MSP430FR5994 Ultrasonic Gas Meter – Quick Start Guide

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ABSTRACT

This quick start guide explains how to build and run an Ultrasonic Gas Meter demo using the MSP430FR5994.

More information about the application can be found at: http://www.ti.com/tool/TIDM-1002.

Contents

1 Hardware

The demo includes and requires the following hardware:

Table 1: Hardware Used for Ultrasonic Gas Meter Demo

Item
1.1 MSP-EXP430FR5994
1.2 Ultrasonic AFE BoosterPack
1.3 Gas Pipe and Transducers
1.4 Fan with Pipe Connector
1.5 DC Power Supply [1]

[1] Not included

1.1 MSP-EXP430FR5994

The MSP-EXP430FR5994 is the EVM used to program, debug and execute the application on the MSP430FR5994 MCU.

More information about the MSP-EXP430FR5994 is available at: http://www.ti.com/tool/msp-exp430fr5994

The default configuration is shown in the following figure:

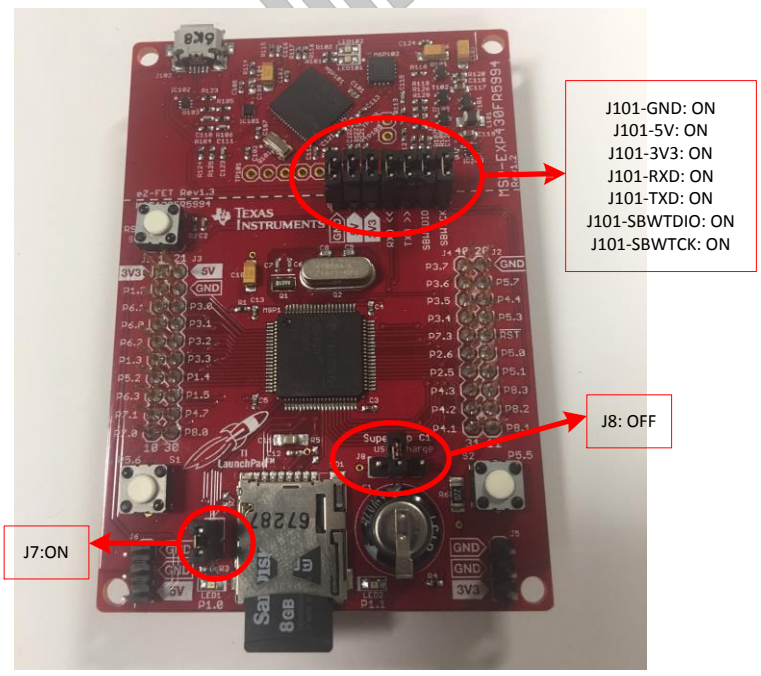


Figure 1: MSP-EXP430FR5994 Default Configuration

1.2 Ultrasonic AFE BoosterPack

TIDM-1002 uses the Ultrasonic AFE BoosterPack to demonstrate the implementation of an Ultrasonic gas meter with MSP430FR5994.

The default configuration of the BoosterPack is shown in the following figure:

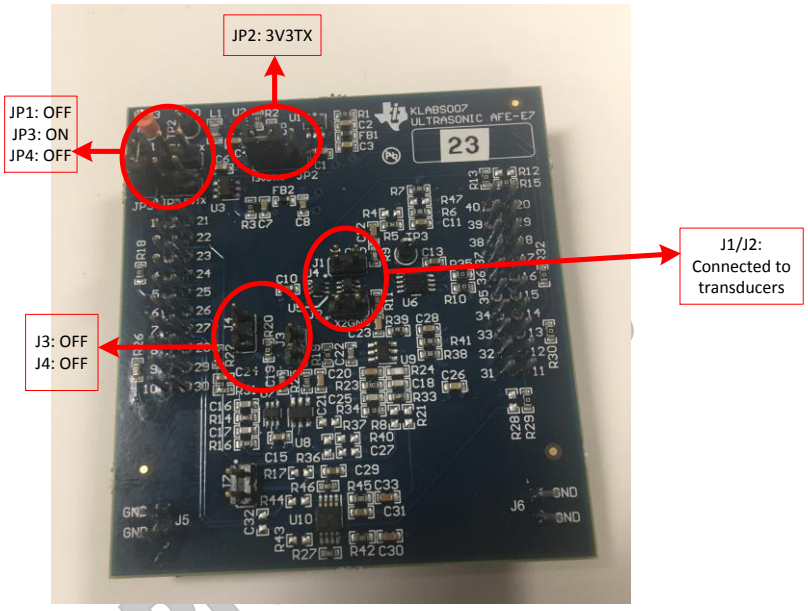


Figure 2: Ultrasonic AFE BoosterPack Default Configuration

1.3 Gas Pipe and Transducers

The demo might include a pipe with 2 transducers. There are different types of transducers used for demo purposes but the pipe should include a label showing the transceiver type.

The picture below shows two types of pipes used for demo purposes:

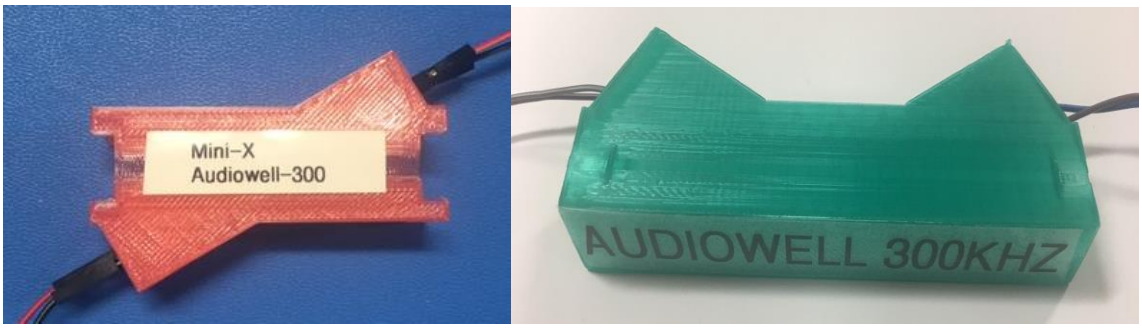


Figure 3: "Mini-X" and 'V' Pipes with Audiowell Transducers

Note:

The meter pipe and transducers included in your demo might be different from the pictures above. Please check the label to distinguish the meter.

1.4 Fan with Pipe Connector

The demo might include a 12V DC fan used for demo purposes. The fan is controlled by a DC voltage and is taped to a PVC pipe which can be attached to the meter pipe.

Figure 4: DC Fan with Pipe Adapter

1.5 DC Power Supply

The demo doesn't include but uses a DC Power supply to control the fan. One example is shown in the following picture:

Figure 5: DC Power Supply

2 Demo Software Package Contents

The contents of the software package used for demo purposes are shown in Table 2.

Table 2: Demo Software Package Contents

File/Folder	Description
binaries/	Folder with pre-built binary files to load demo without building IAR/CCS projects
FR5994GasDemo_QS.pdf	This document
MeterConfig/	Folder with configurations used to test different meters/transducers
gasLibrary_1_10_00_11_windows_installer.exe	Installer of Gas Library including example
MSPFlasher_1.3.10.zip	MSP Flasher used to load binaries to the device
tidud03.pdf	User's Guide for Ultrasonic Gas Meter TI Design
USS_GUI_1_00_02_04.zip	GUI used to configure device and run demo

2.1 Software Preparation

1. Extract **USS_GUI_1_00_02_04.zip** to the folder of your preference.

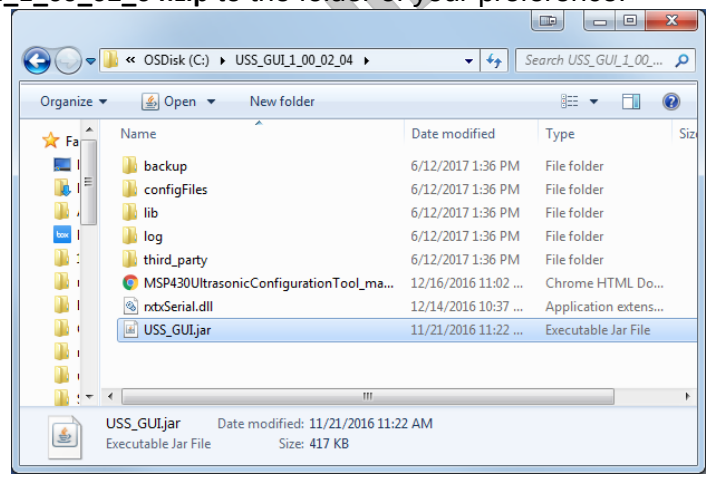


Figure 6: USS GUI Folder

2. (Optional): Install **gasLibrary_1_10_00_11_windows_installer.exe** to be able to modify and rebuild the application using CCS or IAR as described in Appendix B and Appendix C.

