

Quick Start Guide for Gas Flow Meter

This getting started guide reviews the contents of the [MSP430FR6043 ultrasonic sensing evaluation module \(EVM430-FR6043\)](#) and tells you how to quickly get started with the MSP430FR6043 device for evaluating and developing a gas flow meter solution. For detailed information on designing a gas flow meter, please refer to the [reference design for gas flow measurement \(TIDM-02003\)](#)

Contents

1	Introduction	3
1.1	Package Contents	3
1.2	What is Not Included	3
1.3	System Requirement	3
2	Connect the EVM to the Gas Flow Meter	3
3	Flashing the EVM and Installing the GUI	6
4	USS GUI	8
4.1	Connecting to the Platform	8
4.2	Configuration Parameters	10
4.3	Capturing the ADC Signals	16
4.4	Capturing Waveforms.....	20
4.5	Frequency Response	21
5	Meter Characterization	24
5.1	Single Shot Standard Deviation	24
5.2	Zero Flow Drift Testing	24
5.3	Flow Testing	25

List of Figures

1	EVM430-FR6043 Connected to gas flow pipe (without ground can)	4
2	EVM430-FR6043 connected to gas flow meter embedded in grounded can	5
3	EVM430-FR6043 Jumper Settings	6
4	Uniflash: Select MSP430FR6043 Device	7
5	Uniflash: Load Image	7
6	Selecting the EVM Configuration and Gas Application Mode	8
7	USS GUI Connected to EVM	9
8	Parameters Tab	10
9	Configuration Timing Diagram.....	12
10	Advanced Parameters Tab	13
11	Representative Captured Waveform	14
12	Captured ADC Signal.....	16
13	Gap Between Pulse Start and ADC Capture Set Too Long	17
14	Gap Between Pulse Start and ADC Capture Set Too Short	18
15	Captured ADC Signal With Bad Connection	19
16	Capturing Waveforms.....	20
17	Frequency sweep Configuration setting	21
18	Frequency Sweep Peak Amplitudes.....	22
19	Single Shot Standard Deviation	24
20	Flow Test Setup	25

21	Flow Rate Testing	26
----	-------------------------	----

Trademarks

Code Composer Studio is a trademark of Texas Instruments.
IAR Embedded Workbench is a registered trademark of IAR Systems.
All other trademarks are the property of their respective owners.

1 Introduction

This getting started guide reviews the EVM430-FR6043 and provides an overview on how to quickly get started with the EVM430-FR6043 for gas flow meter solution.

1.1 Package Contents

The package includes:

- a. USS evaluation module (EVM) version 2.0 hardware that has the MSP430FR6043 device with interfaces to a transducer pair: <http://www.ti.com/tool/EVM430-FR6043>
- b. A downloadable SW that runs on the MSP430FR6043 on the EVM430-FR6043: http://software-dl.ti.com/msp430/msp430_public_sw/mcu/msp430/USSSWLib/USSSWLibGas/latest/index_FDS.html. This has three different components:
 - a. The graphical user interface (GUI) 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. This is part of the USSSWLib windows installer.
 - b. The USS Library and supporting documentation of the APIs that are available in the library. This is available as part of the USSSWLib windows installer.
 - c. An application example project that is supported by Code Composer Studio™ IDE (CCS) or IAR Embedded Workbench® IDE. This project uses TI's Ultrasonic Sensing Solution (USS) Library and interfaces to the GUI. This is part of the Gas Demo Application installer.

1.2 What is Not Included

A 3D printed plastic pipe with 200-kHz transducers from Jiakang that are placed in a face 2 face configuration is used as an example in this document. This sensor is available from Jiakang at their [Ultrasonic Gas Flow Transducers product page](#). The specific transducers used is the product PN:PSC200K018102H3AD6-B1.

1.3 System Requirement

The system requires the latest Java and Uniflash. If it is not already installed, it can be installed from <https://java.com/en/download/> and <http://www.ti.com/tool/UNIFLASH>, respectively.

2 Connect the EVM to the Gas Flow Meter

This section describes the hardware connections. For more details of the hardware connections, see the [EVM430-FR6043 Hardware Guide](#).

1. The gas pipe configuration and the transducer connection to the EVM pins prior to insertion in the can is shown in [Figure 2](#).

