MSP430FR6043-based ultrasonic gas flow meter

This guide provides an overview on how to get started quickly with the MSP430FR6043 MCU for gas flow meter solution based on ultrasonic technology.

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1 Introduction

Thank you for your interest in the MSP430FR6043 kit for gas flow meters. This quick start guide reviews the documentation and collateral material relevant to the development of an ultrasonic-based gas flow meter solution using the MSP430FR6043. This guide also includes a step-by-step guide explaining how to run and customize the application and a troubleshooting section.

1.1 Package Contents and Related Documentation and Tools

- Hardware
  - EVM430-FR6043: Development platform to evaluate the performance of the MSP430FR6043 for ultrasonic sensing applications.
- Software
  - Ultrasonic Gas Demo Application for MSP430FR6043: This demo application uses TI's Ultrasonic Sensing Solution (USS) Library to implement a gas meter application. Communication with Design Center GUI allows developers to test and customize the performance of the application for different transducers and pipe characteristics. The demo includes source code and project files for Code Composer Studio™ IDE (CCS) and IAR Embedded Workbench® IDE (IAR).
  - Ultrasonic Sensing Software Library (USSLib): This library provides the means to configure the ultrasonic analog front end in MSP430FR604x devices and help to integrate it with the application software for development of ultrasonic sensing applications. The library includes libraries for CCS and IAR as well as a simple code example.
- Ultrasonic Tools
  - Ultrasonic Sensing Design Center: PC application used to control the configurable parameters of the transducers and view the results including the delta time of flight (DTOF), absolute time of flight (ATOF), measured flow rate, and ADC waveforms.
- Documentation
  - EVM430-FR6043 hardware guide: Includes a detailed description of the EVM430-FR6043 features and supported configurations.
  - MSP430FR6043 ultrasonic sensing design center user's guide: Explains usage and features of the Ultrasonic Sensing Design Center and includes a description of the USSLib parameters which can be modified by Design Center.
  - Ultrasonic sensing software library documentation: Detailed documentation of the library APIs and configuration structures available in the library is available in the USSLib package.
- Additional Tools
  - Code Composer Studio IDE (CCS): Integrated development environment (IDE) supporting TI's Microcontroller and Embedded Processors portfolio. The software package included in this demo includes CCS projects.
  - IAR Embedded Workbench for MSP430 (EW430): Complete debugger and C/C++ compiler toolchain for building and debugging embedded applications based on MSP430 microcontrollers. The software package included in this demo includes IAR projects.
  - MSP Flasher: Open-source shell-based interface for programming MSP430 microcontrollers.

2 Hardware

The following hardware is used by the MSP430FR6043-based gas meter demo.

- EVM430-FR6043 (see Section 2.1)
- Gas pipe and transducers (not included) (see Section 2.2)
- Fan with pipe connector (not included) (see Figure 2)

2.1 EVM430-FR6043

The MSP430FR6043-based ultrasonic gas flow meter software package supports the EVM430-FR6043-E2 revision. The following sections show the configuration required to program, debug and execute the application.

2.1.1 EVM430-FR6043-E2

Figure 1 shows the EVM430-FR6043-E2, and Table 1 lists its default configuration.

