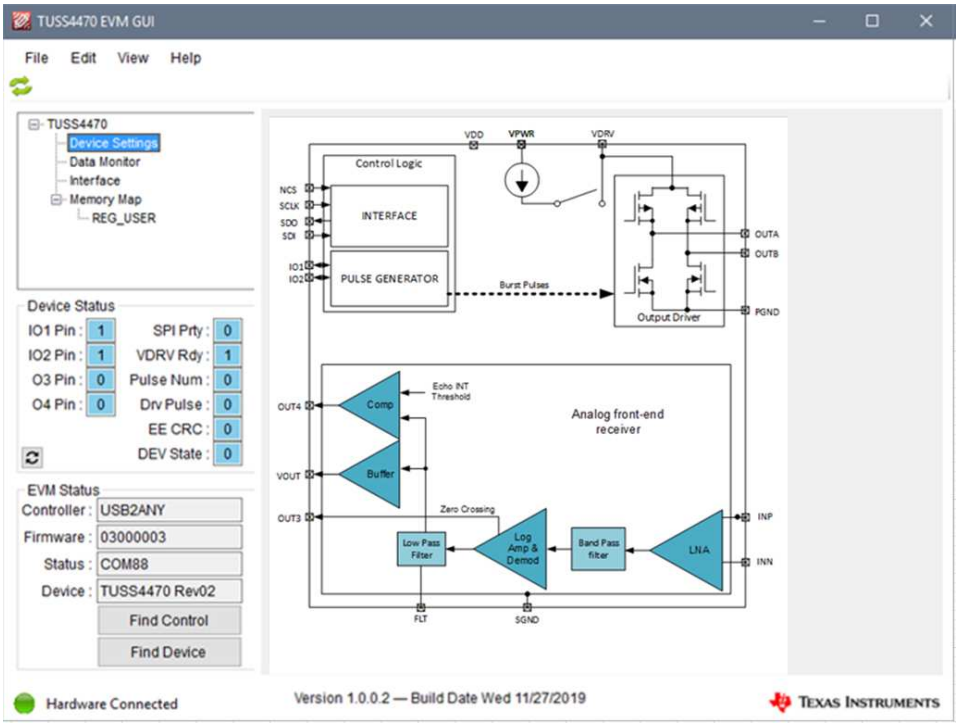


Figure 8. TUSS44x0 EVM GUI Starting Screen With Successful EVM Connection Status

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 *Data Monitor* 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 TUSS44x0 GUI Left Panel

The left panel of the GUI contains the listing of pages in a tree view format, and the current status of USB connectivity 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. Four primary nodes are listed, and each loads a different page (see Figure 9 for an example).

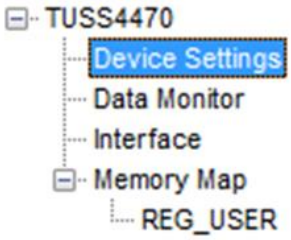


Figure 9. Tree View Page Listing

3.4.2 Device Status

The GUI monitors the device status by periodically reading back the device status registers. All status error bits must read a given state for the device to be in the normal or working state, and is indicated by a blue back color. If any of the status bits read an irregular state, an operational fault exists or the register map is corrupt, and the device may not function properly, and is indicated by a red back color. The Device Status automatically updates after each time of flight command measurement. To manually update the Device Status fields at any time, click the refresh button in the bottom left corner.

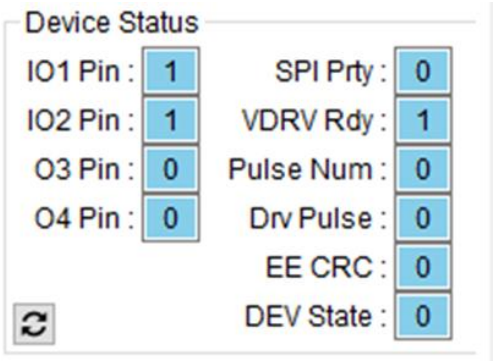


Figure 10. Faults and Errors Tab

Table 3 lists descriptions of the device error status bits.

Table 3. Device Error Status Descriptions

DEVICE STATUS	DESCRIPTION
VDRV_READY	Set when VDRV power regulator has reached the programmed voltage level. This is also indicated by VDRV_READY bit.
PULSE_NUM_FLT	Set if the burst sequence was terminated before completing the pulse number selected. This is also indicated by PULSE_NUM_FLT bit.
DRV_PULSE_FLT	Set if there is a "stuck" fault detected during pulsing in a burst sequence. This is also indicated by DRV_PULSE_FLT bit.
EE_CRC_FLT	Set if there is a CRC Error when loading internal EEPROM memory. This is also indicated by EE_CRC_FLT bit.
DEV_STATE	Device State: 00 - LISTEN, 01 - BURST, 10 - STANDBY, 11 - SLEEP

Table 4 lists descriptions of the device information status bits.

Table 4. Device Information Status Descriptions

DEVICE STATUS	DESCRIPTION
IO1 Pin	IO1 Pin logic level status used for driver control.
IO2 Pin	IO2 Pin logic level status used for driver control.
O3	O3 Pin logic level status used for zero-crossing.
O4	O4 Pin logic level status used for echo interrupt.

3.4.3 EVM Status

The GUI can automatically detect the presence of the MSP-EXP430F5529LP after being flash programmed with the *tuss44x0-firmware.bat* file. In the event of a successful, partially successful, or failed connection between the PC, MSP-EXP430F5529LP, and TUSS44x0 EVM, the EVM status fields are updated according to Table 5.

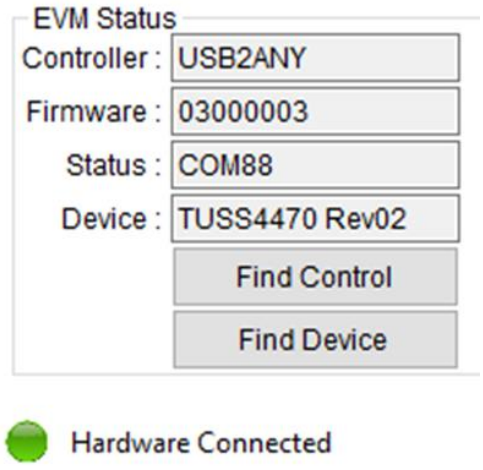


Figure 11. EVM Status – Success

Table 5. EVM Status Possibilities

EVM STATUS	SUCCESS	PARTIAL SUCCESS	FAILURE
USB Controller	MSP-EXP430F5529LP	MSP-EXP430F5529LP	(blank)
USB Firmware	03000000	03000000	(blank)
Connection Status	COMx	COMx	(blank)
Device Status	TUSS44x0	N/A or Wrong Addr or (blank)	N/A or Wrong Addr or (blank)

Table 6 lists a definition for each EVM Status field.

Table 6. EVM Status Field Definitions

EVM STATUS	DEFINITION
USB Controller	The MSP-EXP430F5529LP is programmed with TI's USB2ANY Controller (U2A) host interface (I/F) controller firmware. The GUI calls API functions for the U2A to execute. The U2A I/F is the only compatible USB controller for the TUSS44x0 EVM GUI.
USB Firmware	The U2A firmware may be updated for improvements or bug fixes by TI. Version 03000000 is the initially released version. See the About section of the GUI to determine which version of firmware is available and expected for compatible GUI operation.
Connection Status	Typically, only one U2A is connected to a PC, though the U2A APIs are able to distinguish multiple U2A devices on the same USB bus by serial COM port identification. The GUI automatically detects and uses the first available U2A COM port. TI advises that a single U2A I/F be connected to your PC during the evaluation of the TUSS44x0 EVM.
Device Status	When a SPI read command is successfully executed during TUSS44x0 GUI start-up, the status will update with the connected device part number based on the Dev ID value. At the GUI's start-up, a read command of the Device ID is attempted to determine which specific part number is available. If the status reads back fails to *N/A or Wrong Addr*, use the following checklist to troubleshoot: • Is the BoosterPack™ Plug-in Module correctly stacked on the LaunchPad™ Development Kit? • Is the TUSS44x0 EVM powered with a voltage of 5 to 36 V? • Is the power supply unit able to source at least 20 mA at VDD? • If the device was powered after the GUI was first initialized, click the *Find Device* button to retry the TUSS44x0 check.

If the GUI does not automatically detect the presence of the EVM, the *Find Device* button is available to manually check for the USB controller. When the USB controller is manually detected and successfully connected, the *Find Device* button can be used to manually scan for a connected TUSS44x0 device by issuing the aforementioned Device ID register read command. If the device is power cycled during GUI evaluation, click the *Find Device* button to refresh the GUI controls and indicators.

In the event that no TUSS44x0 EVM is connected, but the user is still interested in an example of the GUI configuration for a working device, the *Simulate* button populates all controls with default values and lets the user run the GUI with simulated results. The TUSS44x0 Status field displays *SIMULATE* when in simulation mode. When an actual TUSS44x0 device is connected, the status updates automatically.

3.5 TUSS44x0 GUI Center Panel

The center panel is the primary interface for the user to configure the TUSS44x0 device settings, read/write/program device memory, and monitor/export the ultrasonic time-of-flight results.

3.5.1 Device Settings

The device settings give the user access to the TUSS44x0 random access memory (RAM), which includes driver strength, receiver sensitivity, logarithmic amplifier gain, and test mode controls. At power-up, the device always defaults with generic settings for out-of-box performance, but typically requires additional optimization by adjusting the device settings.

3.5.1.1 Block Diagram

The block diagram representation of the TUSS44x0 is a simplified view of the settings on the *Data Monitor* page superimposed onto a visual equivalent of each device function.

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. The frequency of a single transducer is fixed, but the drive strength can be reduced or increased using the number of pulses and current limit.

Receiver — The gain selected on the block diagram view enables or disables various stages of the log amplifier. This group is specific to amplifying the raw ultrasonic echo received. A small gain is favorable for short range measurements to prevent saturation of the returning ultrasonic signal. A large gain is favorable for long-range measurements. The bandpass filter bandwidth is able to filter the raw amplified ultrasonic echo received from the AFE to create an analog echo envelope output at the VOUT pin.