3. (Optional): Extract **MSPFlasher_1.3.10.zip** to be able to re-flash the MSP430FR5994 as described in Appendix A.

3 Running the Demo

1. Set hardware in Default configuration as shown in Figure 1 and Figure 2.

2. The MSP430FR5994 should come pre-programmed and ready to run, but if necessary, re-flash the device following the steps described in Appendix A.

3. Connect MSP-EXP430FR5994 to Ultrasonic AFE BoosterPack aligning the Launchpad/BoosterPack connectors as shown in the following figure:

Figure 7: MSP-EXP430FR5994 Connected to USS AFE BoosterPack

4. Connect the transducer terminal to the USS AFE BoosterPack.
The transducers should be connected to J1 and J2 in the Boosterpack, with the black cable connected to each GND pin. The order of the connections is only important to determine the direction of air flow.

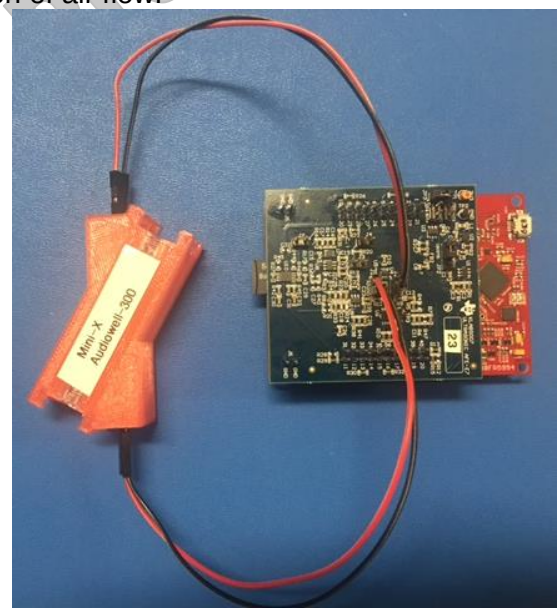


Figure 8: Transducers connected to EVM

5. Connect the MSP-EXP430FR5994 to the PC through USB using J102 connector.

6. Connect the DC fan to the ultrasonic pipe.

7. Connect the fan's positive (red) and negative (black) terminals to the DC power supply as shown in Figure 9:

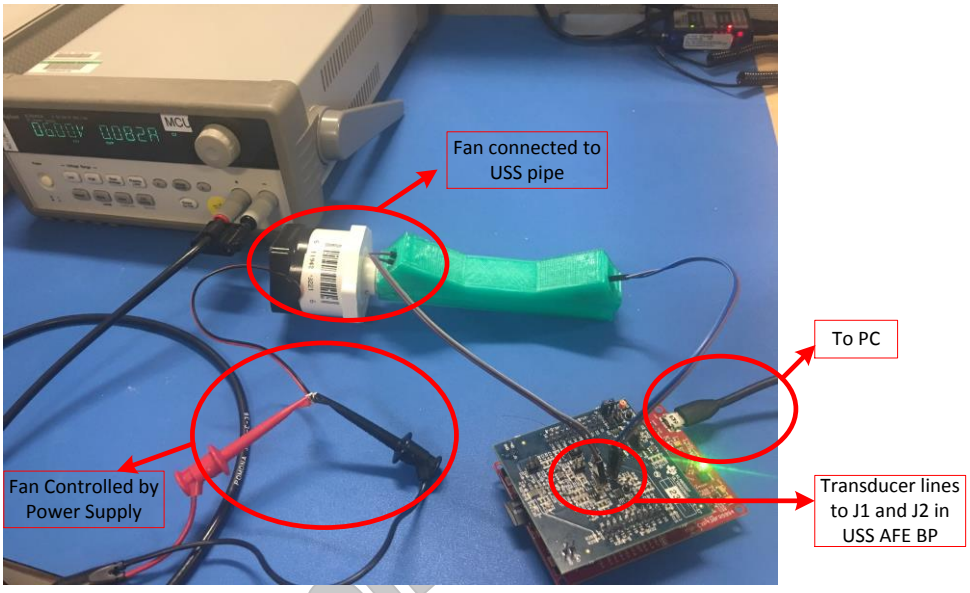


Figure 9: Connections of Ultrasonic Gas Meter Demo

8. Open the folder where the Ultrasonic GUI was extracted to (**USS_GUI_1_00_02_04.zip**) and run the GUI by double-clicking USS_GUI.jar.
   The GUI will start running in the disconnected state.
   The GUI should run after a splash screen displaying the disconnected state:

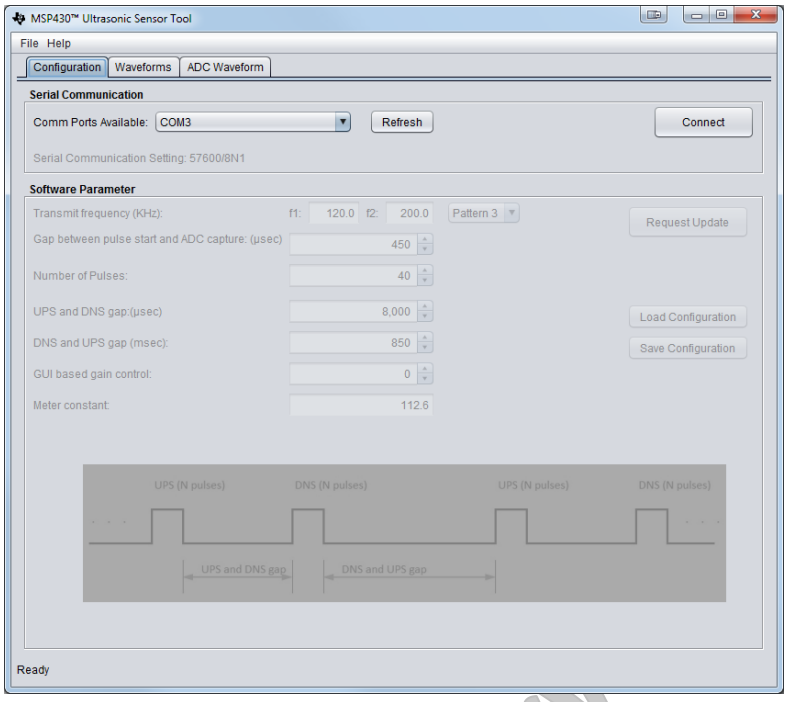


Figure 10: Disconnected USS GUI

9. The GUI will display all connected and enumerated COM ports. Select the port “MSP Application UART1”.

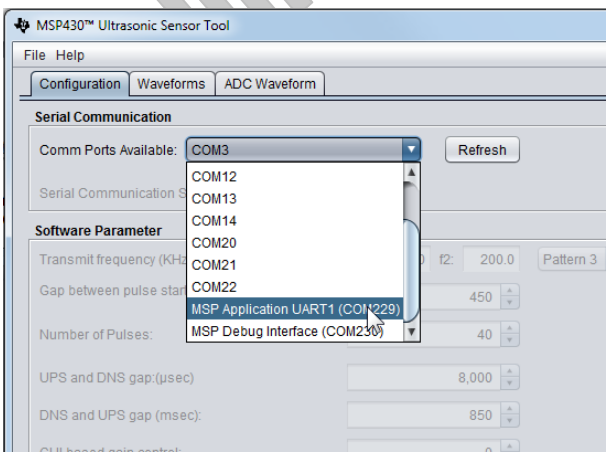


Figure 11: Selecting the COM port

10. Click the “Connect” Button. The GUI should go to the connected state

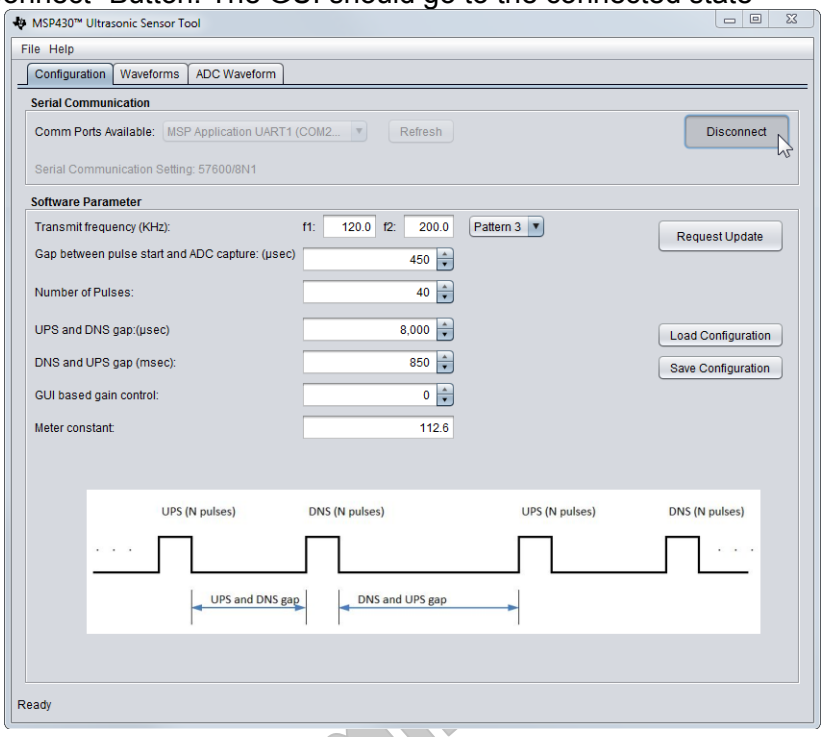


Figure 12: Connected USS GUI

11. Click on “Load Configuration” and select the configuration file inside **MeterConfig/** corresponding to your meter and transducers:

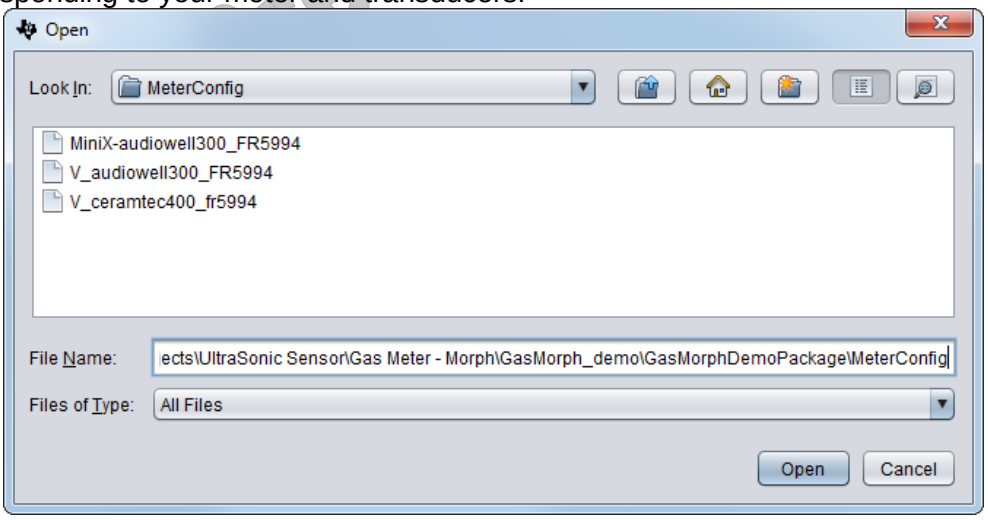
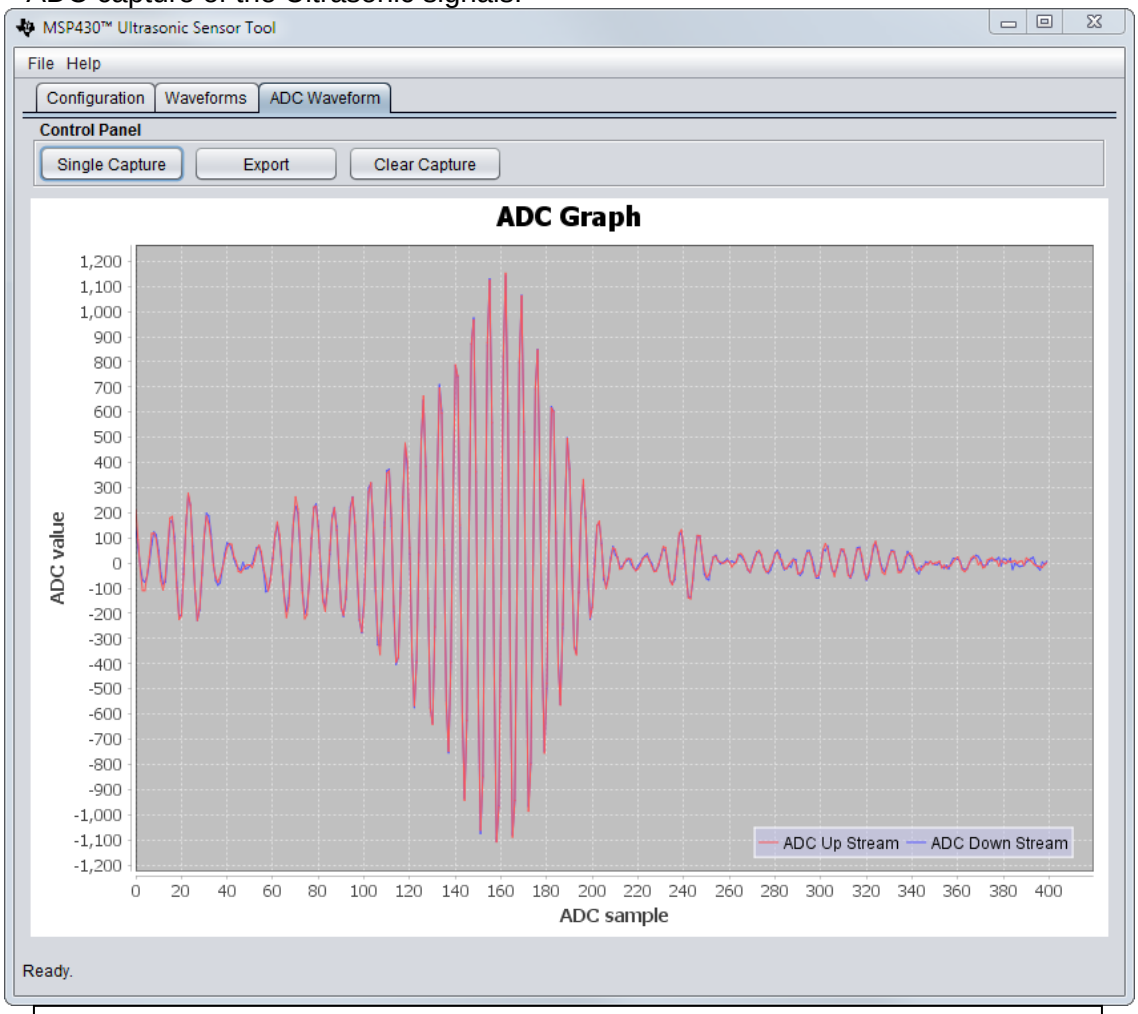


Figure 13: Selecting a Configuration File in USS GUI

12. Click on “Request Update”. The green LED on MSP-EXP430FR5994 (LED1 on bottom of board) should toggle and the GUI will show a message to indicate a successful operation.

13. Select the “ADC Waveform” tab and click on “Single Capture”. The GUI will request an ADC capture of the Ultrasonic signals:



Note:

The ADC waveform might look different than the image above but it should have sufficient amplitude, the upstream and downstream should look almost identical (without flow), and the complete signals should be in the capture window.

For debugging information, please refer to Section 0.

14. Select the “Waveforms” tab and click the “Start” button. The GUI will start plotting the data received from the device:

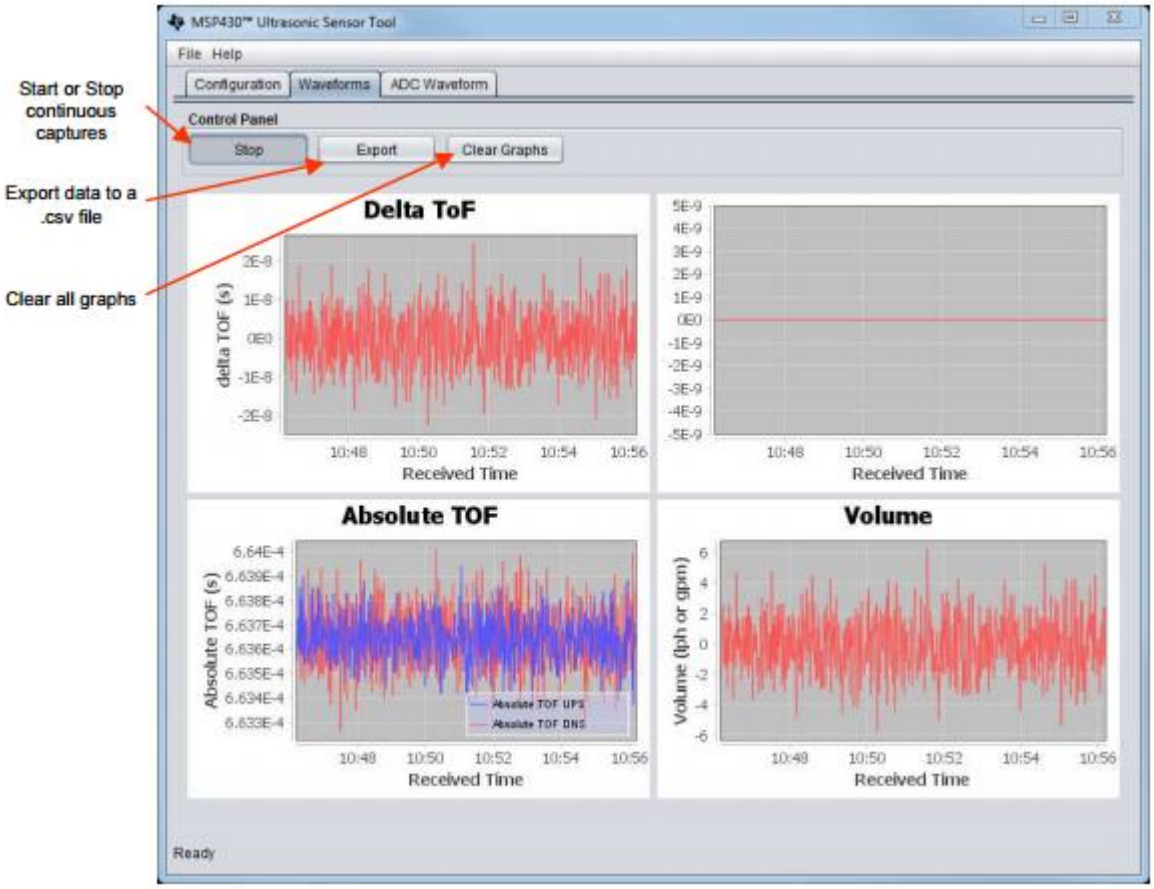


Figure 14: TOF Waveforms

> Note:
>
> For debugging information about the waveforms, please refer to Section 5.

3.1 Flow Demo

The flow demo shows the capability of the Ultrasonic Gas Meter AFE to detect changes in air flow rate.

Follow the next steps:

1. Change the air flow rate by adjusting the DC voltage of the power supply.

2. The GUI will show the effect of changing air flow in the Absolute and Differential Time-of-Flight (TOF) and volume.

   The DC fan is expected to have an air flow of ~0.5CFM at 12V and 0.15CFM at 4V.

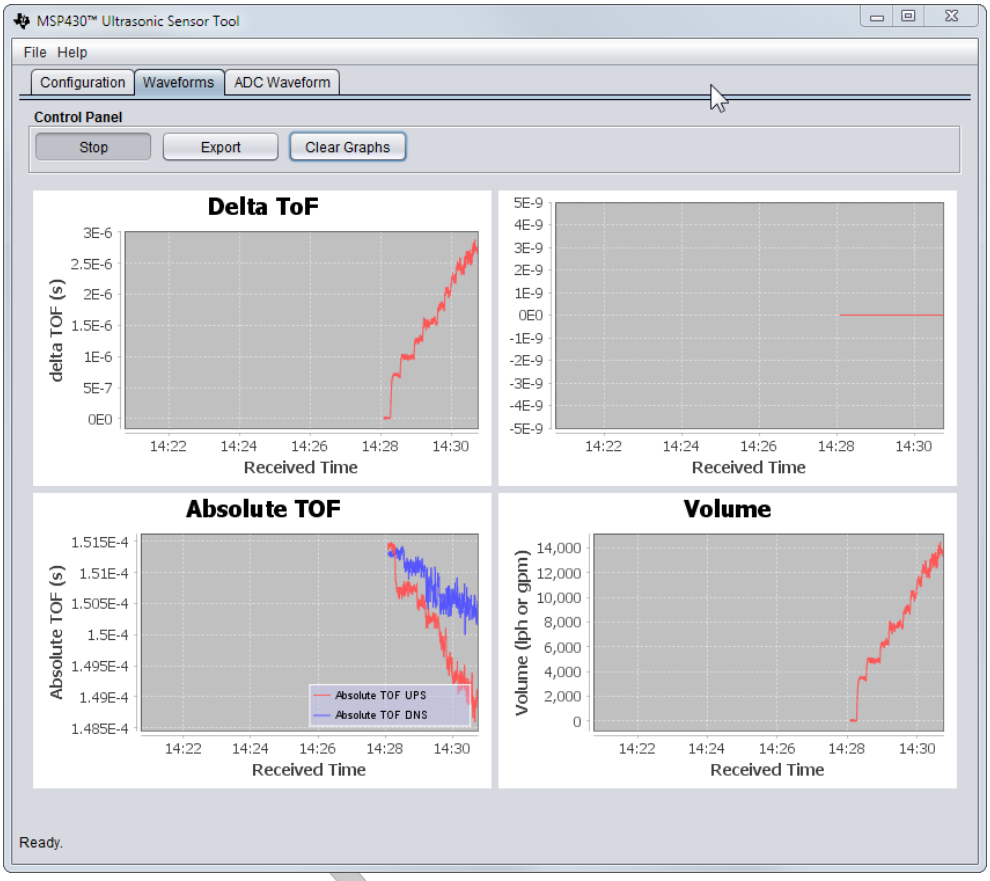


Figure 15: GUI showing Air Flow

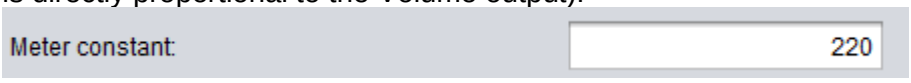
3.2 Adjusting Volume output

The “Volume” plot shows the flow rate as a factor of the TOF (absolute and differential) and a meter constant.

This meter constant depends on the meter characteristics and the desired output units.

To adjust the volume, follow the next steps:

1. Select the “Configuration” window.
2. Change the “Meter Constant” parameter to a desired value (i.e. the meter constant is directly proportional to the Volume output).



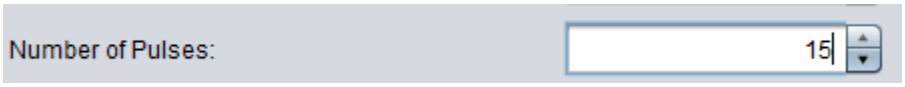
3. Click the “Request Update” button
4. The Volume output should change proportionally to the change of the parameter.

3.3 Changing Number of Pulses

The number of pulses sent to the transducers determines the shape and amplitude of the received signal.

The effect of changing number of pulses can be observed by following the next steps:

1. Select the “Configuration” Window.
2. Modify the “Number of Pulses” parameter to a desired value.



3. Click the “Request Update” button.
4. Check the effect on the “ADC Waveform” tab.

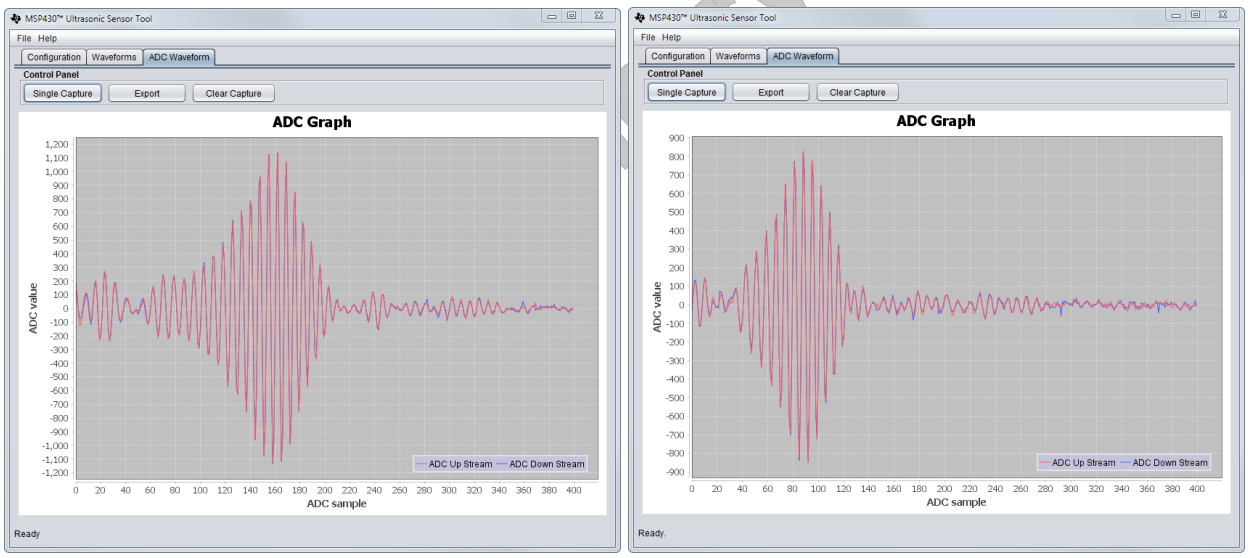


Figure 16: Decreasing the Number of Pulses

4 Customizing the Demo to Receive Signal from Different Transducers/Pipes

1. Set hardware in Default configuration as shown in Figure 1 and Figure 2.

2. The MSP430FR5994 should come pre-programmed and ready to run, but if necessary, re-flash the device following the steps described in Appendix A.