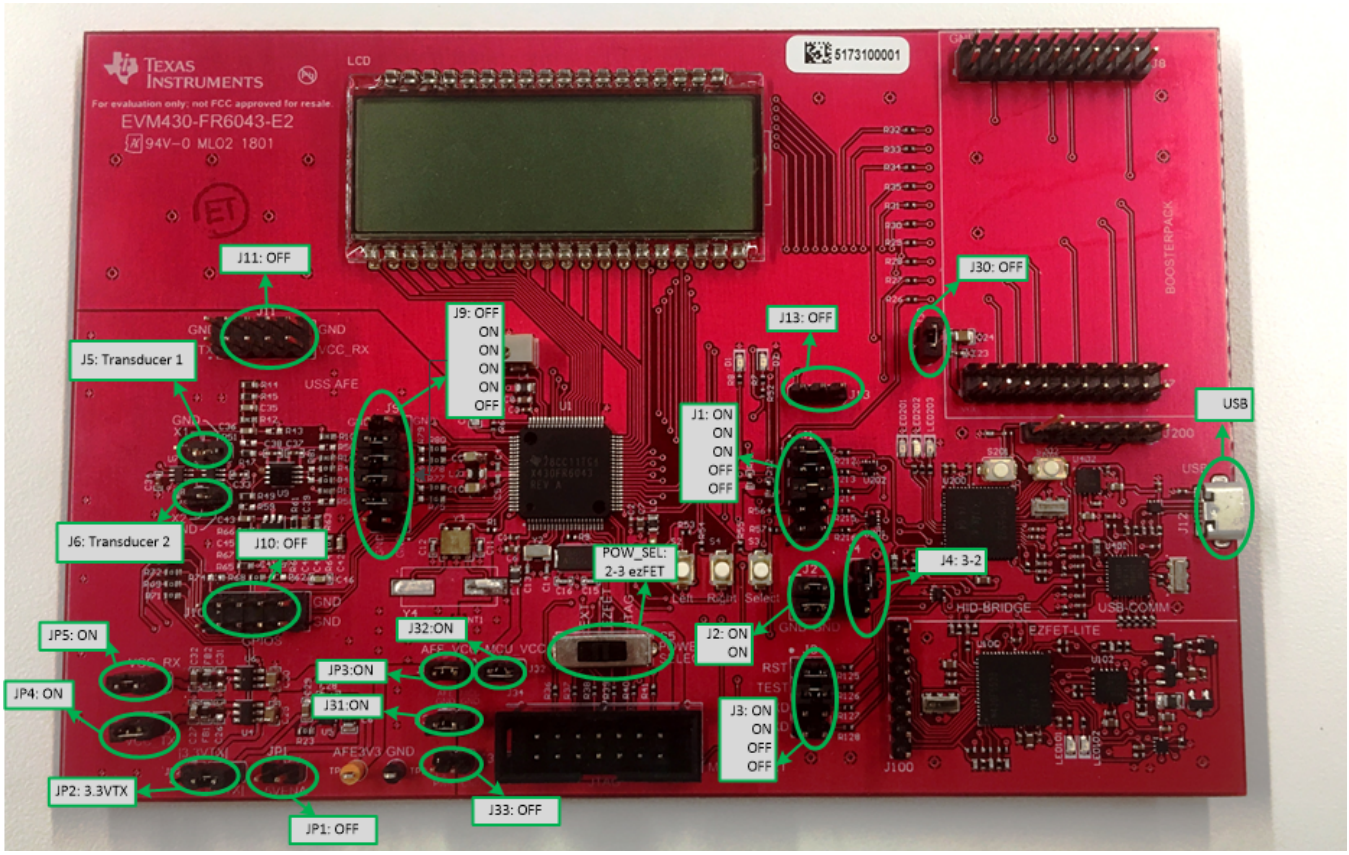


Figure 1. EVM430-FR6043-E2 Default Configuration

Table 1. Description of EVM430-FR6043-E2 Default Configuration

Jumper	Default Configuration	Description
J1	1-2: ON 3-4: ON 5-6: ON 7-8: OFF 9-10: OFF	Allows communication to Design Center using I^2C.
J2	1-2: ON 3-4: ON	Provides power to EVM from USB.
J3	1-2: ON 3-4: ON 5-6: OFF 7-8: OFF	Allows programming and debugging using integrated ezFET. Back-channel UART is disabled.
J4	2-3: ON	Uses USB LDO to provide power to the EVM.
J5	Transducer 1	Used to connect transducer #1.
J6	Transducer 2	Used to connect transducer #2
J9	1-2: OFF 3-4: ON 5-6: ON 7-8: ON 9-10: OFF	Connects transducer signals to Analog Front End (AFE).
J10	OFF	Provides access to AFE pins. Not used for this demo.
J11	OFF	Provides access to AFE pins. Not used for this demo.

Table 1. Description of EVM430-FR6043-E2 Default Configuration (continued)

Jumper	Default Configuration	Description
J13	OFF	Provides access to MTIF pins. Not used for this demo.
J30	OFF	VCC disconnected from expansion connector.
J31	ON	Connects AFE ground to MCU ground.
J32	ON	Provides power to MCU. Can be used for power measurement.
J33	OFF	Used to provide external power. Not used when powered through USB.
JP1	OFF	5V circuitry is not used. Provides power to AFE circuitry. Can be used for power measurement.
JP2	3.3VTX	Enables 3.3-V circuitry. 5-V circuitry is not used
JP3	ON	Provides power to AFE. Can be used for power measurement.
JP4	ON	Provides power to AFE transmit circuitry. Can be used for power measurement.
JP5	ON	Provides power to AFE receive circuitry. Can be used for power measurement.

The configuration shown in Figure 1 and Table 1 provides power through USB and allows communication to a PC with Design Center using I^2C. See the EVM430-FR6043 hardware guide for more information on different configurations.

2.2 Gas Pipe and Transducers

The demo allows developers to use custom pipes and transducers by connecting them to the J5 and J6 connectors. A DC fan can be used to demonstrate air flow (see Figure 2).