3.5.2 Data Monitor

The *Data Monitor* page displays the ultrasonic echo data dump and the ultrasonic measurement results. Additional controls including bit field manipulation, data export, parameter sweeps, and external synchronized triggering is offered on this page.

3.5.2.1 Run Options

Use the Run Options panel to configure the time-of-flight settings and execute a time-of-flight command to update the chart and table results.

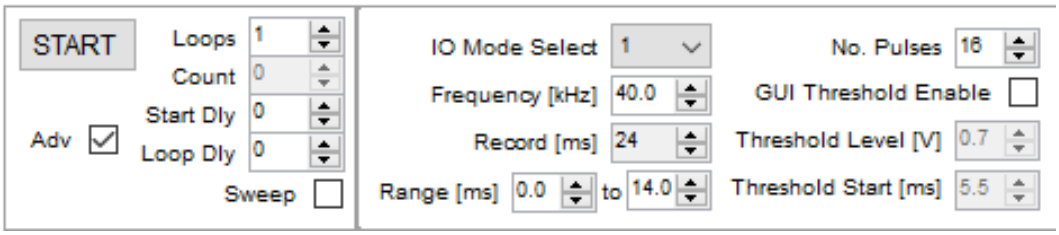


Figure 12. Data Monitor - Run Options

These settings are defined as follows:

START — I nitiates a time-of-flight command to update the Data Dump chart, Measurement & Diagnostic chart, and Tabulated Results. Applies the updated run option changes before executing the time-of-flight command. The command is executed using the SPI or GPIO interface channel designated by the selected IO Mode.

Adv — The Advanced Bit Field Controls (Adv) view control either hides (unchecked) or shows (checked) the Adv panel from the Data Monitor page. When visible, the REG_USER bit field values are updated on the Adv panel after every time-of-flight command.

Loops — The number of loops determines how many time-of-flight commands are automatically issued to the TUSS44x0 device by the GUI. To run an indefinite number of loops, set the value to 0.

Count — A counter to indicate how many time-of-flight commands have been executed in the given loop range.

Loop Delay — This field determines how much delay in milliseconds is added between each loop command.

Start Delay — This field determines how much delay in milliseconds is added before the first time-of-flight command is executed.

Sweep — Enables minimum to maximum parameter value sweep of each checked field in the Advanced Bitfield View panel. After the sweep is complete, the pre-sweep values are set.

IO Mode Select — Determines if IO Mode 0, 1, 2, or 3 will be used to generate a burst.

Frequency — Sets the frequency at which the IO1 and/or IO2 pins will toggle for burst generation. Configurable from 30 to 1000 kHz.

Record — Sets the record length of the ADC in 12 ms increments up to 73 ms. The MSP430F5529 ADC captures 2048 samples over the specified record length.

Range — Sets the minimum and maximum time values of the Data Dump chart to focus on a specific range within the record length.

Pulses — Sets the number of pulses to generate during burst. Configurable from 1 to 63 pulses.

GUI Threshold Enable — Enabled the GUI based threshold to find the peak amplitude from the Threshold Start in time above the Threshold Level in voltage.

Threshold Level — Sets the GUI based threshold level in 0.1-V increments.

Threshold Start — Sets the start time in milliseconds for when the GUI should start searching for a peak amplitude.

3.5.2.2 Data Dump

Plots and exports the graphical results for the VOUT echo envelope, echo interrupt, zero-crossing, and GUI threshold.

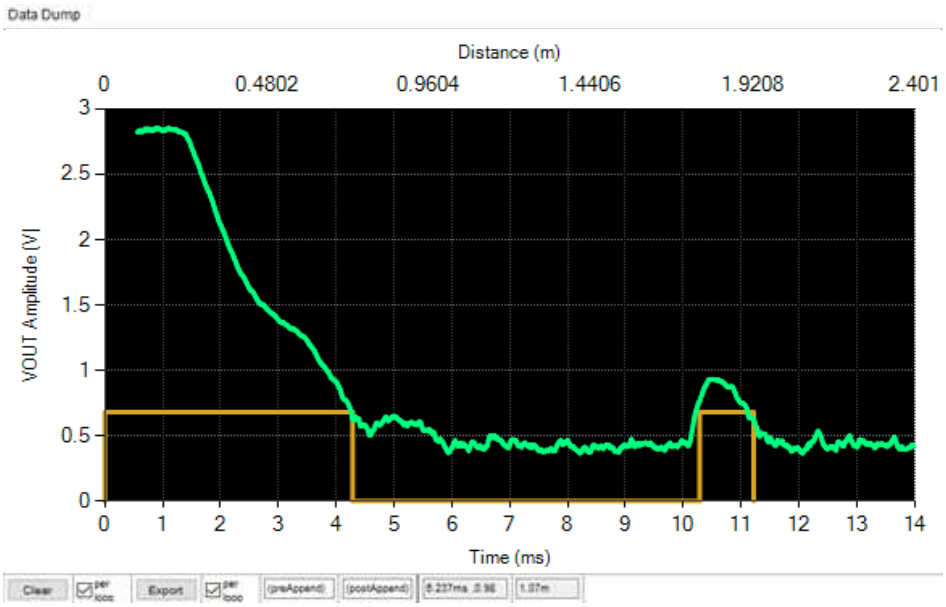


Figure 13. Data Monitor - Data Dump

Clear — Immediately removes all points from the chart.

Clear Per Loop — Removes all points from the chart before each time-of-flight command.

Export — Immediately exports the chart data as an XML file.

Export Per Loop — Exports the chart data as an XML file at the end of each time-of-flight command.

Pre-Append Export Name — A custom string to append to the beginning of the exported XML file.

Post-Append Export Name — A custom string to append to the end of the exported XML file.

Cursor Indicators — When any area of the chart is clicked, the cursor will report the approximate time (milliseconds), amplitude, and distance (m) at the indicators.

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.
- Configure the device settings for the selected profile. As a minimum requirement, the user is responsible for setting the transducer specified frequency, burst pulse count, and driver current strength. 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.

3.5.2.3 Measurements and Diagnostics

Plots and exports the echo time-of-flight converted to distance (meters) and amplitude per sample based on the GUI threshold.

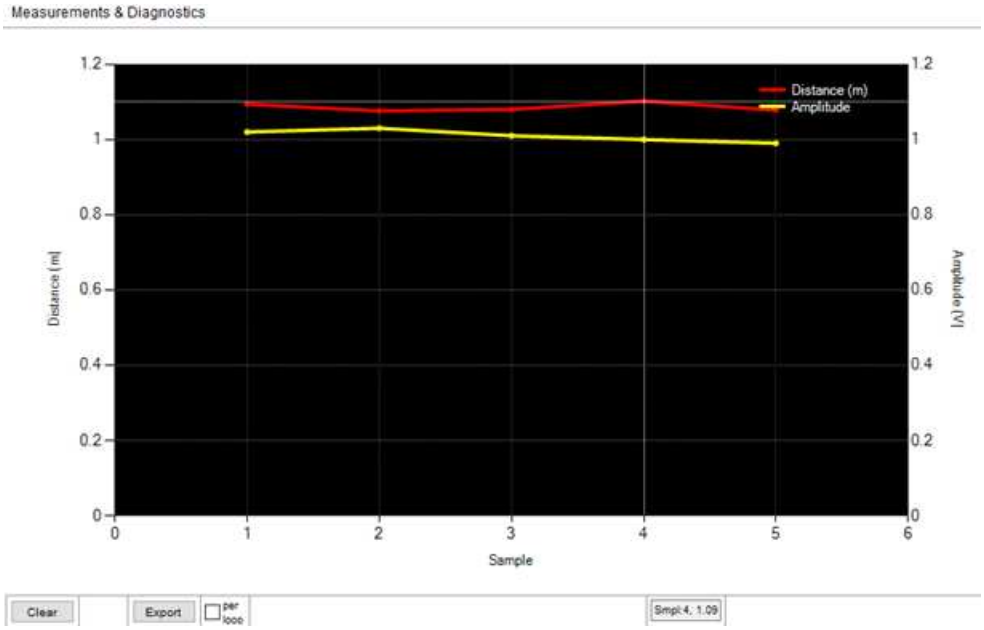


Figure 14. Data Monitor - Measurement and Diagnostics

Clear — Immediately removes all points from the chart.

Export — Immediately exports the chart data as an XML file.

Export Per Loop — Exports the chart data as an XML file at the end of each time-of-flight command.

Cursor Indicators — When any sample of the chart is clicked, the cursor will report the distance (meters) at the indicator .

3.5.2.4 Tabulated Results

Tabulates and exports the numerical results for the last command cycle's time-of-flight (milliseconds) result, time-of-flight converted to distance (meters) and amplitude, for one object based on the GUI threshold. The GUI always refers to the maximum VOUT amplitude value exceeding the threshold as the object. If the decay is captured within the GUI threshold start time, the GUI may assume the decay to be the object. TI recommends setting the GUI threshold start time to the end of decay. When the Echo Interrupt feature of pin O4 is enabled, the low-to-high toggle transition result is displayed in the Tabulated Results.

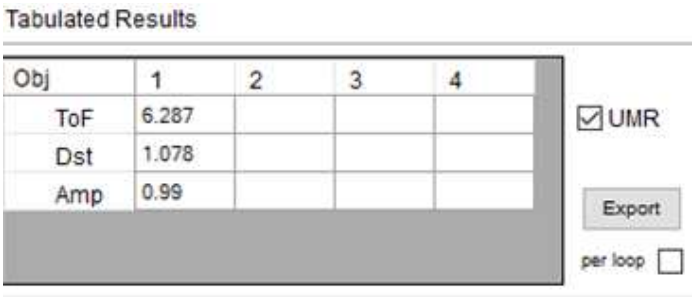


Figure 15. Data Monitor - Tabulated Results

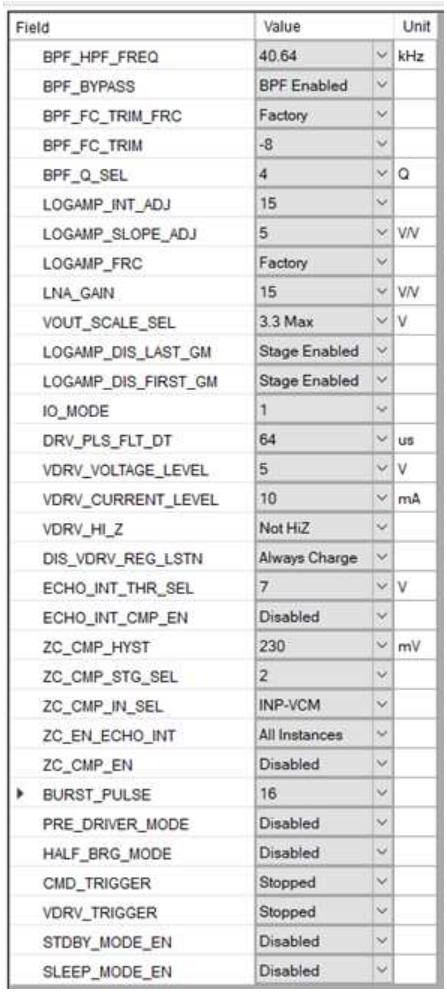
UMR Checkbox — When checked, updates the ultrasonic measurement results (UMR) table with the echo information.