3. Connect MSP-EXP430FR5994 to Ultrasonic AFE BoosterPack aligning the Launchpad/BoosterPack connectors as shown in Figure 7.

4. Connect the transducer terminal to the USS AFE BoosterPack.
   The transducers should be connected to J1 and J2 in the Boosterpack, with the black cable connected to each GND pin. The order of the connections is only important to determine the direction of air flow.
   If available, connect the ground shield of the pipe to connectors J5 or J6 in the AFE BoosterPack.

5. Connect the MSP-EXP430FR5994 to the PC through USB using J102 connector.

6. Open the folder where the Ultrasonic GUI was extracted to (**USS_GUI_1_00_02_04.zip**) and run the GUI by double-clicking USS_GUI.jar.
   The GUI will start running in the disconnected state.
   The GUI should run after a splash screen displaying the disconnected state as shown in Figure 10.

7. The GUI will display all connected and enumerated COM ports. Select the port “MSP Application UART1”.

8. Click the “Connect” Button. The GUI should go to the connected state

9. Click on “Load Configuration” and select a configuration file inside **MeterConfig/** which can be used as a base to test the new transducers.
   In this example, we will use the Ceramtec 400 configuration since the custom meter uses 400Khz transducers, although the dimensions are different.

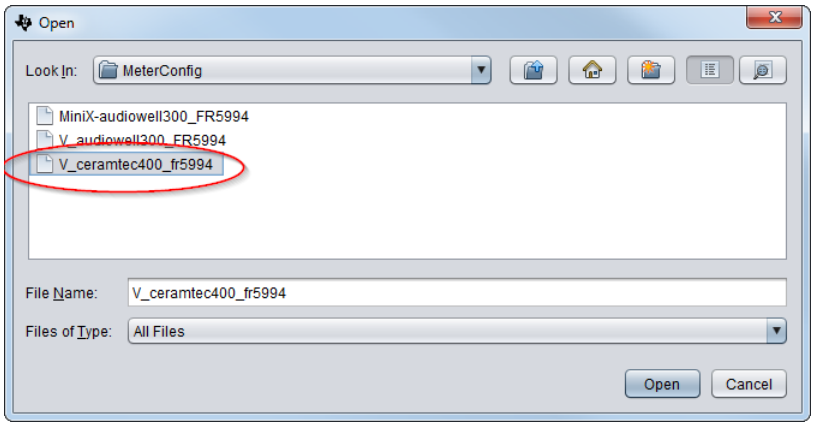


Figure 17. Selecting Ceramtec 400Khz Configuration

10. The ADC Waveform might show a capture which is incorrect due to the propagation time, transducer frequency, etc.

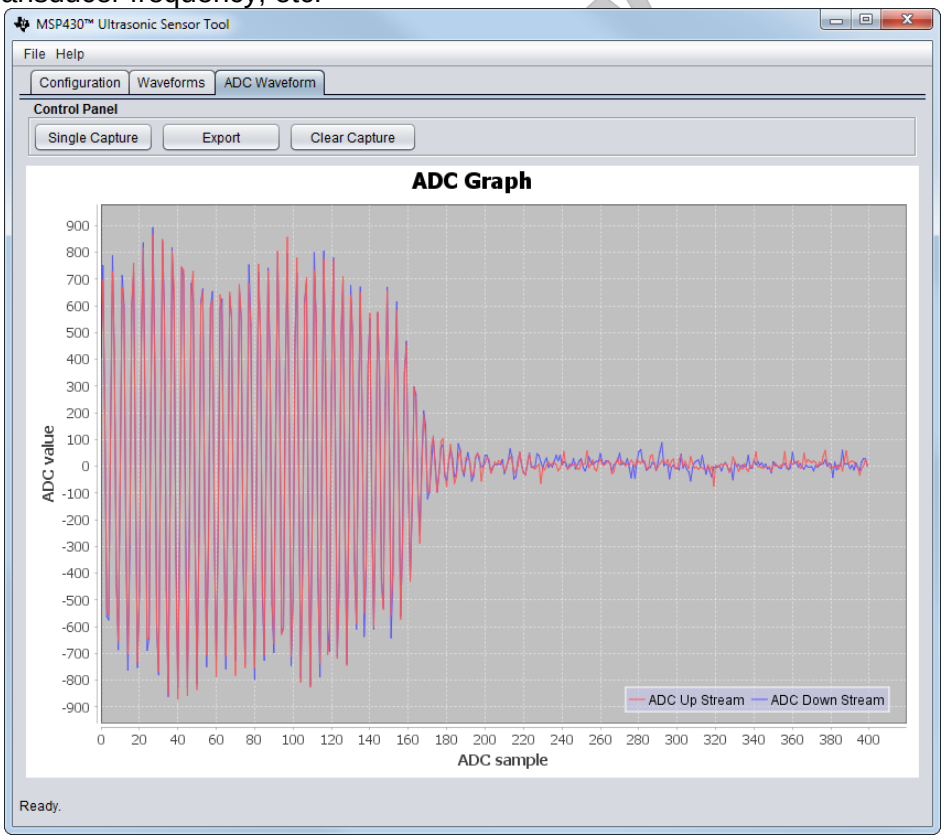


Figure 18: Incorrect ADC Waveform Capture

The waveform from the ADC capture can be used to customize some of the GUI parameters; however, this guide shows how to verify the physical connections to the pipe.

11. Connect an oscilloscope to pin labeled “15” on right BoosterPack connector and pin “6” of left connector.
    - Pin “15” is connected to the output pin, which based on our default configuration is expected to generate 40 pulses of 360Khz-440Khz twice (once for Upstream and once for Downstream) every ~850ms.
    - Pin “6” is the signal obtained by the RX transducer, amplified by the dual-stage amplifier, and going to the ADC input of MSP430FR5994.

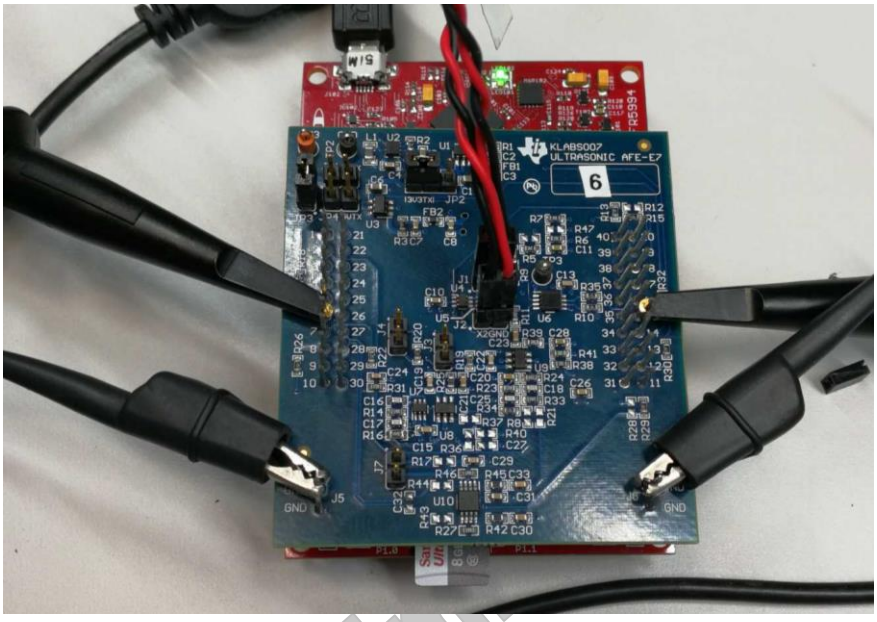


Figure 19: Oscilloscope connected to AFE BoosterPack

The signals should look as below for a long capture:

Figure 20: Long Oscilloscope Capture of Signals To/From Transducers

- CH1 (in yellow) is connected to the output pin, while CH2 (in blue) is connected to the ADC input.
- Note that there are multiple output “bursts” for each upstream/downstream. For each output “burst”, there should be an input signal.
  If no input is detected, this indicates a problem in the physical connection to one of the transducers.
- The current default configuration is expected to generate 22 pulses every ~1 second.
  10 + 1 dummy transfer for each upstream and downstream since our signal sampling frequency is 2MSPS but our ADC sampling is 200KSPS.
- The gap between complete UPS/DNS sequences is defined by “DNS and UPS gap”. In the capture above, the gap is ~850ms:

12. Zoom-in on one of the captures as shown in the following figure:

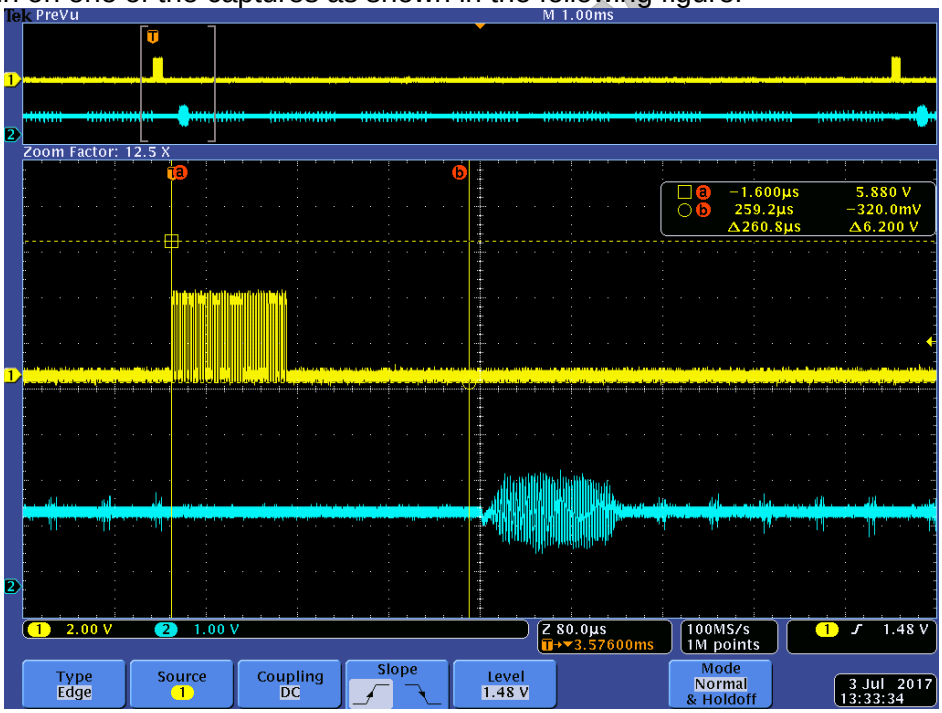
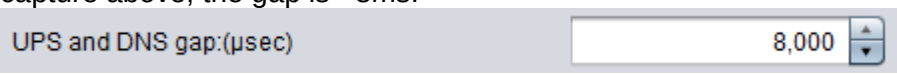


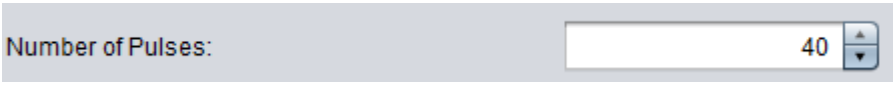
Figure 21: Oscilloscope Capture for one Ultrasonic Signal Capture

- The gap between each signal bursts is defined by “UPS and DNS gap”. In the capture above, the gap is ~8ms:



This parameter can be adjusted to ensure that the signal stabilizes before the next capture, but it has an adverse effect on power consumption.

- The number of pulses sent on each burst is given by “Number of Pulses”. In the capture above, the number of pulses is 40:

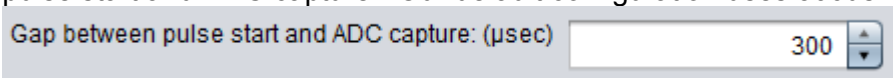


This parameter can be customized to increase the amplitude of the received signal at the expense of higher power consumption.

- The frequency of the transmitted pulses is defined by “Transmit Frequency”. In the capture above, the device generates pulses between 360Khz and 440Khz. Note that the device generates a modulated “multi-tone” pattern to generate a better response from the transducers.

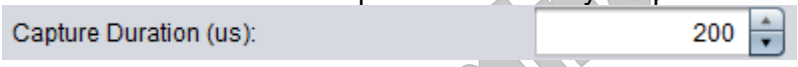
This parameter must be customized according to the excitation frequency of the transducers.

- The gap between the output burst and ADC sampling is defined by “Gap between pulse start and ADC capture”. Our default configuration uses 300us.



This parameter must be customized according to the propagation delay of the meter pipe. The oscilloscope capture above shows a propagation delay of ~260us for our new meter.

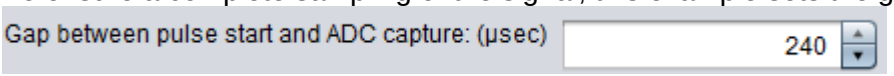
- The duration of the ADC capture is defined by “Capture Duration”:



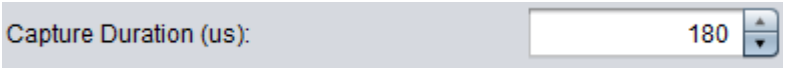
This parameter must be adjusted according to the duration of the received signal.

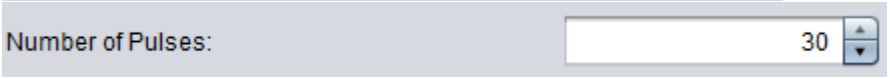
The parameters above are commonly modified to obtain a proper signal. For a complete description of the GUI parameters, please refer to http://www.ti.com/tool/TIDM-1002.

13. Modify the GUI parameters as needed.
    The following modifications were done for the custom meter used in this example:
    - As observed in the oscilloscope capture, the only necessary modification is the “Gap between pulse start and ADC capture”.
      To ensure a complete sampling of the signal, this example sets the gap to 240us:



    - Additionally, we will set the number of pulses to 30 and reduce the capture duration to 180us:





14. Update the configuration by clicking “Request Update”

15. Take an ADC Waveform Capture to check the effect on the signal:

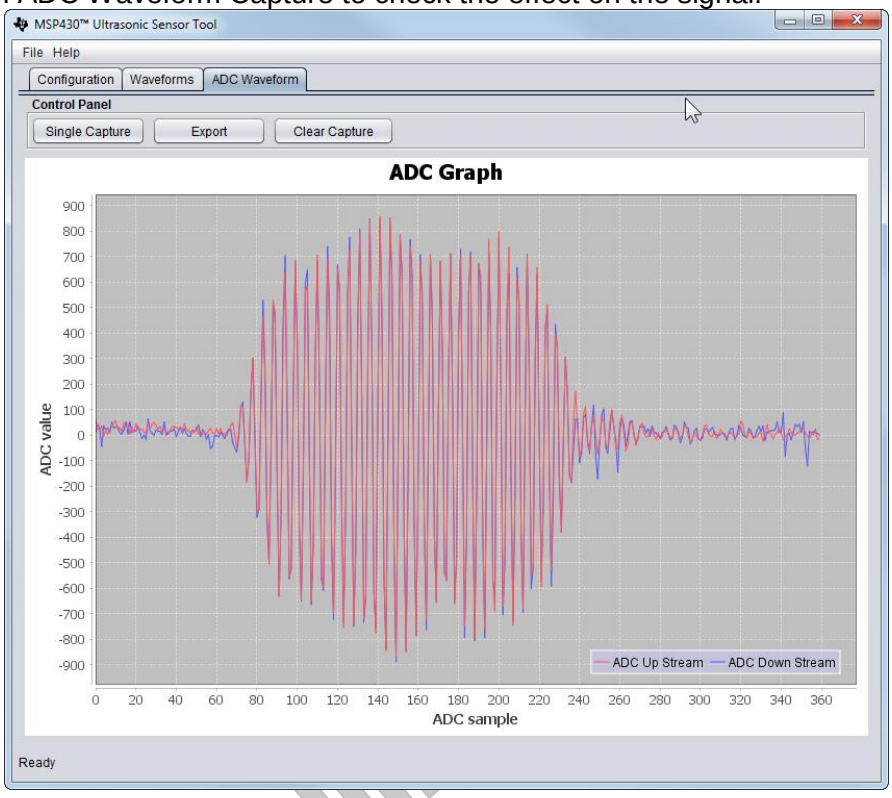
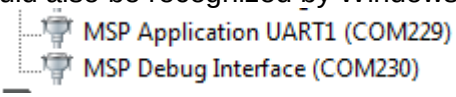


Figure 22: Correct ADC Waveform after Adjusting Parameters

If needed, repeat steps 13-15 to adjust the signal response.

5 FAQs and Troubleshooting

- **Q: GUI doesn't recognize EVM**
  A:
  - Make sure MSP-EXP430FR5994 is connected to PC.
  - The device should also be recognized by Windows 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 at http://www.ti.com/MSPdrivers.
  - Click the Refresh Button on the GUI to
  - If needed, try restarting the GUI.

- **Q: GUI is not updating device after loading a new configuration**
  A:
  - Try pressing the "Request Button" again. The MSPFR5994 is usually in LPM3 mode, and some devices can miss the "Wake-up" event sent by the GUI at a baudrate of 57,600bps. In such case, LED1 on the MSP-EXP430FR5994 won't turn on when the update is requested.
  - Try re-flashing the device as described in Appendix A.
  - Some configurations might not be supported by the device. The current GUI won't display an error message, but the LEDs on MSP-EXP430FR5994 will stay ON to indicate an error. If so, try a different configuration.