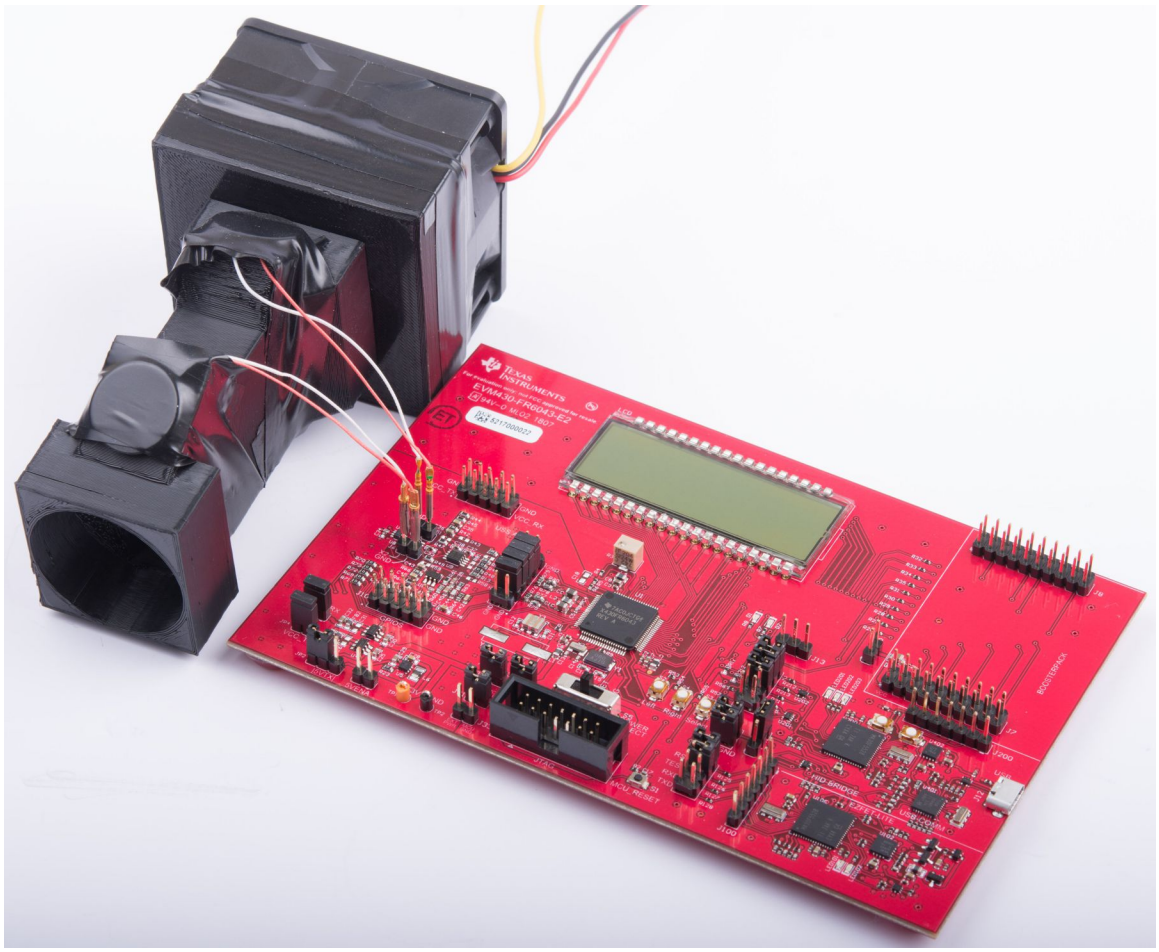


Figure 2. EVM430-FR6043 Connected to Gas-Flow Meter

3 Software

The gas meter application requires installation of the following software packages:

- Ultrasonic Gas Demo Application for MSP430FR6043
  - The example can be installed to the folder of your preference. By default, the application is installed to the following folder (the version of the code example might be different):

    C:\ti\msp\UltrasonicGasFR6043_02_10_10_03
- Ultrasonic Sensing Design Center
  - Design Center can be installed to the folder of your preference. By default, this folder is as follows (the version of USS Design Center might be different):

    C:\ti\msp\USS_1.71.02.02
- (Optional) Ultrasonic Sensing Software Library (USSLib)
  - The library can be installed to the folder of your preference. By default, this folder is as follows (the version of the library might be different):

    C:\ti\msp\USSLib_02_10_10_02
- (Optional) MSP Flasher
  - Used to flash prebuilt application binaries. See Section 6 for more details.

4 Running the Application

1. Set the EVM430-FR6043 to the default configuration (see Section 2.1.1).
2. The MSP430FR6043 is shipped factory-programmed and ready to run. If necessary, reprogram the device following the steps in Section 6.
3. Connect the transducers to J5 and J6 on the EVM430-FR6043.

   The order of the transducers is important only to determine the direction of flow.

   If the transducers have polarity, connect the negative or GND cable to the corresponding J5 or J6 GND pin (see Figure 2).
4. Connect the EVM430-FR6043 to the PC through USB.

5. Open the *Ultrasonic Sensing Design Center.*
   Design Center launches in the disconnected state (see Figure 3).

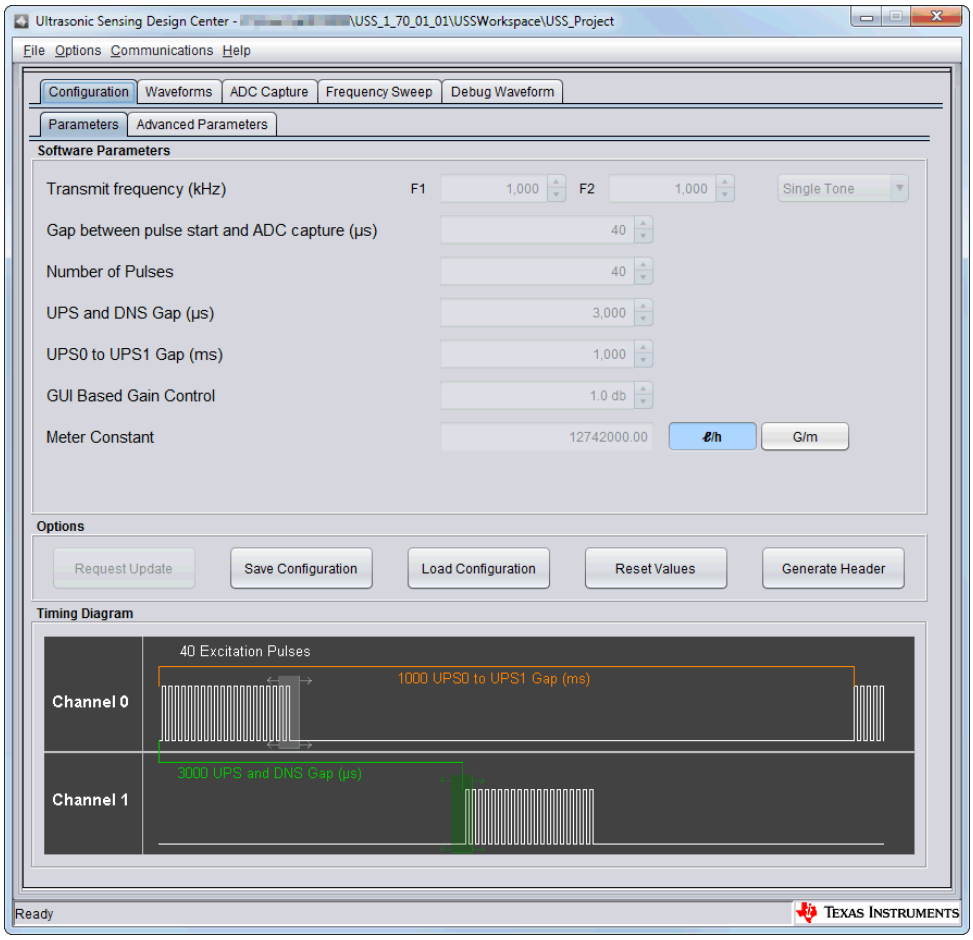


Figure 3. Design Center in Disconnected State

6. To connect to the EVM, click **Communications** → **Connect** or press F1.

   If the connection is successful, the Design Center reports the connection and detects the ID of the EVM430-FR6043 (see Figure 4).