Export — Immediately exports the table data as a CSV file.

Export Per Loop — Exports the table data as a CSV file at the end of each time-of-flight command.

3.5.2.5 Advanced Bit Field Controls

The Advanced Bit Field Controls (Adv) panel is a GUI-specific feature to display all bit field controls as user readable combo box selectable values. Additional features include a bit field sweep and external sync-trigger.



Field	Value	Unit
BPF_HPF_FREQ	40.64	kHz
BPF_BYPASS	BPF Enabled	
BPF_FC_TRIM_FRC	Factory	
BPF_FC_TRIM	-8	
BPF_Q_SEL	4	Q
LOGAMP_INT_ADJ	15	
LOGAMP_SLOPE_ADJ	5	V/V
LOGAMP_FRC	Factory	
LNA_GAIN	15	V/V
VOUT_SCALE_SEL	3.3 Max	V
LOGAMP_DIS_LAST_GM	Stage Enabled	
LOGAMP_DIS_FIRST_GM	Stage Enabled	
IO_MODE	1	
DRV_PLS_FLT_DT	64	us
VDRV_VOLTAGE_LEVEL	5	V
VDRV_CURRENT_LEVEL	10	mA
VDRV_HI_Z	Not HiZ	
DIS_VDRV_REG_LSTN	Always Charge	
ECHO_INT_THR_SEL	7	V
ECHO_INT_CMP_EN	Disabled	
ZC_CMP_HYST	230	mV
ZC_CMP_STG_SEL	2	
ZC_CMP_IN_SEL	INP-VCM	
ZC_EN_ECHO_INT	All Instances	
ZC_CMP_EN	Disabled	
BURST_PULSE	16	
PRE_DRIVER_MODE	Disabled	
HALF_BRG_MODE	Disabled	
CMD_TRIGGER	Stopped	
VDRV_TRIGGER	Stopped	
STDBY_MODE_EN	Disabled	
SLEEP_MODE_EN	Disabled	

Figure 16. Data Monitor - Advanced Bit Field Controls

3.5.2.5.1 Bit Fields

When the combo box control for a bit field is updated, the associated register is immediately updated. If a bit field value can be represented as the output of an equation, an adjacent text box automatically updates to reflect the resulting value at the given unit.

3.5.2.5.2 Bit Field Sweeps

For each available bit field in the Advanced Bit Field Control view, the GUI can be enabled to automatically sweep between a user defined range of acceptable values. To run the bit field sweep, select the bit field to be swept, check the En checkbox, and click the START button in the Run Options group. The bit field value automatically increments after each time-of-flight loop, and reruns until the maximum bit field value is reached.

3.5.2.5.3 External Sync and Trigger

To synchronize the time-of-flight command with an external system or another TUSS44x0 EVM, use the external sync and trigger run feature. When the En checkbox is checked, the GUI/EVM becomes a sync-slave, where BOOSTXL-TUSS44x0 pin-11 monitors for a low-to-high transition. The Master checkbox enables the GUI/EVM to act as the sync-master, such that the MSP-EXP430F5529LP forces a low-to-high transition on BOOSTXL-TUSS44x0's pin-13 when the START button is clicked in the Run Options group.

3.5.3 Interface Mode

The TUSS44x0 devices offers a SPI modes of communication to interface with a master controller. The SPI interface offers complete register access, and compatibility of the 3.3-V and 5.0-V low-logic level serial communication format for direct interfacing to other micro-controllers.

3.5.3.1 Serial Peripheral Interface (SPI)

The TUSS44x0 device includes a SPI digital communication interface. The main function of the SPI is to enable writes to and reads from all addresses available for SPI access, including access to all user RAM register memory locations on the TUSS44x0 device. The SPI digital communication is a master-slave communication link in which the TUSS44x0 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 17. Interface - SPI

The SPI page contains elements to configure master's SPI port, and manually send and receive command data. The controls available on the *SPI* tab are as follows:

- Setup

  Clock Rate — As part of the SPI configuration, the user can specify a SPI clock of up to 8 MHz. The GUI's default clock rate is 1 MHz.

  Configure Button — Applies the SPI configuration settings to the micro-controller.

- Single Frame Communication

  Read/Write Button —S ends a 16-bit SPI read/write frame.

  Single R/W Scripting Input — Allows for multiple 16-bit SPI read/write frames based on the following hex-input format with a semicolon delimiter: PACKET0;PACKET1;PACKET2 . For example: 2A8C;01FF;50B4;...

  Run Script — Runs the loaded script input. Each read/write command is executed with a 500 ms delay.

- IO Pin Configuration

  OUT HI — Immediately sets the state of the IOx pin to a logic-high 3.3-V output.

  OUT LO — Immediately sets the state of the IOx pin to a logic-low 0-V output.

  IN HI-Z — Immediately sets the state of the IOx pin to a floating input.

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.

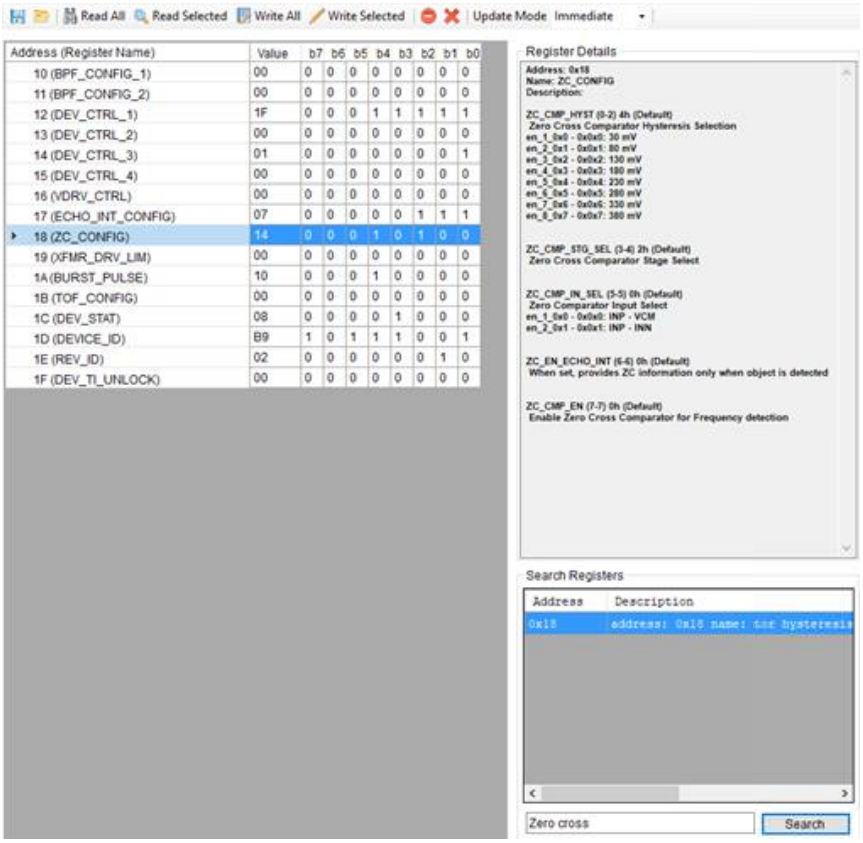


Figure 18. Memory Map Page

Table 7 defines the primary buttons at the top of the *Memory Map* page.

Table 7. 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.
Write Single		Write the value of the currently selected register, or all registers highlighted in yellow with pending changes.
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 and instantly writes to the modified register, and updates the associated *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 TUSS44x0 device with the changes, the *Write All* or *Write Single* buttons must be clicked.

A row on the *Memory Map* page highlighted blue indicates a selected row. A row on the *Memory Map* page highlighted yellow indicates a queued modification to the grid, but a pending write to the TUSS44x0 device.

For a selected row, the register details are listed in the *Register* tab of the right panel. For details about the *Register Details* tab, see Section 3.5.4.1.

3.5.4.1 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.

3.5.4.1.1 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 are listed as a result. Multiple registers may contain cross-references to the keyword, and thus multiple registers can be listed as results.

3.6 TUSS44x0 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 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 TUSS44x0 device (see Figure 19).

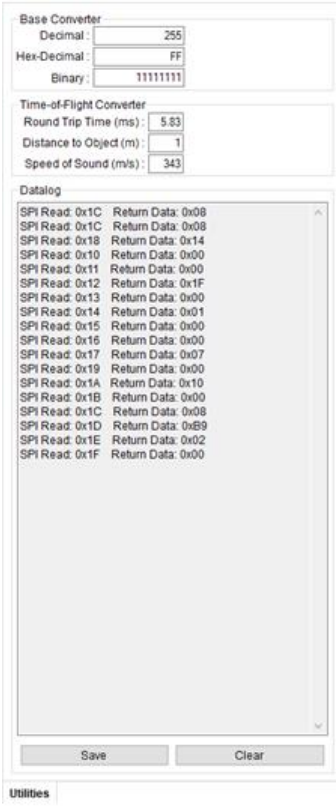


Figure 19. Utilities Tab

3.6.1.1 Base Converter

To convert between binary, decimal, or hexadecimal, the base converter lets the user enter a value from one base, and the GUI calculates the equivalent value for the other bases. All numeric up-down control values are displayed as decimal values in the GUI, thus this tool can be effective for converter between decimal and hexadecimal.