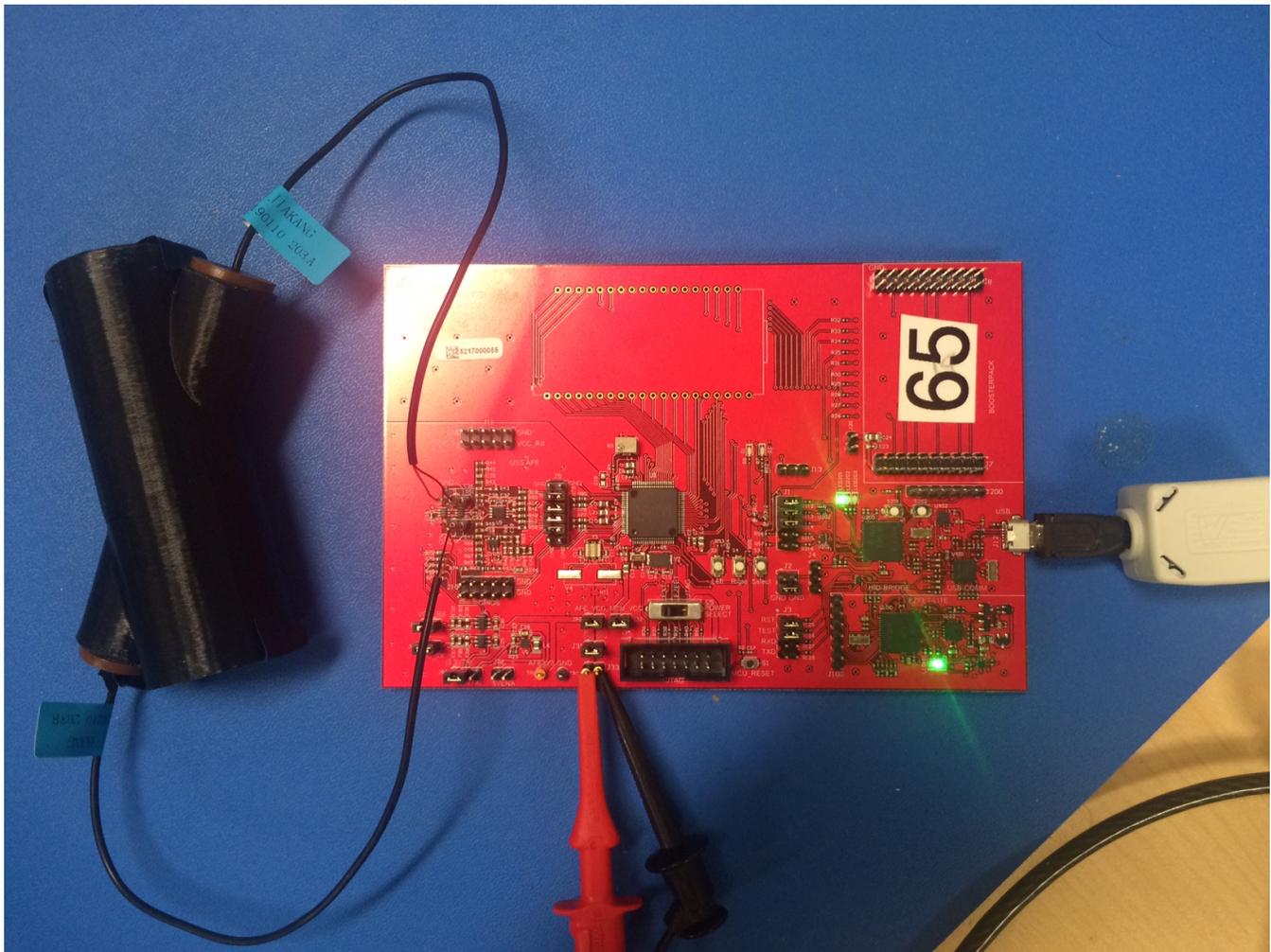


Figure 1. EVM430-FR6043 Connected to gas flow pipe (without ground can)

2. Connect the EVM430-FR6043 to the gas flow meter (see [Figure 1](#)). The pipe needs to be inserted in a metallic can to minimize noise. The can also needs to be grounded using one of the ground pins on the EVM.