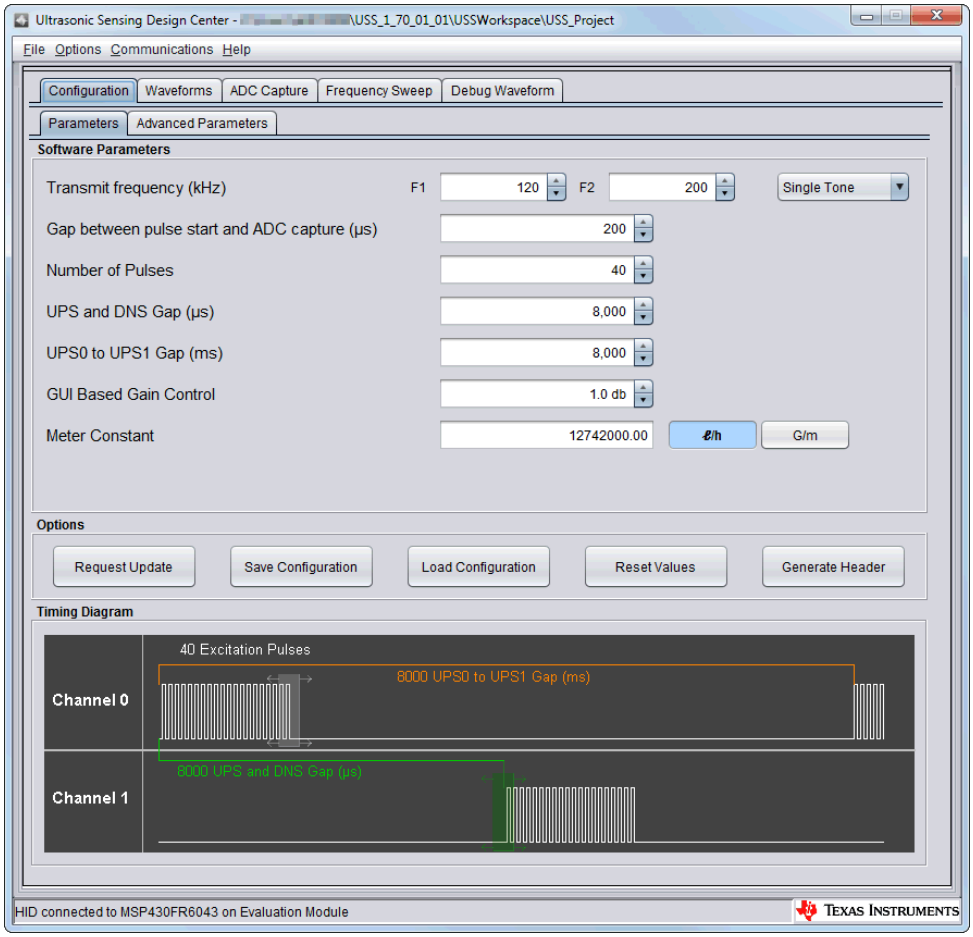


Figure 4. Design Center in Connected State

7. Click **Load Configuration**, go to the mtr_gui_config in the *Ultrasonic Gas Demo Application for MSP430FR6043,* and select one of the example configurations.

   The default folder is:

   C:\ti\msp\<Ultrasonic_Gas_Demo_application_version>\examples\mtr_gui_config

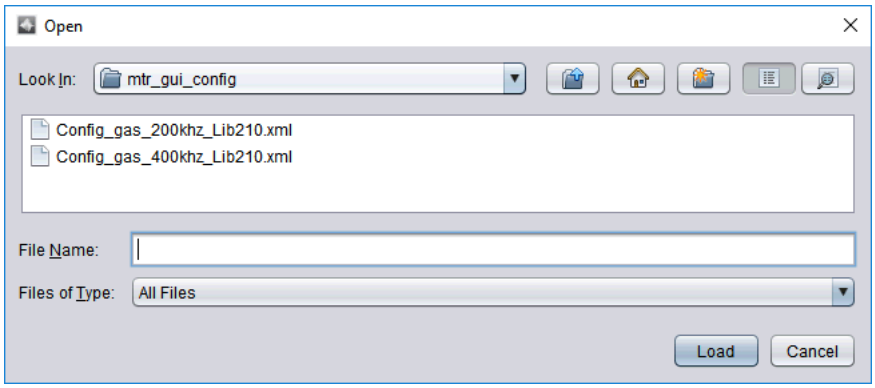


Figure 5. Loading a Configuration

8. Click **Request Update**. The Design Center shows a message to indicate a successful update.

9. Select the ADC Capture window and click **Capture**. Design Center requests and plots an ADC capture of the ultrasonic signals (see Figure 6).