3.6.1.2 Time-of-Flight Converter

Because the TUSS44x0 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. All conversions from time-of-flight to distance reference the speed of sound value in this tool.

3.6.1.3 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 new text file for each save button click. The text file is saved with the term *datalog* and a date-time stamp in the "My Documents\Texas Instruments\TUSS Generation III\TUSS44x0" directory.

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. The different menu options are defined as follows:

- File

XDS110 Program — The user can manually force program the MSP-EXP430F5529LP by navigating to and selecting the appropriate batch file in the file explorer view. The micro-USB cable must be connected to the LaunchPad's USB port to allow XDS110 programming.

Power Budget Calculator — The user can approximate the average power consumption of the TUSS44x0 device by specifying the required device parameters, power modes, and command interval length.

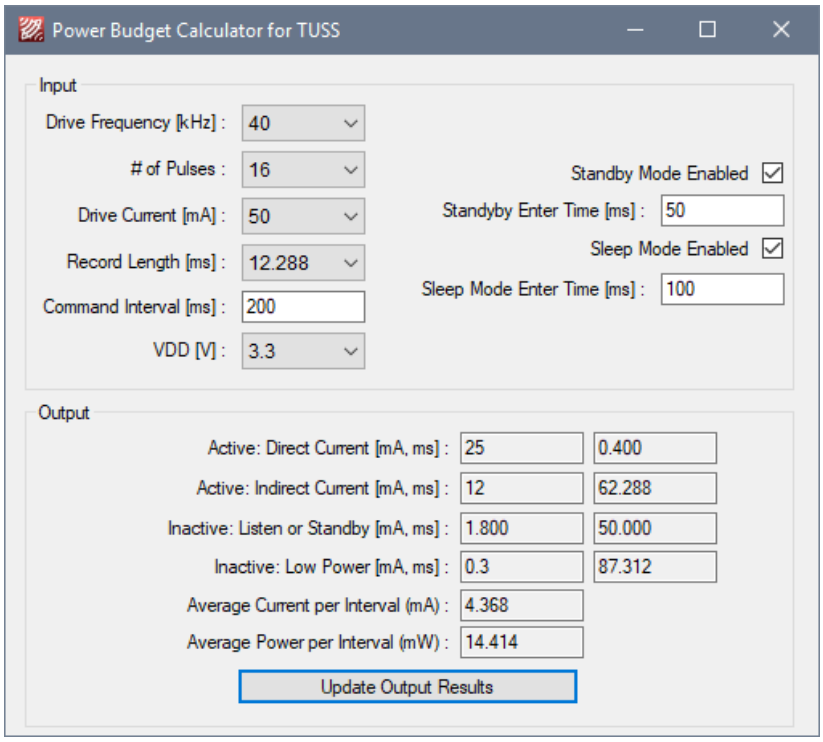


Figure 20. Power Budget Calculator

Data Plotter — All XML charted data exported from the Data Monitor page can be loaded into the plotter for post-analysis, overlap, comparison, CSV export, and averaging.

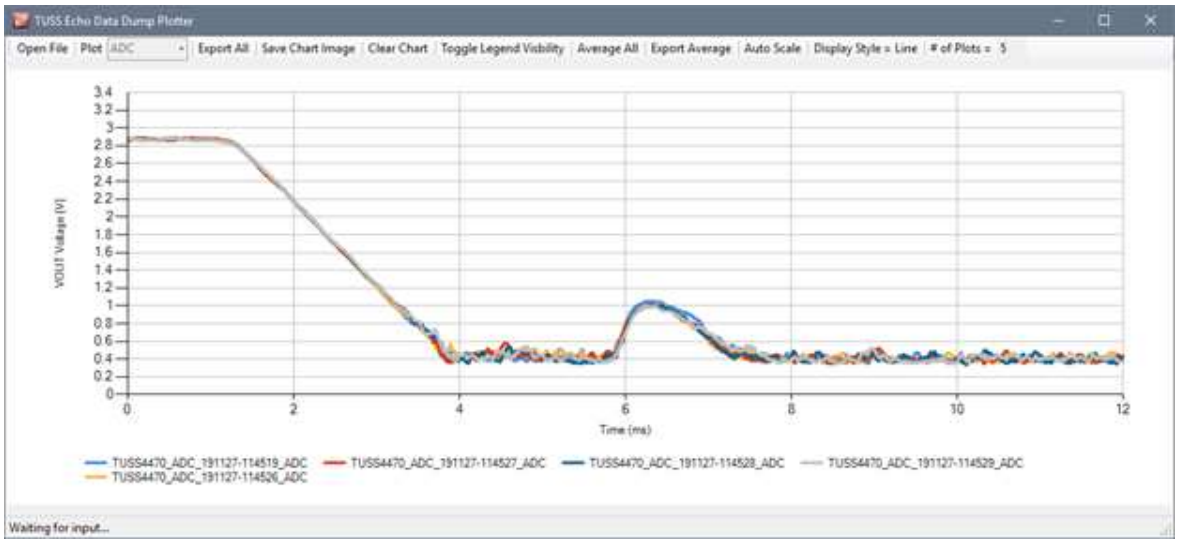


Figure 21. Data Plotter

Exit — This option disconnects the U2A I/F from the GUI so that the I/F can be used by another instance of the GUI, or other program.

- Edit

  Datalogs Enabled/Disabled — When enabled (default), every GUI action and micro-controller command is logged in the Datalog text box in the Utility tab.

  Dialogs Enabled/Disabled —When enabled (default), the GUI will prompt the user with a Message Box when critical action must be taken by the user, or when an import status message is available. When disabled, the GUI will surpress all Message Box prompts, which is required when needing to run an automated script uninterrupted.

- View

  Right Panel — The utility tab 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 TUSS44x0 device.

  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 TUSS44x0. 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 includes a virtual green LED to indicate that the EVM is operating correctly, and that a TUSS44x0 device is detected. If the virtual LED turns red, either the EVM hardware has disconnected, or a TUSS44x0 device was not detected.