- **Q: ADC Waveform looks incorrect**
  A:
  - The pipe and transducers are only provided for demo purposes and they were not manufactured for high robustness. The default configurations provided in **MeterConfig/** were tested before shipment but a misalignment or change of position of transducers during transportation might affect the results. In such case, try re-adjusting the cables and/or the position of the transducers.
  - Verify the polarity of the transducers by swapping the connection of the red and black cables.
  - Try adjusting the "Gap between pulse start and ADC capture" in the GUI. This parameter adjusts the propagation delay in case the received signal is not centered properly on the ADC capture

- **Q: Delta TOF (dTOF) and Volume data in Waveform window looks noisy**
  A:
  - 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 Ultrasonic AFE Boosterpack GND using connectors J5 and J6.
  - A USB cable with ferrite can help reduce noise when connected to PC.
  - A clean power supply can help reduce noise.

- **Q: Delta TOF (dTOF) or Volume doesn't vary perfectly proportional to the DC voltage**
  A:
  - The DC fan provided for demo purposes is not highly accurate.

- **Q: There is variation when the fan is off.**
  A:
  - 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 Ultrasonic AFE Boosterpack GND using connectors J5 and J6.
  - A USB cable with ferrite can help reduce noise when connected to PC.
  - A clean power supply can help reduce noise.

- **Q: What is the air flow range tested with this reference design.**
  A:
  - The 12V DC fan included for demo purposes was measured to have a flow rate of approximately ~0.5CFM at 12V and ~0.15CFM at 4V.
  - The reference design has been tested with other fans and meter configurations, including a 2.9CFM fan discussed in TIDM-1002.

Appendix A. Flashing the binaries

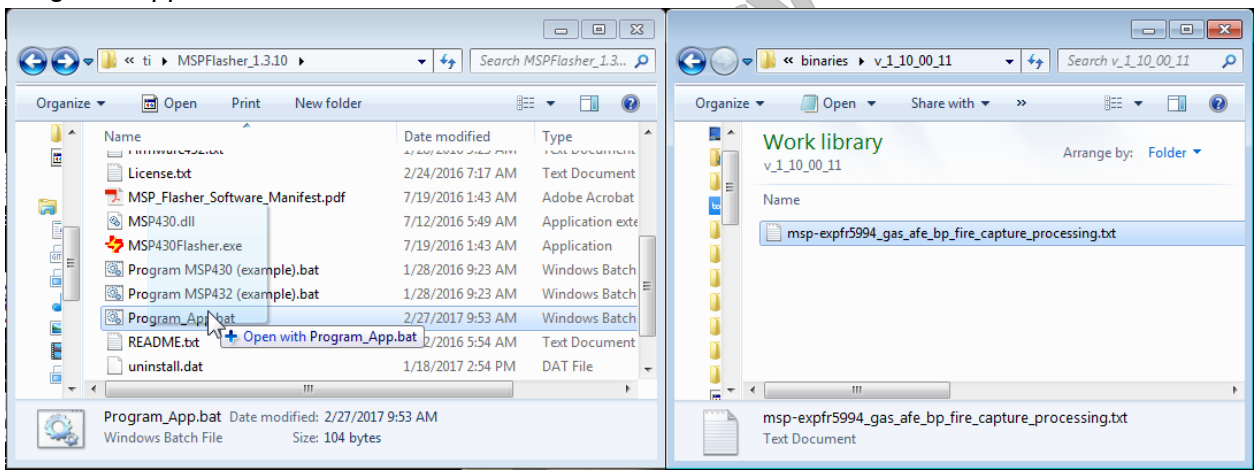
1. LaunchPad must be connected to USB using the default configuration discussed in Figure 1.

2. Unzip **MSPFlasher_1.3.10.zip** and place it in the following location:
   `C:\ti\MSPFlasher_1.3.10`

> Note:
>
> The installation folder can differ but this will affect the execution of the batch file used for this example.

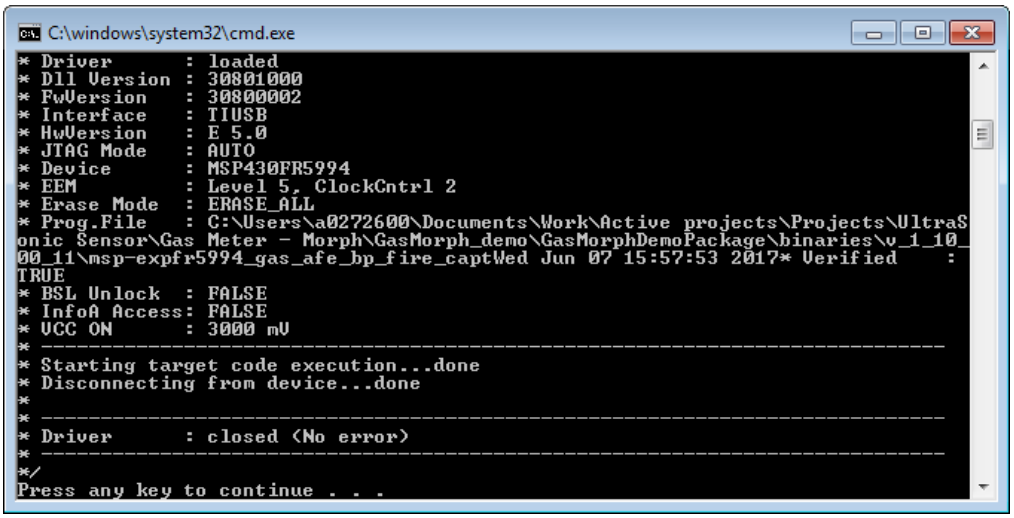
3. Open the **binaries** in Windows explorer and go to the following location:
   binaries\v_1_10_00_11

4. Drag-and-drop the binary file (*msp-expfr5994_gas_afe_bp_fire_capture_processing.txt*) into *Program_App.bat*



> Note:
>
> MSP430Flasher.exe can also be used to program the device without using the batch file. Check MSP430 Flasher documentation for more details (http://www.ti.com/tool/msp430-flasher).