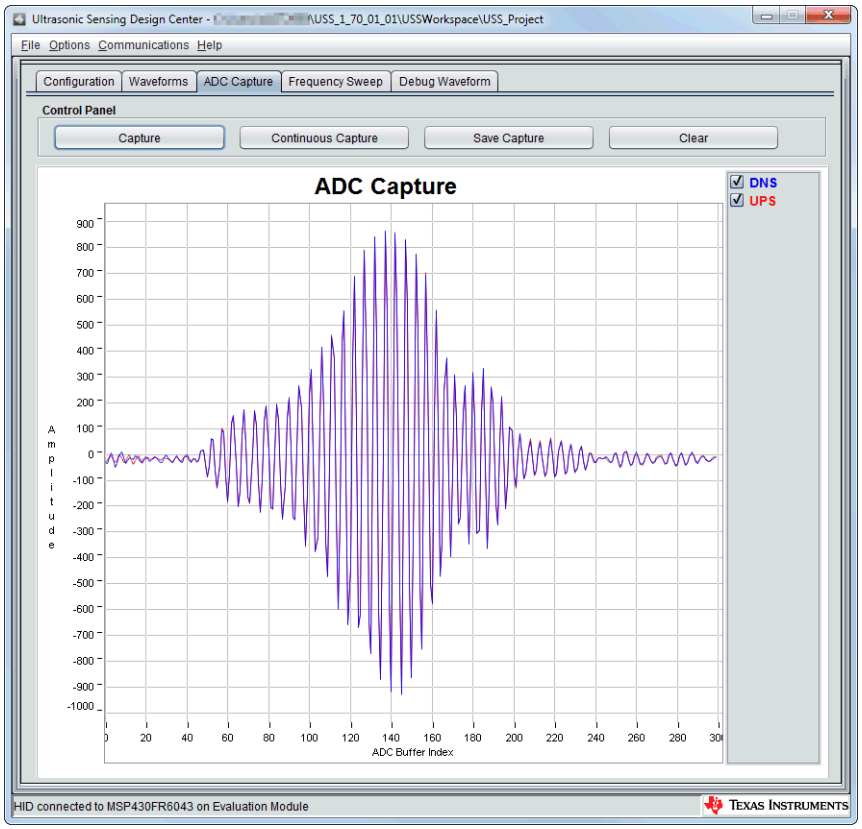


Figure 6. ADC Capture in Design Center

NOTE: The ADC waveform might be different from Figure 6, but it should have sufficient amplitude, the upstream and downstream should look almost identical (without flow), and the complete signals should fit in the capture window.

For debugging information, see Section 7.

10. Select the Waveforms tab and click **Start**. The Design Center plots the data received from the device (see Figure 7).

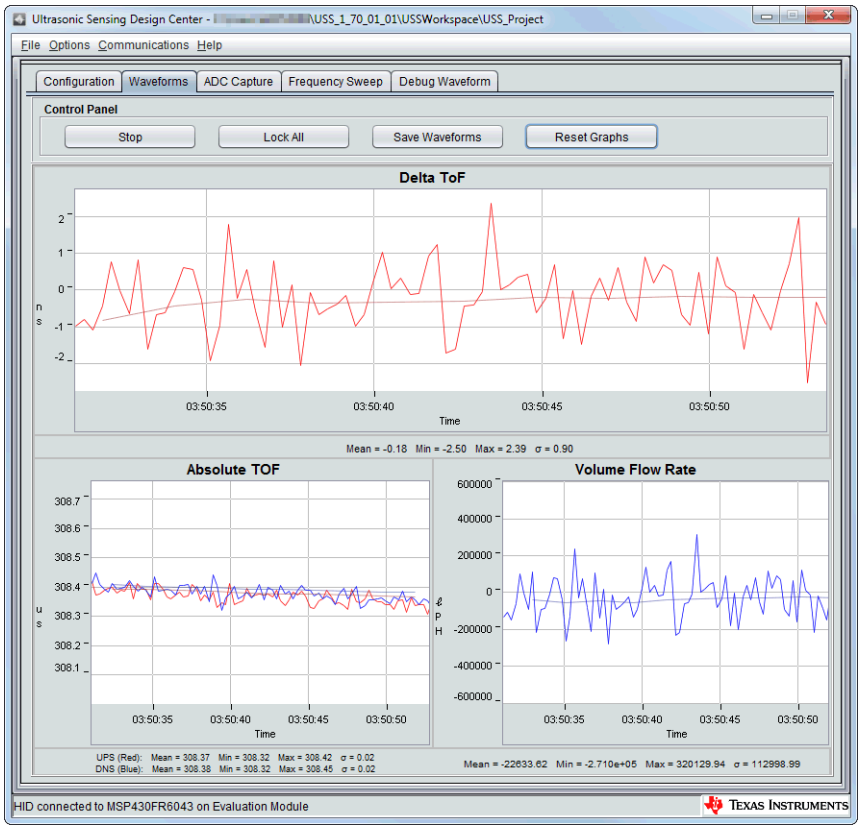


Figure 7. Waveforms in Design Center

NOTE: For information about debugging the waveforms, see Section 7.

11. For other features and configuration of Design GUI, see the MSP430FR6043 Ultrasonic Sensing Design Center User's Guide.

5 Customizing the Demo

The *Ultrasonic Gas Demo Application for MSP430FR6043* can be used to connect with different transducers and pipes by following the next steps:

1. Follow Steps 1 to 6 in Section 4 to connect the EVM430-FR6043 to the Ultrasonic Sensing Design Center.
2. Load a default configuration in mtr_gui_config as a starting point to test the new transducers.
3. Send the configuration to the device.

4. Attempt to take an ADC capture.

   The ADC Capture might be incorrect due to factors such as propagation time, transducer frequency, and gain (see Figure 8).

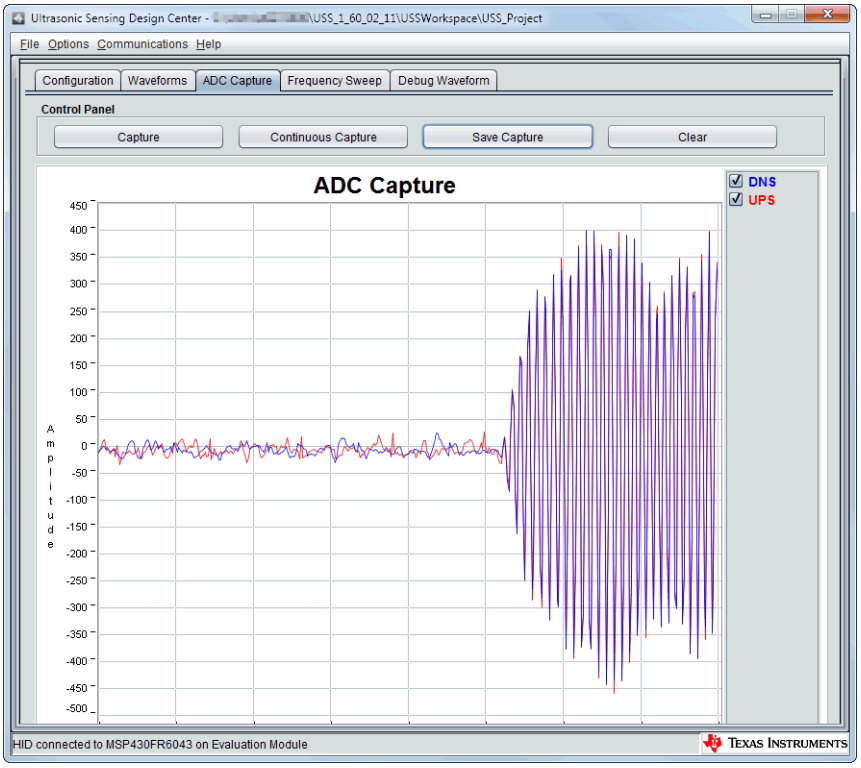


Figure 8. Incorrect ADC Capture

5. It is possible to modify some of the parameters based on a visual inspection of the waveform, or an oscilloscope can be used to observe and adjust the signals. Connect an oscilloscope to one of the transducer terminals and to the ADC input (see Figure 9).