4 Schematic, Bill of Materials, and Layout

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

4.1 BOOSTXL-TUSS44x0 (Active)

4.1.1 Schematics

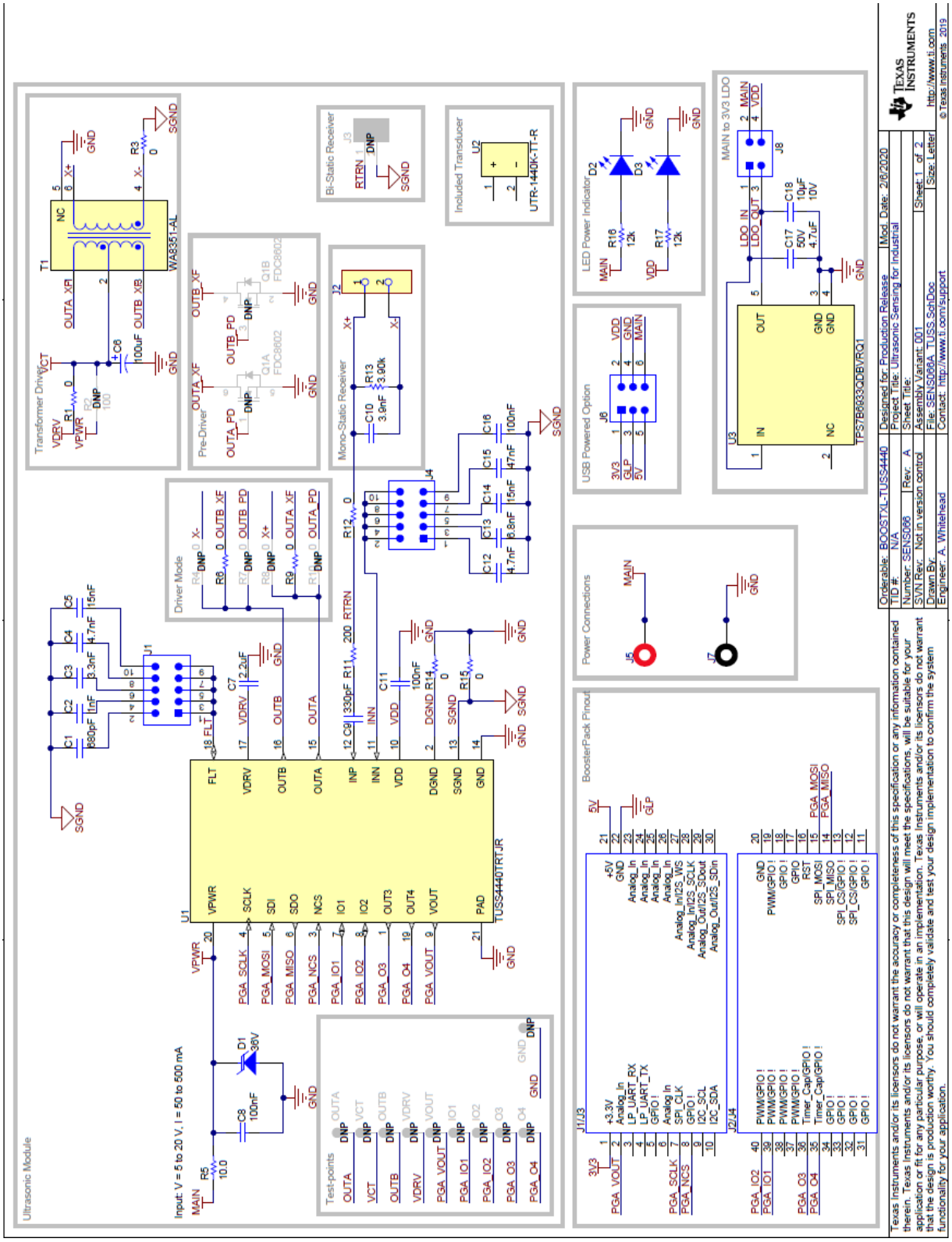


Figure 22. BOOSTXL-TUSS4440 Schematic

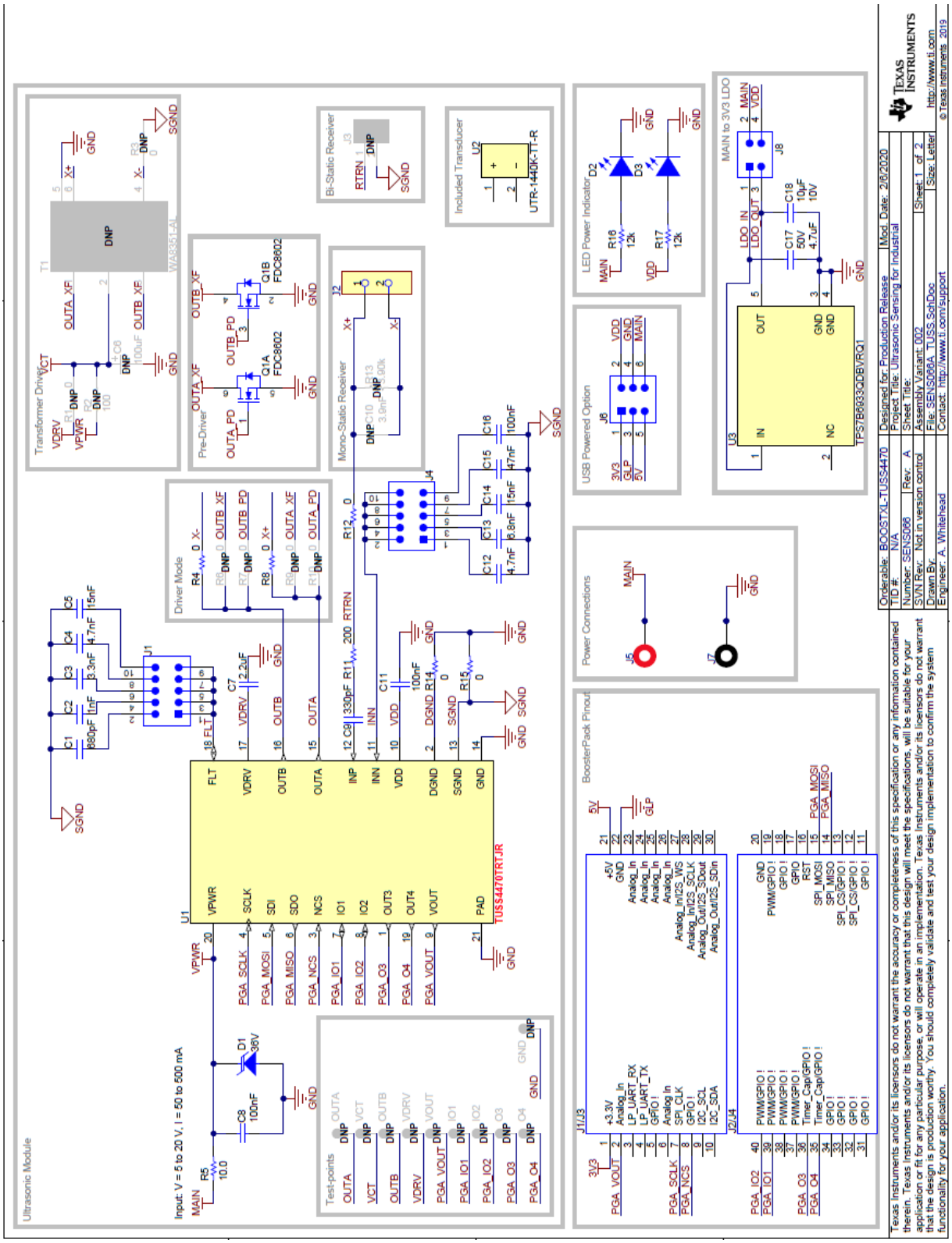


Figure 23. BOOSTXL-TUSS4470 Schematic

4.1.2 Bill of Materials

Table 8 and Table 9 list the bill of materials (BOM).

Table 8. Bill of Materials for BOOSTXL-TUSS4440

DESIGNATOR	QUANTITY	VALUE	DESCRIPTION	PACKAGE	PART NUMBER	MANUFACTURER
C1	1	680pF	CAP, CERM, 680 pF, 50 V, +/- 10%, X7R, 0603	0603	C0603C681K5RACTU	Kemet
C2	1	1000pF	CAP, CERM, 1000 pF, 50 V,+/- 10%, X7R, 0603	0603	CL10B102KB8NNNC	Samsung Electro-Mechanics
C3	1	3300pF	CAP, CERM, 3300 pF, 50 V, +/- 10%, X7R, 0603	0603	C0603C332K5RACTU	Kemet
C4, C12	2	4700pF	CAP, CERM, 4700 pF, 50 V, +/- 10%, X7R, 0603	0603	885012206087	Wurth Elektronik
C5, C14	2	0.015uF	CAP, CERM, 0.015 uF, 25 V, +/- 5%, C0G/NP0, 0603	0603	C0603C153J3GACTU	Kemet
C6	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	2.2uF	CAP, CERM, 2.2 uF, 50 V, +/- 10%, X5R, 0805	0805	C2012X5R1H225K125AB	TDK
C8, C11, C16	3	0.1uF	CAP, CERM, 0.1 uF, 50 V, +/- 10%, X7R, AEC-Q200 Grade 1, 0603	0603	CGA3E2X7R1H104K080AA	TDK
C9	1	330pF	CAP, CERM, 330 pF, 100 V, +/- 5%, C0G/NP0, 0603	0603	C1608C0G2A331J080AA	TDK
C10	1	3900pF	CAP, CERM, 3900 pF, 100 V,+/- 5%, X7R, 0603	0603	06031C392JAT2A	AVX
C13	1	6800pF	CAP, CERM, 6800 pF, 50 V, +/- 10%, X7R, 0603	0603	C0603C682K5RACTU	Kemet
C15	1	0.047uF	CAP, CERM, 0.047 uF, 50 V, +/- 10%, X7R, 0603	0603	C1608X7R1H473K080AA	TDK
C17	1	4.7uF	CAP, CERM, 4.7 uF, 50 V, +/- 10%, X7R, 1206	1206	C3216X7R1H475K160AC	TDK
C18	1	10uF	CAP, CERM, 10 µF, 10 V,+/- 10%, X5R, 0603	0603	GRM188R61A106KE69D	MuRata
D1	1	36V	Diode, TVS, Uni, 36 V, 75 Vc, SOD-323	SOD-323	CDSOD323-T36S	Bourns

Table 8. Bill of Materials for BOOSTXL-TUSS4440 (continued)

D2, D3	2	Green	LED, Green, SMD	1.6x0.8mm	LTST-C193KGKT-5A	Lite-On
J1, J4	2		Header, 1.27mm, 5x2, Gold, SMT	Header, 1.27mm, 5x2, SMT	GRPB052VWQS-RC	Sullins Connector Solutions
J1/J3, J2/J4	2		Receptacle, 2.54mm, 10x2, Tin, TH	10x2 Receptacle	SSQ-110-03-T-D	Samtec
J2	1		2 Position Wire to Board Terminal Block Horizontal with Board 0.200"	HDR2	1888687	Phoenix Contact
J5	1		Standard Banana Jack, insulated, 10A, red	571-0500	571-0500	DEM Manufacturing
J6	1		Header, 100mil, 3x2, Gold, TH	Sullins 100mil, 2x3, 230 mil above insulator	PBC03DAAN	Sullins Connector Solutions
J7	1		Standard Banana Jack, insulated, 10A, black	571-0100	571-0100	DEM Manufacturing
J8	1		Header, 100mil, 2x2, Tin, TH	Header, 2x2, 2.54mm, TH	PEC02DAAN	Sullins Connector Solutions
LBL1	1		Thermal Transfer Printable Labels, 0.650" W x 0.200" H - 10,000 per roll	PCB Label 0.650 x 0.200 inch	THT-14-423-10	Brady
R1, R3, R6, R9, R12, R14, R15	7	0	RES, 0, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	RMCF0603ZT0R00	Stackpole Electronics Inc
R5	1	10.0	RES, 10.0, 1%, 0.1 W, 0603	0603	RC0603FR-0710RL	Yageo
R11	1	200	RES, 200, 1%, 0.1 W, 0603	0603	RC0603FR-07200RL	Yageo
R13	1	3.90k	RES, 3.90 k, 1%, 0.1 W, 0603	0603	RC0603FR-073K9L	Yageo
R16, R17	2	12k	RES, 12 k, 5%, 0.1 W, 0603	0603	RC0603JR-0712KL	Yageo
SH-J1, SH-J2, SH-J3, SH-J4	4		Shunt, 2.54mm, Gold, Black	Shunt, 2.54mm, Black	60900213421	Wurth Elektronik
SH-J5, SH-J6, SH-J7, SH-J8	4		Shunt, 1.27 mm, with handle, Black		M50-2000005	Harwin
T1	1	3mH	Transformer, 3000 uH, SMT	8.2x6.6mm	WA8351-AL	Coilcraft
U1	1		Ultrasonic Signal Conditioning For Transformer Driven Sensors, RTJ0020J (WQFN-20)	RTJ0020J	TUSS4440TRTJR	Texas Instruments
U2	1		Ultrasonic Xmr/Receiver, TH	Dia 14.4mm	UTR-1440K-TT-R	PUI Audio

Table 8. Bill of Materials for BOOSTXL-TUSS4440 (continued)

U3	1		Automotive High-Voltage Ultralow-IQ Low-Dropout Regulator, DBV0005A (SOT-23-5)	DBV0005A	TPS7B6933QDBVRQ1	Texas Instruments
FID1, FID2, FID3, FID4, FID5, FID6	0		Fiducial mark. There is nothing to buy or mount.	N/A	N/A	N/A
J3	0		Header, 100mil, 2x1, Tin, TH	Header, 2 PIN, 100mil, Tin	PEC02SAAN	Sullins Connector Solutions
Q1	0	100V	MOSFET, 2-CH, N-CH, 100 V, 1.2 A, SuperSOT-6	SuperSOT-6	FDC8602	Fairchild Semiconductor
R2	0	100	RES, 100, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW0603100RFKEA	Vishay-Dale
R4, R7, R8, R10	0	0	RES, 0, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	RMCF0603ZT0R00	Stackpole Electronics Inc
TP1, TP2, TP3, TP4, TP5, TP6, TP7, TP8, TP9, TP10	0		Test Point, Compact, White, TH	White Compact Testpoint	5007	Keystone