5. MSP430 Flasher should detect the LaunchPad and program the device:

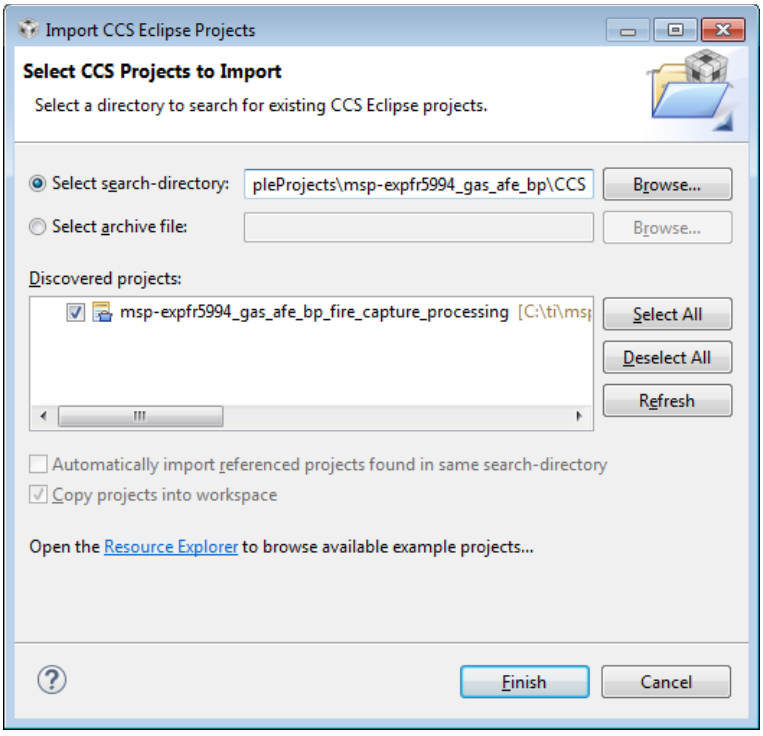


Appendix B. Importing and Building Project in CCS

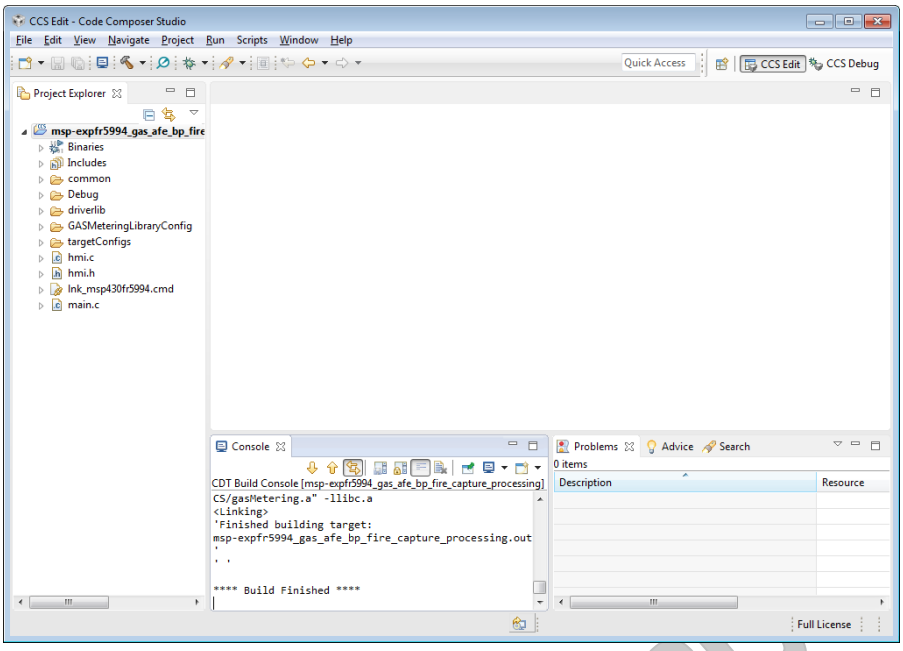
1. Open a workspace in CCS
2. Select Menu→Project→Import CCS Projects
3. In the new window, select the following search directory:
   `C:\ti\msp\gasLibrary_1_10_00_11\examples\ExampleProjects\msp-expfr5994_gas_afe_bp\CCS`

> Note:
> The Gas Library folder can vary depending on its installation.

4. CCS should discover the project:



5. Click on “Finish”
6. The project will be imported into CCS
7. Build the project

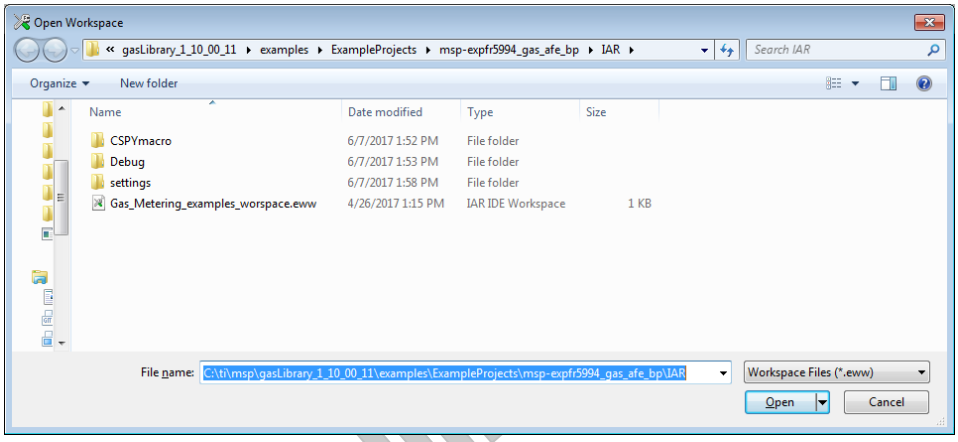


Appendix C. Importing and Building Project in IAR

1. Open IAR

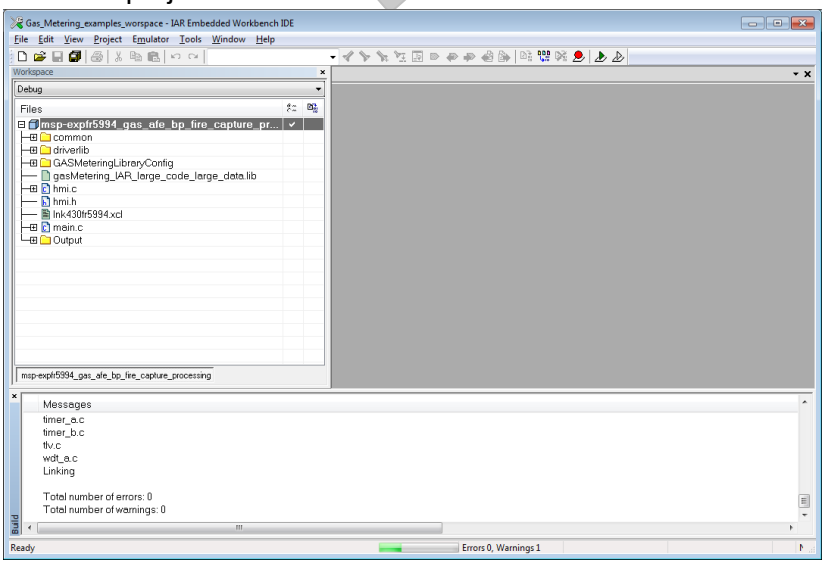
2. Select Menu→File→Open Workspace and open the following file:
   `C:\ti\msp\gasLibrary_1_10_00_11\examples\ExampleProjects\msp-expfr5994_gas_afe_bp\IAR\Gas_Metering_examples_worspace.eww`

> Note:
>
> The Gas Library folder can vary depending on its installation.



3. IAR will open the workspace, including the project “msp-expfr5994_gas_afe_bp_fire_capture_processing”.

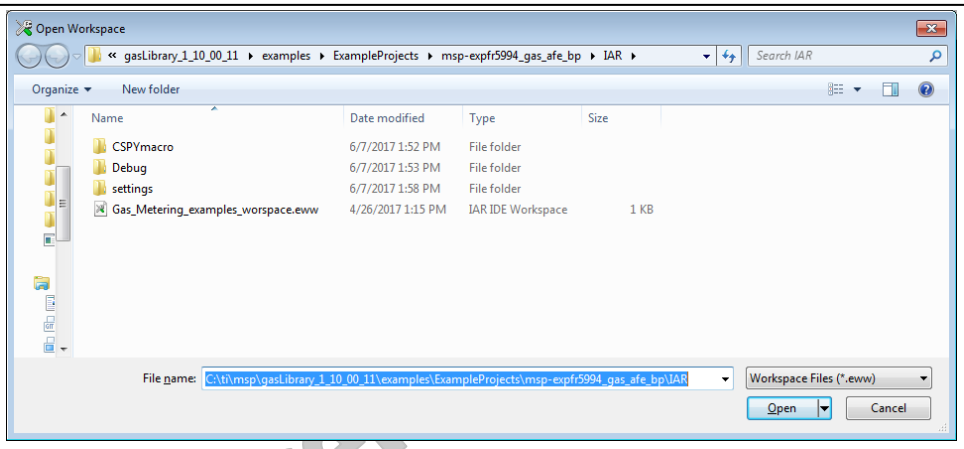
4. Build the project



1. Program the EVM as described in

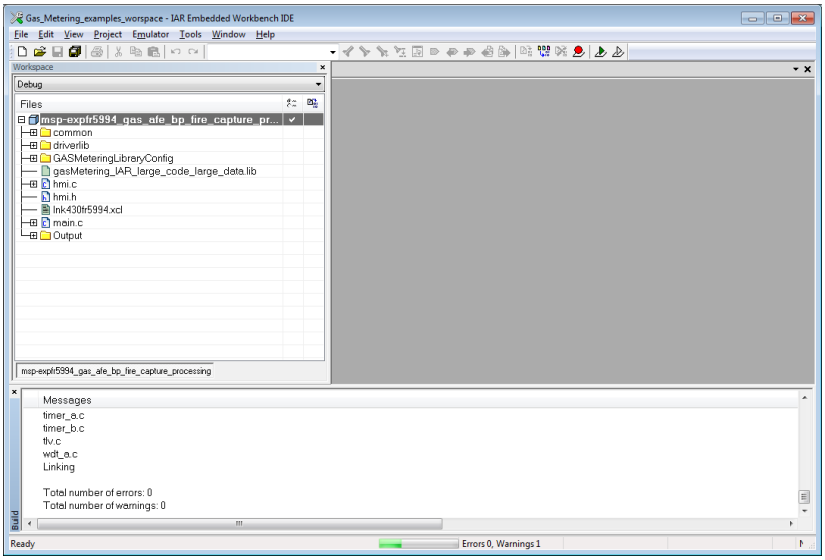
2. Select Menu→File→Open Workspace and open the following file:
   `C:\ti\msp\gasLibrary_1_10_00_11\examples\ExampleProjects\msp-expfr5994_gas_afe_bp\IAR\Gas_Metering_examples_worspace.eww`

> Note:
>
> The Gas Library folder can vary depending on its installation.



3. IAR will open the workspace, including the project “msp-expfr5994_gas_afe_bp_fire_capture_processing”.

4. Build the project



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