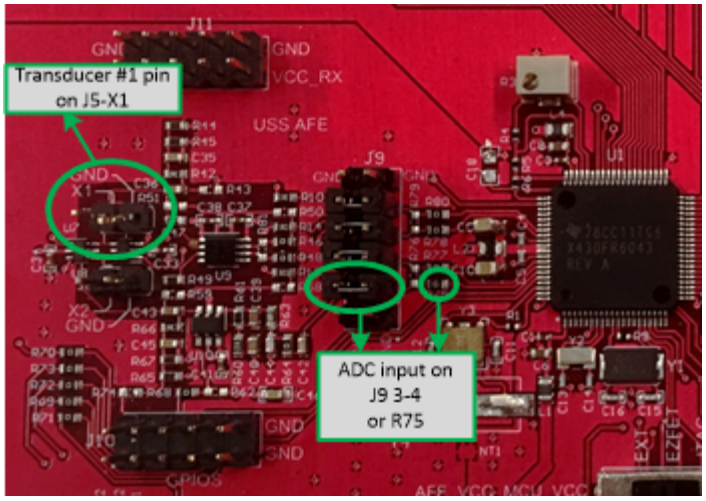


Figure 9. Oscilloscope Connections for EVM430-FR6043-E2

6. Observe the signal in the oscilloscope. Figure 10 shows that it takes approximately 305 µs for the signal to arrive to the ADC input (in blue). Because of this, the signal is not received completely.

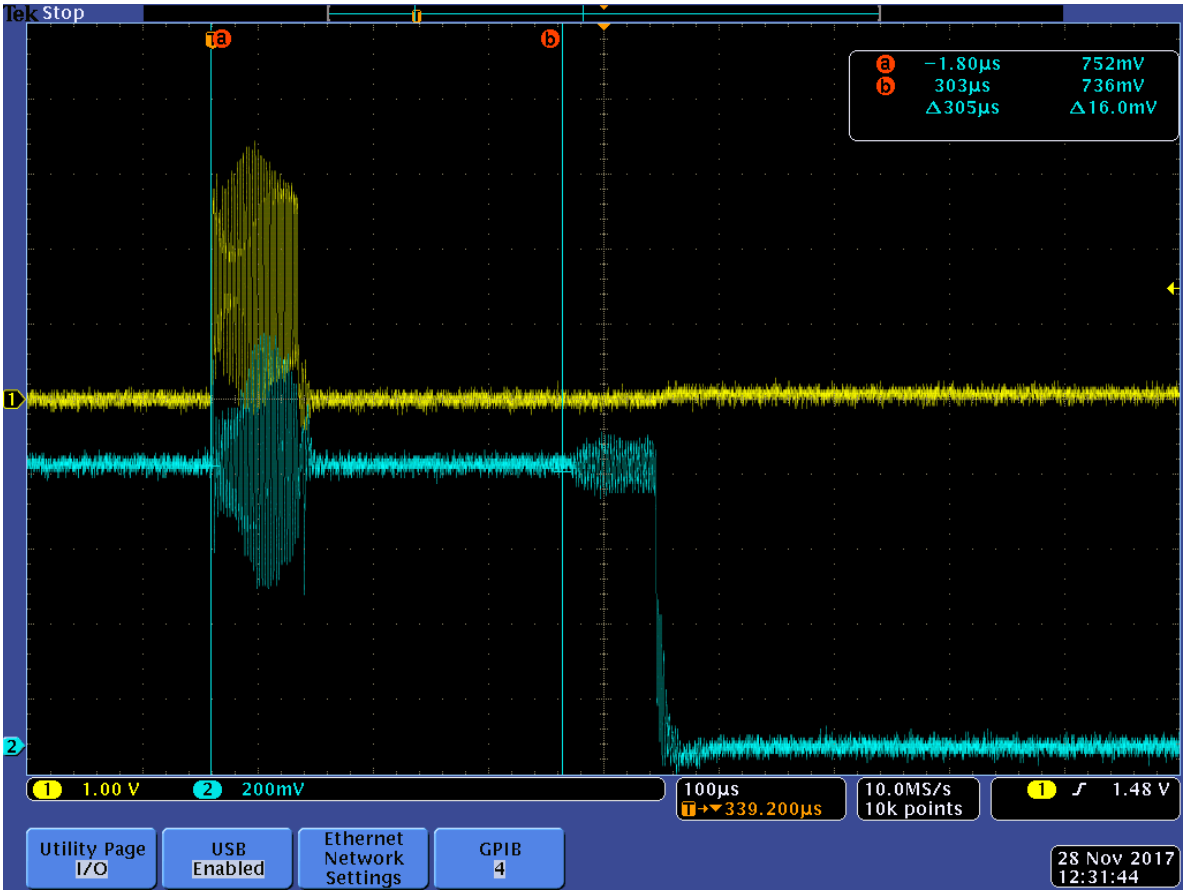
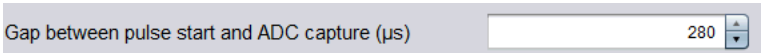


Figure 10. Unadjusted Signal in Oscilloscope

7. Adjust the parameters as needed, some of the most common parameters follow:
   a. As observed in Figure 8 and Figure 10, the biggest problem with the current configuration is that the ADC capture is occurring too early. This parameter can be adjusted using the “Gap between pulse start and ADC capture”.



   b. The transducer transmit frequency can be adjusted manually based on the parameters of the transducers; however, TI recommends running a Frequency Sweep to determine the optimal configuration of the device.