Table 9. Bill of Materials for BOOSTXL-TUSS4470

DESIGNATOR	QUANTITY	VALUE	DESCRIPTION	PACKAGE	PART NUMBER	MANUFACTURER
C1	1	680pF	CAP, CERM, 680 pF, 50 V, +/- 10%, X7R, 0603	0603	C0603C681K5RACTU	Kemet
C2	1	1000pF	CAP, CERM, 1000 pF, 50 V,+/- 10%, X7R, 0603	0603	CL10B102KB8NNNC	Samsung Electro-Mechanics
C3	1	3300pF	CAP, CERM, 3300 pF, 50 V, +/- 10%, X7R, 0603	0603	C0603C332K5RACTU	Kemet
C4, C12	2	4700pF	CAP, CERM, 4700 pF, 50 V, +/- 10%, X7R, 0603	0603	885012206087	Wurth Elektronik
C5, C14	2	0.015uF	CAP, CERM, 0.015 uF, 25 V, +/- 5%, C0G/NP0, 0603	0603	C0603C153J3GACTU	Kemet
C7	1	2.2uF	CAP, CERM, 2.2 uF, 50 V, +/- 10%, X5R, 0805	0805	C2012X5R1H225K125AB	TDK
C8, C11, C16	3	0.1uF	CAP, CERM, 0.1 uF, 50 V, +/- 10%, X7R, AEC-Q200 Grade 1, 0603	0603	CGA3E2X7R1H104K080AA	TDK
C9	1	330pF	CAP, CERM, 330 pF, 100 V, +/- 5%, C0G/NP0, 0603	0603	C1608C0G2A331J080AA	TDK
C13	1	6800pF	CAP, CERM, 6800 pF, 50 V, +/- 10%, X7R, 0603	0603	C0603C682K5RACTU	Kemet
C15	1	0.047uF	CAP, CERM, 0.047 uF, 50 V, +/- 10%, X7R, 0603	0603	C1608X7R1H473K080AA	TDK
C17	1	4.7uF	CAP, CERM, 4.7 uF, 50 V, +/- 10%, X7R, 1206	1206	C3216X7R1H475K160AC	TDK
C18	1	10uF	CAP, CERM, 10 µF, 10 V,+/- 10%, X5R, 0603	0603	GRM188R61A106KE69D	MuRata
D1	1	36V	Diode, TVS, Uni, 36 V, 75 Vc, SOD-323	SOD-323	CDSOD323-T36S	Bourns
D2, D3	2	Green	LED, Green, SMD	1.6x0.8mm	LTST-C193KGKT-5A	Lite-On
J1, J4	2		Header, 1.27mm, 5x2, Gold, SMT	Header, 1.27mm, 5x2, SMT	GRPB052VWQS-RC	Sullins Connector Solutions
J1/J3, J2/J4	2		Receptacle, 2.54mm, 10x2, Tin, TH	10x2 Receptacle	SSQ-110-03-T-D	Samtec
J2	1		2 Position Wire to Board Terminal Block Horizontal with Board 0.200"	HDR2	1888687	Phoenix Contact
J5	1		Standard Banana Jack, insulated, 10A, red	571-0500	571-0500	DEM Manufacturing
J6	1		Header, 100mil, 3x2, Gold, TH	Sullins 100mil, 2x3, 230 mil above insulator	PBC03DAAN	Sullins Connector Solutions

Table 9. Bill of Materials for BOOSTXL-TUSS4470 (continued)

J7	1		Standard Banana Jack, insulated, 10A, black	571-0100	571-0100	DEM Manufacturing
J8	1		Header, 100mil, 2x2, Tin, TH	Header, 2x2, 2.54mm, TH	PEC02DAAN	Sullins Connector Solutions
LBL1	1		Thermal Transfer Printable Labels, 0.650" W x 0.200" H - 10,000 per roll	PCB Label 0.650 x 0.200 inch	THT-14-423-10	Brady
Q1	1	100V	MOSFET, 2-CH, N-CH, 100 V, 1.2 A, SuperSOT-6	SuperSOT-6	FDC8602	Fairchild Semiconductor
R4, R8, R12, R14, R15	5	0	RES, 0, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	RMCF0603ZT0R00	Stackpole Electronics Inc
R5	1	10.0	RES, 10.0, 1%, 0.1 W, 0603	0603	RC0603FR-0710RL	Yageo
R11	1	200	RES, 200, 1%, 0.1 W, 0603	0603	RC0603FR-07200RL	Yageo
R16, R17	2	12k	RES, 12 k, 5%, 0.1 W, 0603	0603	RC0603JR-0712KL	Yageo
SH-J1, SH-J2, SH-J3, SH-J4	4		Shunt, 2.54mm, Gold, Black	Shunt, 2.54mm, Black	60900213421	Wurth Elektronik
SH-J5, SH-J6, SH-J7, SH-J8	4		Shunt, 1.27 mm, with handle, Black		M50-2000005	Harwin
U1	1		Ultrasonic Sensor Signal Conditioner IC for Directly Driven Sensors, RTJ0020J (WQFN-20)	RTJ0020J	TUSS4470TRTJR	Texas Instruments
U2	1		Ultrasonic Xmr/Receiver, TH	Dia 14.4mm	UTR-1440K-TT-R	PUI Audio
U3	1		Automotive High-Voltage Ultralow-IQ Low-Dropout Regulator, DBV0005A (SOT-23-5)	DBV0005A	TPS7B6933QDBVRQ1	Texas Instruments
C6	0	100uF	CAP, AL, 100 uF, 35 V, +/- 20%, 0.34 ohm, AEC-Q200 Grade 2, SMD	SMT Radial D8	EEE-FK1V101XP	Panasonic
C10	0	3900pF	CAP, CERM, 3900 pF, 100 V,+/- 5%, X7R, 0603	0603	06031C392JAT2A	AVX
FID1, FID2, FID3, FID4, FID5, FID6	0		Fiducial mark. There is nothing to buy or mount.	N/A	N/A	N/A
J3	0		Header, 100mil, 2x1, Tin, TH	Header, 2 PIN, 100mil, Tin	PEC02SAAN	Sullins Connector Solutions
R1, R3, R6, R7, R9, R10	0	0	RES, 0, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	RMCF0603ZT0R00	Stackpole Electronics Inc
R2	0	100	RES, 100, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW0603100RFKEA	Vishay-Dale
R13	0	3.90k	RES, 3.90 k, 1%, 0.1 W, 0603	0603	RC0603FR-073K9L	Yageo

Table 9. Bill of Materials for BOOSTXL-TUSS4470 (continued)

T1	0	3mH	Transformer, 3000 uH, SMT	8.2x6.6mm	WA8351-AL	Coilcraft
TP1, TP2, TP3, TP4, TP5, TP6, TP7, TP8, TP9, TP10	0		Test Point, Compact, White, TH	White Compact Testpoint	5007	Keystone

4.1.3 Board Layout and Component Placement

Figure 24 and Figure 25 show the board layout and component placement.

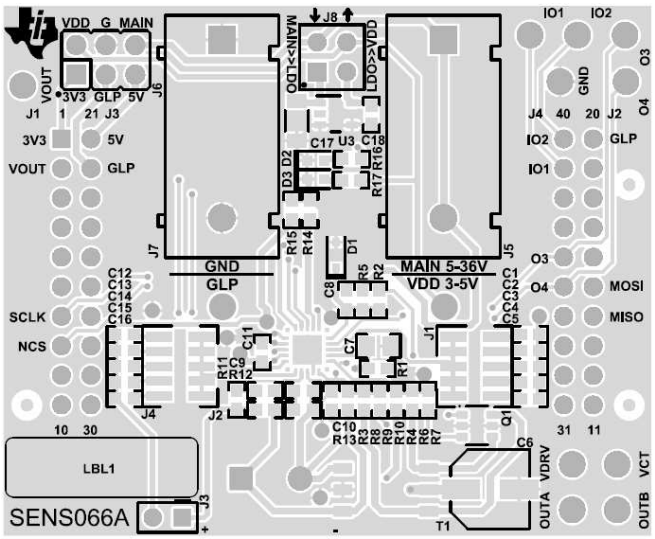


Figure 24. Top Overview of BOOSTXL-TUSS44x0 Layout and Components

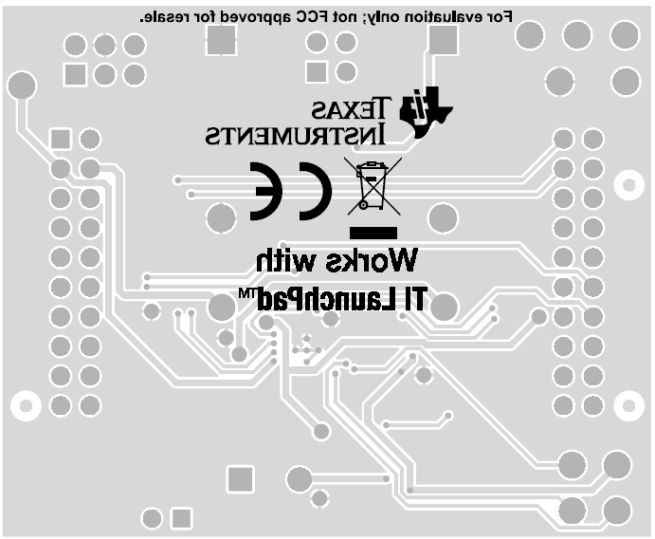


Figure 25. Bottom Overview of BOOSTXL-TUSS44x0 Layout and Components

4.2 BOOST-TUSS44x0 (Discontinued)

4.2.1 Schematics

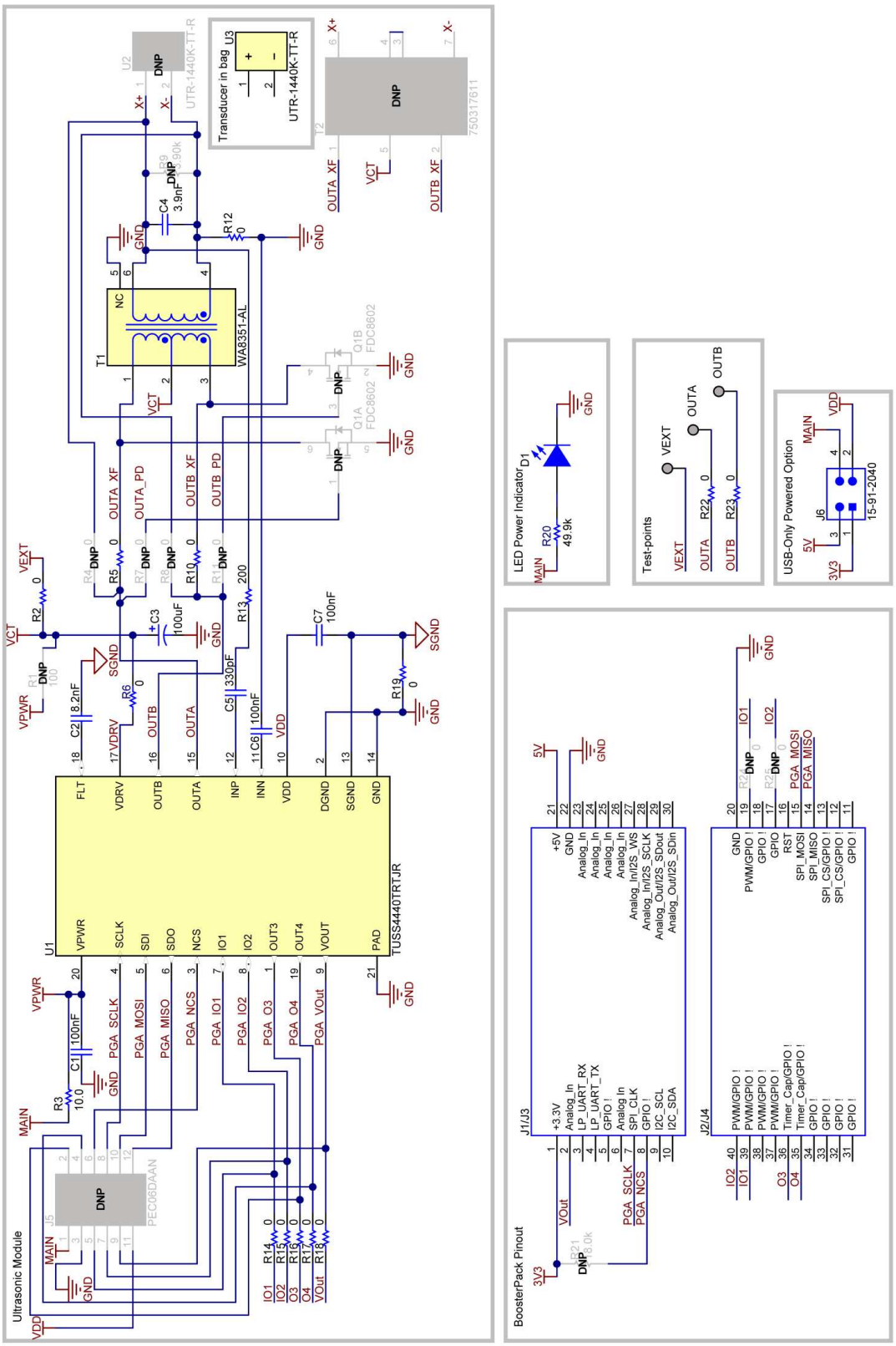


Figure 26. BOOST-TUSS4440 Schematic

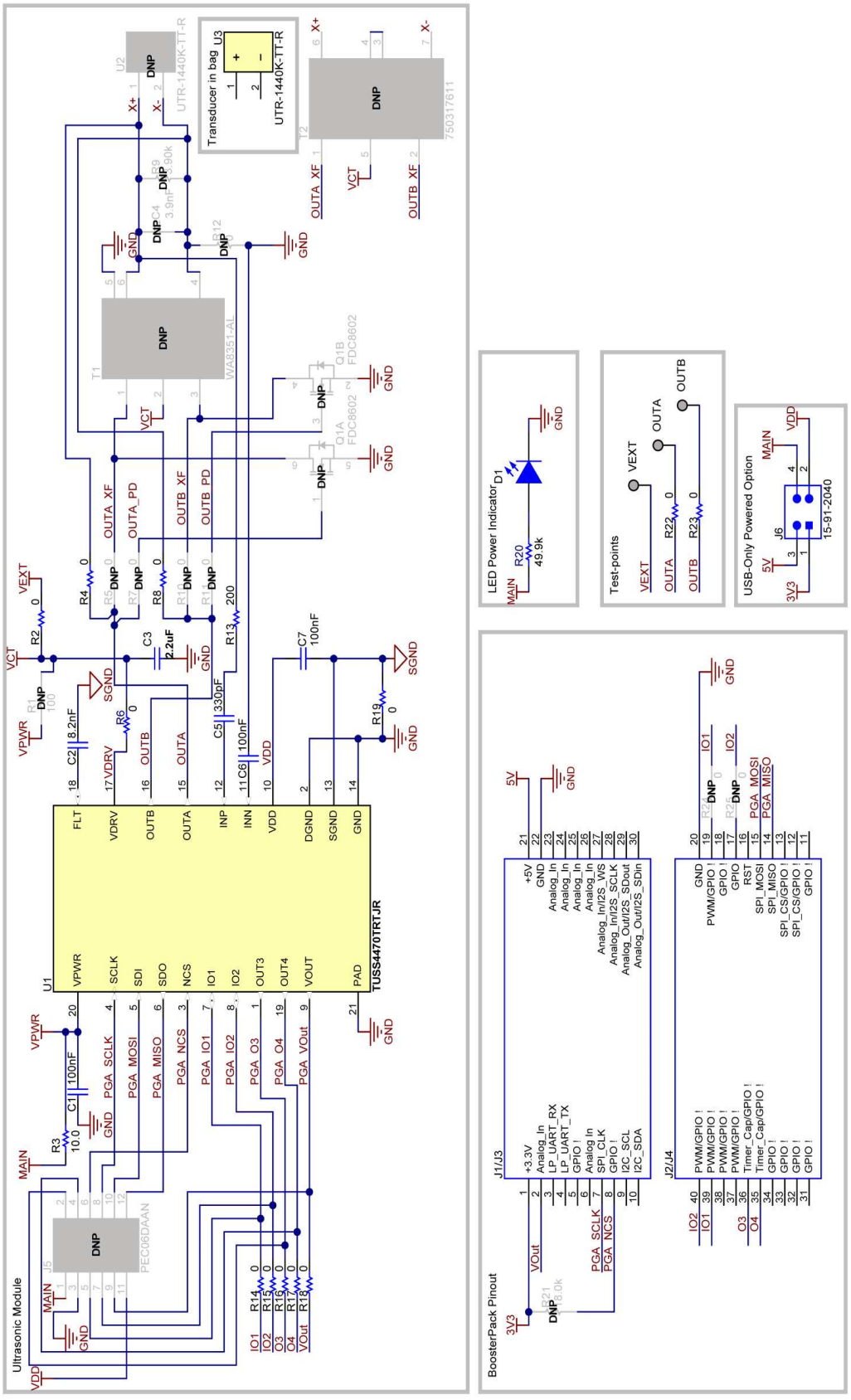


Figure 27. BOOST-TUSS4470 Schematic

4.2.2 Bill of Materials

Table 10 and Table 11 list the bill of materials (BOM).

Table 10. Bill of Materials for BOOST-TUSS4440

DESIGNATOR	QUANTITY	VALUE	DESCRIPTION	PACKAGE	PART NUMBER	MANUFACTURER
C1, C6, C7	3	0.1uF	CAP, CERM, 0.1 uF, 50 V, +/- 10%, X7R, AEC-Q200 Grade 1, 0603	0603	CGA3E2X7R1H104K080AA	TDK
C2	1	8200pF	CAP, CERM, 8200 pF, 50 V,+/- 10%, X7R, 0603	0603	CL10B822KB8NNNC	Samsung Electro-Mechanics
C3	1	100uF	CAP, AL, 100 uF, 35 V, +/- 20%, 0.34 ohm, AEC-Q200 Grade 2, SMD	SMT Radial D8	EEE-FK1V101XP	Panasonic
C4	1	3900pF	CAP, CERM, 3900 pF, 100 V,+/- 5%, X7R, 0603	0603	06031C392JAT2A	AVX
C5	1	330pF	CAP, CERM, 330 pF, 100 V, +/- 5%, C0G/NP0, 0603	0603	C1608C0G2A331J080AA	TDK
D1	1	Green	LED, Green, SMD	1.6x0.8mm	LTST-C193KGKT-5A	Lite-On
J1/J3, J2/J4	2		Receptacle, 2.54mm, 10x2, Tin, TH	10x2 Receptacle	SSQ-110-03-T-D	Samtec
J6	1		Header, 100mil, 2x2, Tin, SMT	2x2 100mil Tin Header	15-91-2040	Molex
LBL1	1		Thermal Transfer Printable Labels, 0.650" W x 0.200" H - 10,000 per roll	PCB Label 0.650 x 0.200 inch	THT-14-423-10	Brady
R2, R5, R6, R10, R12, R14, R15, R16, R17, R18, R19, R22, R23	13	0	RES, 0, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	RMCF0603ZT0R00	Stackpole Electronics Inc
R3	1	10.0	RES, 10.0, 1%, 0.1 W, 0603	0603	RC0603FR-0710RL	Yageo
R13	1	200	RES, 200, 1%, 0.1 W, 0603	0603	RC0603FR-07200RL	Yageo
R20	1	49.9k	RES, 49.9 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW060349K9FKEA	Vishay-Dale
SH-J1, SH-J2	2		Shunt, 2.54mm, Gold, Black	Shunt, 2.54mm, Black	60900213421	Wurth Elektronik
T1	1	3mH	Transformer, 3000 uH, SMT	8.2x6.6mm	WA8351-AL	Coilcraft
TP3, TP4, TP5	3		Test Point, Miniature, SMT	Test Point, Miniature, SMT	5019	Keystone
U1	1		Ultrasonic Signal Conditioning For Transformer Driven Sensors, RTJ0020J (WQFN-20)	RTJ0020J	TUSS4440TRTJR	Texas Instruments