      For more information, see the MSP430FR6043 Ultrasonic Sensing Design Center User’s Guide.

   c. The number of pulses affects the amplitude and shape of the waveform:

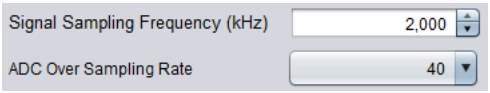
   d. The UPS and DNS gap adjusts the time between upstream and downstream captures. This parameter can be adjusted to ensure enough settling time for the signals.

e. The UPS0 to UPS1 gap adjusts the measurement rate. Adjust to increase or decrease the measurement rate as a tradeoff of power consumption.

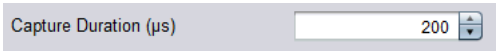
f. The Gain control adjusts the gain or attenuation of the signal. Adjust this parameter to ensure proper signal amplitude.

g. The signal sampling frequency can be adjusted to increase or decrease the sampling rate as a tradeoff of power consumption. Ensure a sampling rate at least 3.5x the transducer frequency.

The sampling rate is typically modified together with the ADC oversampling rate, since some combinations can result in an invalid PLL setting. For more information, see the MSP430FR6043 Ultrasonic Sensing Design Center User's Guide (SLAU755).



h. The capture duration can be adjusted to ensure enough time to capture the signal, including drifts due to temperature or flow. This parameter will affect the total number of samples which is limited by the application, and it will also affect power consumption due to processing time.



8. Update the configuration, check the signal and repeat adjustments as needed.

6 Flashing the Binaries

1. The EVM430-FR6043 must be to connected to USB using the default configuration in Section 2.1.1.
2. Install MSP Flasher. The default folder depends on the version:

   C:\ti\<MSP_Flasher_version>\
3. In a command prompt, go to the *Ultrasonic Gas Demo Application for MSP430FR6043* **image** folder. The default folder is:

   C:\ti\msp\<Ultrasonic_Gas_Demo_application_version>\image
4. In a command prompt, run the following command:

   C:\ti\<MSP_Flasher_version>\MSP430Flasher.exe –w <application_text_file> -v –g –z [VCC]

5. MSP Flasher detects the EVM and programs the device (see Figure 11).

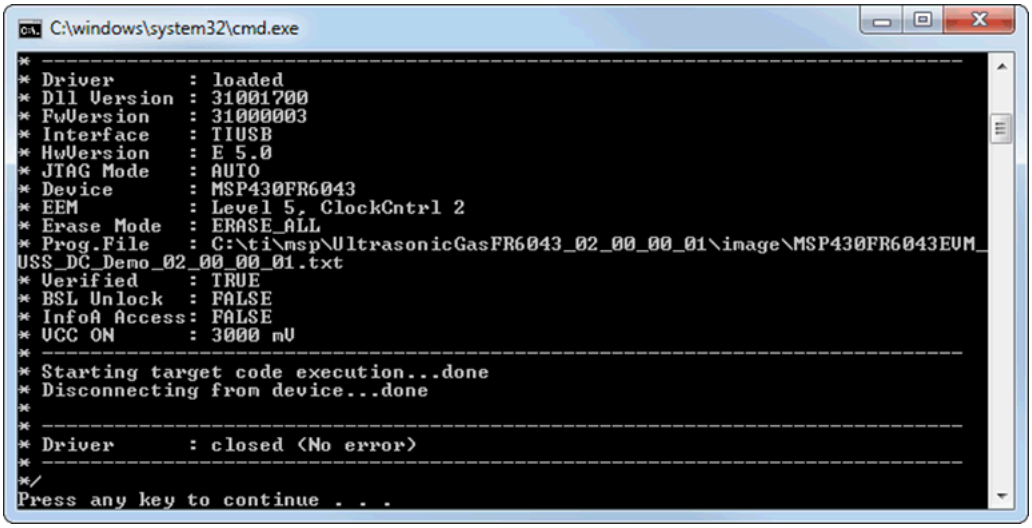


Figure 11. Successful Execution of MSP Flasher

For more information about MSP Flasher, see the MSP Flasher User's Guide.

7 Troubleshooting

1. **Problem: The GUI doesn't recognize EVM.**

   Solutions:

   - Make sure the EVM430-FR6043 is connected to PC.
   - The EVM includes an HID bridge which should recognized by Windows Device Manager as two HID devices:

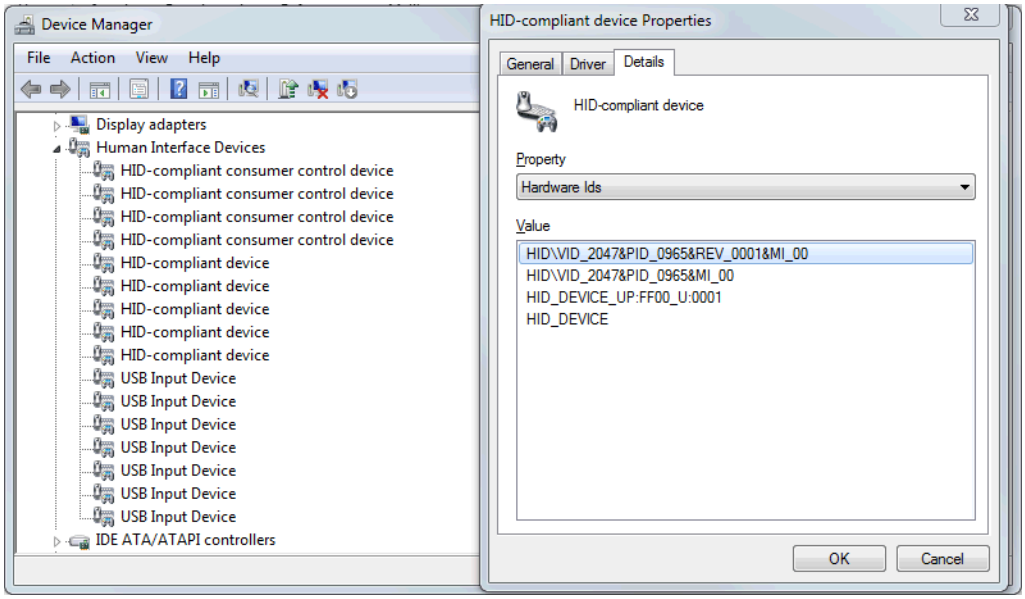


Figure 12. HID Bridge in Device Manager

   - Make sure the jumpers as set properly to power the board and to communicate with HID Bridge. Check the EVM430-FR6043 hardware guide for more details.
   - Try restarting the GUI.
   - If needed, reprogram the EVM as explained in Section 6.

2. **Problem: GUI is connected, but not updating device after loading a new configuration.**

   Solutions:

   - Some configurations are not supported by the device. The GUI will display an error. Try with a different configuration, or modifying the firmware to support your custom configuration.
   - Try re-flashing the device as described in Section 6.

3. **Problem: MSP Flasher, CCS or IAR cannot program and debug the EVM.**

   Solutions:

   - Make sure EVM430-FR6043 is connected to PC.
   - The EVM includes eZ-FET circuitry which is used to program and debug the MSP430FR6043. This device should be recognized by Windows Device Manager as two HID devices:

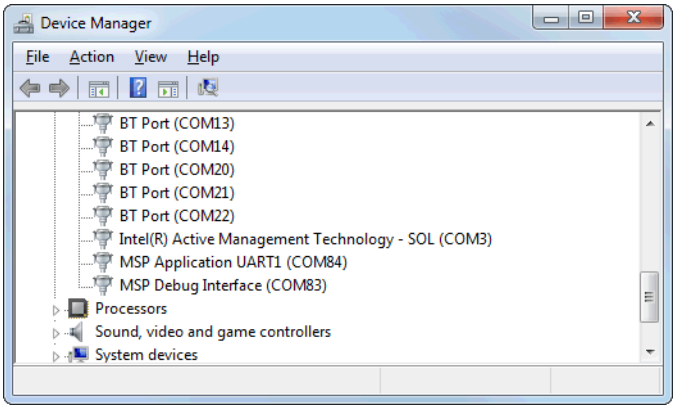


Figure 13. eZ-FET in Device Manager

   - Drivers are needed for proper operation. TI recommends installing the drivers by installing an IDE such as TI CCS or IAR EW430. Drivers are also available from http://www.ti.com/MSPdrivers.
   - Make sure the jumpers as set properly to power the board and to communicate with eZ-FET. See the EVM430-FR6043 hardware guide for more details.

4. **Problem: ADC waveform looks incorrect.**

   Solutions:

   - Verify the polarity of the transducers.
   - Try adjusting the Design Center parameters as described in Section 5.

5. **Problem: Delta TOF (dTOF) and Volume Flow Rate data in the waveform window look noisy.**

   Solutions:

   - The GUI adjusts the zoom automatically depending on the input. If the dTOF is not varying much, the signal will look noisy even though the change is minimal. Try changing the air flow rate to observe a more noticeable change.
   - Gas meters are usually placed inside a shielded case to reduce noise. In such case, connect the GND shield to the EVM430-FR6043 ground using a connector such as J31 for revision E1 of the EVM, or TP2 for revision E2.
   - A USB cable with ferrite can help reduce noise when connected to PC.
   - A clean power supply can help reduce noise.

6. **Problem: There is variation on dTOF and Volume Flow Rate even without flow.**

   Solutions:

   - Zero-flow-drift (ZFD) tests are typically performed to observe the expected variation of the system and determine the minimum detectable flow. These tests require the meter to be sealed to reduce air flow to the minimum possible.
   - Gas meters are usually placed inside a shielded case to reduce noise. In such case, connect the GND shield to the EVM430-FR6043 ground using a connector such as J31 for revision E1 of the EVM, or TP2 for revision E2.
   - A USB cable with ferrite can help reduce noise when connected to PC.
   - A clean power supply can help reduce noise.

7. **Additional comments or questions?**

   - Submit comments or questions to the TI E2E™ community forums.
   - Configuration files, ADC captures (single and continuous), and waveform captures help to determine issues with the EVM, software, or Design Center.

8 References

1. MSP430FR6043 ultrasonic sensing design center user's guide
2. EVM430-FR6043 hardware guide

9 REACH Compliance

In compliance with the Article 33 provision of the EU REACH regulation, TI notifies you that this EVM includes components containing at least one Substance of Very High Concern (SVHC) above 0.1%. These uses from Texas Instruments do not exceed 1 ton per year. The SVHCs are:

Component Manufacturer	Component Part Number	SVHC Substance	SVHC CAS
Murata	CSTCR4M00G15L99-R0	Lead Titanium Zirconium Oxide	12626-81-2
Murata	CSTCR6M00G53Z-R0	Lead Titanium Zirconium Oxide	12626-81-2
Abracon	ABM3-8.000MHZ-D2Y-T	Diboron Trioxide	1303-86-2
Abracon	ABM3-8.000MHZ-D2Y-T	Lead Oxide	1317-36-8
Abracon	AWSCR-8.00CV-T	Boric Acid	10043-35-3
Abracon	AWSCR-8.00CV-T	Lead Oxide	1317-36-8

Revision History

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

Changes from July 19, 2018 to January 24, 2019 **Page**

- Removed references to the EVM430-FR6043-E1 revision throughout document 2
- Changed Figure 2, *EVM430-FR6043 Connected to Gas-Flow Meter* 4
- Removed former Section 2.3 *Fan WIth Pipe Connector* 5
- Updated Section 8, *References* 15

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