Table 10. Bill of Materials for BOOST-TUSS4440 (continued)

DESIGNATOR	QUANTITY	VALUE	DESCRIPTION	PACKAGE	PART NUMBER	MANUFACTURER
U3	1		Ultrasonic Xmr/Receiver, TH	Dia 14.4mm	UTR-1440K-TT-R	PUI Audio
FID1, FID2, FID3, FID4, FID5, FID6	0		Fiducial mark. There is nothing to buy or mount.	N/A	N/A	N/A
H1, H2, H3, H4	0		Machine Screw, Round, #4-40 x 1/4, Nylon, Philips panhead	Screw	NY PMS 440 0025 PH	B&F Fastener Supply
H5, H6, H7, H8	0		Standoff, Hex, 0.5"L #4-40 Nylon	Standoff	1902C	Keystone
J5	0		Header, 100mil, 6x2, Tin, TH	Header, 6x2, 100mil, Tin	PEC06DAAN	Sullins Connector Solutions
Q1	0	100V	MOSFET, 2-CH, N-CH, 100 V, 1.2 A, SuperSOT-6	SuperSOT-6	FDC8602	Fairchild Semiconductor
R1	0	100	RES, 100, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW0603100RFKEA	Vishay-Dale
R4, R7, R8, R11, R24, R25	0	0	RES, 0, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	RMCF0603ZT0R00	Stackpole Electronics Inc
R9	0	3.90k	RES, 3.90 k, 1%, 0.1 W, 0603	0603	RC0603FR-073K9L	Yageo
R21	0	18.0k	RES, 18.0 k, 1%, 0.1 W, 0603	0603	RC0603FR-0718KL	Yageo
T2	0	2nH	Transformer, 0.002 uH, SMD	3.22x4.7mm	750317611	Wurth Elektronik
U2	0		Ultrasonic Xmr/Receiver, TH	Dia 14.4mm	UTR-1440K-TT-R	PUI Audio

Table 11. Bill of Materials for BOOST-TUSS4470

DESIGNATOR	QUANTITY	VALUE	DESCRIPTION	PACKAGE	PART NUMBER	MANUFACTURER
C1, C6, C7	3	0.1uF	CAP, CERM, 0.1 uF, 50 V, +/- 10%, X7R, AEC-Q200 Grade 1, 0603	0603	CGA3E2X7R1H104K080AA	TDK
C2	1	8200pF	CAP, CERM, 8200 pF, 50 V,+/- 10%, X7R, 0603	0603	CL10B822KB8NNNC	Samsung Electro-Mechanics
C3	1	2.2uF	CAP, CERM, 2.2 uF, 50 V, +/- 10%, X5R, 0805	0805	C2012X5R1H225K125AB	TDK
C5	1	330pF	CAP, CERM, 330 pF, 100 V, +/- 5%, C0G/NP0, 0603	0603	C1608C0G2A331J080AA	TDK
D1	1	Green	LED, Green, SMD	1.6x0.8mm	LTST-C193KGKT-5A	Lite-On
J1/J3, J2/J4	2		Receptacle, 2.54mm, 10x2, Tin, TH	10x2 Receptacle	SSQ-110-03-T-D	Samtec
J6	1		Header, 100mil, 2x2, Tin, SMT	2x2 100mil Tin Header	15-91-2040	Molex
LBL1	1		Thermal Transfer Printable Labels, 0.650" W x 0.200" H - 10,000 per roll	PCB Label 0.650 x 0.200 inch	THT-14-423-10	Brady
R2, R4, R6, R8, R14, R15, R16, R17, R18, R19, R22, R23	12	0	RES, 0, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	RMCF0603ZT0R00	Stackpole Electronics Inc
R3	1	10.0	RES, 10.0, 1%, 0.1 W, 0603	0603	RC0603FR-0710RL	Yageo
R13	1	200	RES, 200, 1%, 0.1 W, 0603	0603	RC0603FR-07200RL	Yageo
R20	1	49.9k	RES, 49.9 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW060349K9FKEA	Vishay-Dale
SH-J1, SH-J2	2		Shunt, 2.54mm, Gold, Black	Shunt, 2.54mm, Black	60900213421	Wurth Elektronik
TP3, TP4, TP5	3		Test Point, Miniature, SMT	Test Point, Miniature, SMT	5019	Keystone
U1	1		Ultrasonic Sensor Signal Conditioner IC for Directly Driven Sensors, RTJ0020J (WQFN-20)	RTJ0020J	TUSS4470TRTJR	Texas Instruments
U3	1		Ultrasonic Xmr/Receiver, TH	Dia 14.4mm	UTR-1440K-TT-R	PUI Audio
C4	0	3900pF	CAP, CERM, 3900 pF, 100 V,+/- 5%, X7R, 0603	0603	06031C392JAT2A	AVX
FID1, FID2, FID3, FID4, FID5, FID6	0		Fiducial mark. There is nothing to buy or mount.	N/A	N/A	N/A
H1, H2, H3, H4	0		Machine Screw, Round, #4-40 x 1/4, Nylon, Philips panhead	Screw	NY PMS 440 0025 PH	B&F Fastener Supply
H5, H6, H7, H8	0		Standoff, Hex, 0.5"L #4-40 Nylon	Standoff	1902C	Keystone

Table 11. Bill of Materials for BOOST-TUSS4470 (continued)

DESIGNATOR	QUANTITY	VALUE	DESCRIPTION	PACKAGE	PART NUMBER	MANUFACTURER
J5	0		Header, 100mil, 6x2, Tin, TH	Header, 6x2, 100mil, Tin	PEC06DAAN	Sullins Connector Solutions
Q1	0	100V	MOSFET, 2-CH, N-CH, 100 V, 1.2 A, SuperSOT-6	SuperSOT-6	FDC8602	Fairchild Semiconductor
R1	0	100	RES, 100, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW0603100RFKEA	Vishay-Dale
R5, R7, R10, R11, R12, R24, R25	0	0	RES, 0, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	RMCF0603ZT0R00	Stackpole Electronics Inc
R9	0	3.90k	RES, 3.90 k, 1%, 0.1 W, 0603	0603	RC0603FR-073K9L	Yageo
R21	0	18.0k	RES, 18.0 k, 1%, 0.1 W, 0603	0603	RC0603FR-0718KL	Yageo
T1	0	3mH	Transformer, 3000 uH, SMT	8.2x6.6mm	WA8351-AL	Coilcraft
T2	0	2nH	Transformer, 0.002 uH, SMD	3.22x4.7mm	750317611	Wurth Elektronik
U2	0		Ultrasonic Xmr/Receiver, TH	Dia 14.4mm	UTR-1440K-TT-R	PUI Audio

4.2.3 Board Layout and Component Placement

Figure 28 and Figure 29 show the board layout and component placement.

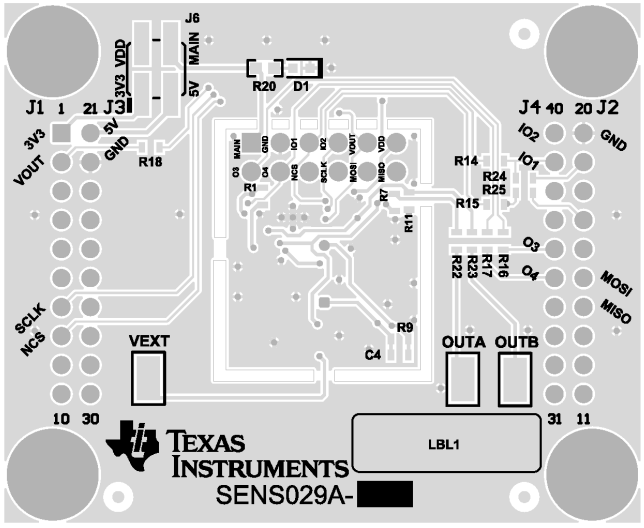


Figure 28. Top Overview of BOOST-TUSS44x0 Layout and Components

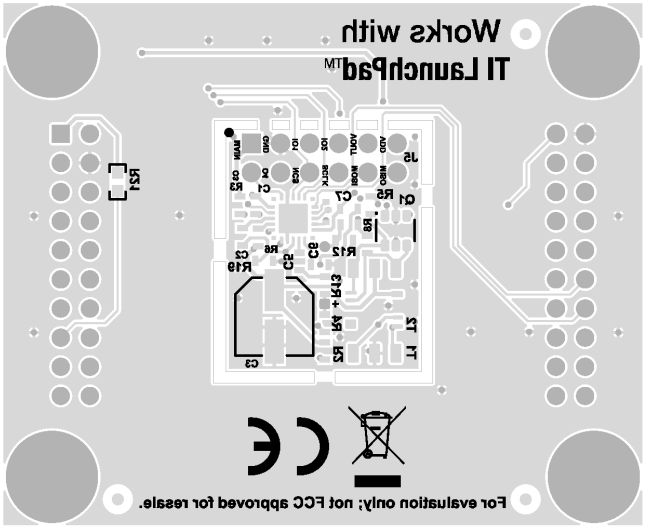


Figure 29. Bottom Overview of BOOST-TUSS44x0 Layout and Components

5 References

For additional reference, refer to:

- *TUSS4440 Transformer Drive Ultrasonic Sensor IC with Logarithmic Amplifier Receiver*
- *TUSS4470 Direct Drive Ultrasonic Sensor IC with Logarithmic Amplifier Receiver*

Revision History

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

Changes from Original (December 2019) to A Revision	Page
• Changed BOOST-TUSS4470 to BOOSTXL-TUSS4470 throughout document	1
• Changed *Setup and Operation* section	4
• Added *Sweep* and *GUI Threshold Enable* to the *Run Options* section	15
• Added *Echo Interrupt* feature information to the *Tabulated Results* section	17
• Changed *Schematic, Bill of Materials, and Layout* section	25

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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。

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東京都新宿区西新宿 6 丁目 2 4 番 1 号
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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.

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