Figure 2. EVM430-FR6043 connected to gas flow meter embedded in grounded can

3. Ensure the ends of the pipe are taped to ensure zero air flow during the initial bringup. That tape can be removed when the flow tests are conducted.
4. Connect the jumpers as shown in [Figure 3](#). The COMM_IRQ, COMM_SDA, and COMM_SCL jumpers on the J1 header are required for communication with the GUI. TEST and RST jumpers on J3 are required to program the board. The POWER SELECT switch S5 should be in the middle position (ezFET), J4 in the right position, and both J2 jumpers set to use USB power. The jumper locations are highlighted in [Figure 3](#). The USB power can be used for quick bringup but for best performance, it is recommended that an external power supply is used.

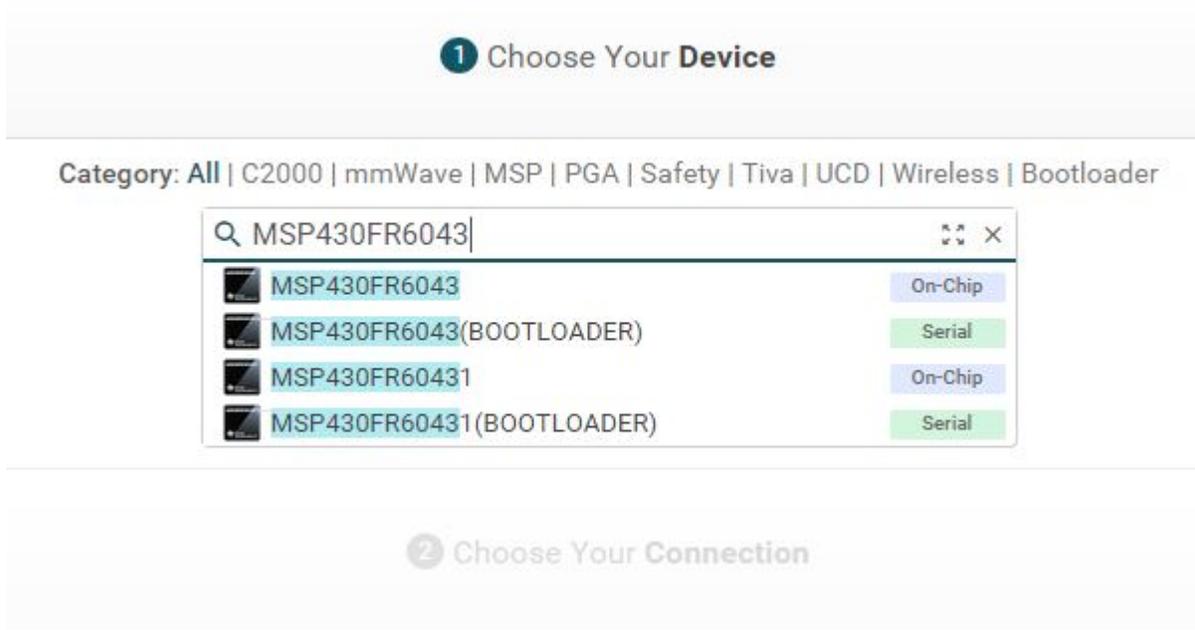


Figure 4. Uniflash: Select MSP430FR6043 Device

4. Choose Connection.
5. Choose image to load. Default image is installed in C:\ti\msp\UltrasonicGasFR6043_02_30_00_01\image where 02_30_00_01 corresponds to the latest version of the release at the time of this publication.
6. Click Load Image.



Figure 5. Uniflash: Load Image

7. Install the Ultrasonic Sensing Design Center GUI, which can be downloaded from http://software-dl.ti.com/msp430/msp430_public_sw/mcu/msp430/USSSWLib/USSSWLibGas/latest/index_FDS.html
A shortcut named USS is installed to the Texas Instruments folder in the Windows Start menu to launch the Ultrasonic Sensing Design Center GUI.

4 USS GUI

4.1 Connecting to the Platform

After you have installed the GUI and flashed the image to the EVM, run the USS GUI. The version of the GUI used for this guide is 2.30.00.03 which is the latest GUI version available at the time of this publication.

First select the correct EVM: EVM430-FR6043 & meter option of Gas using the Menu item: "Options"-> "Meter Options" as shown in [Figure 6](#).

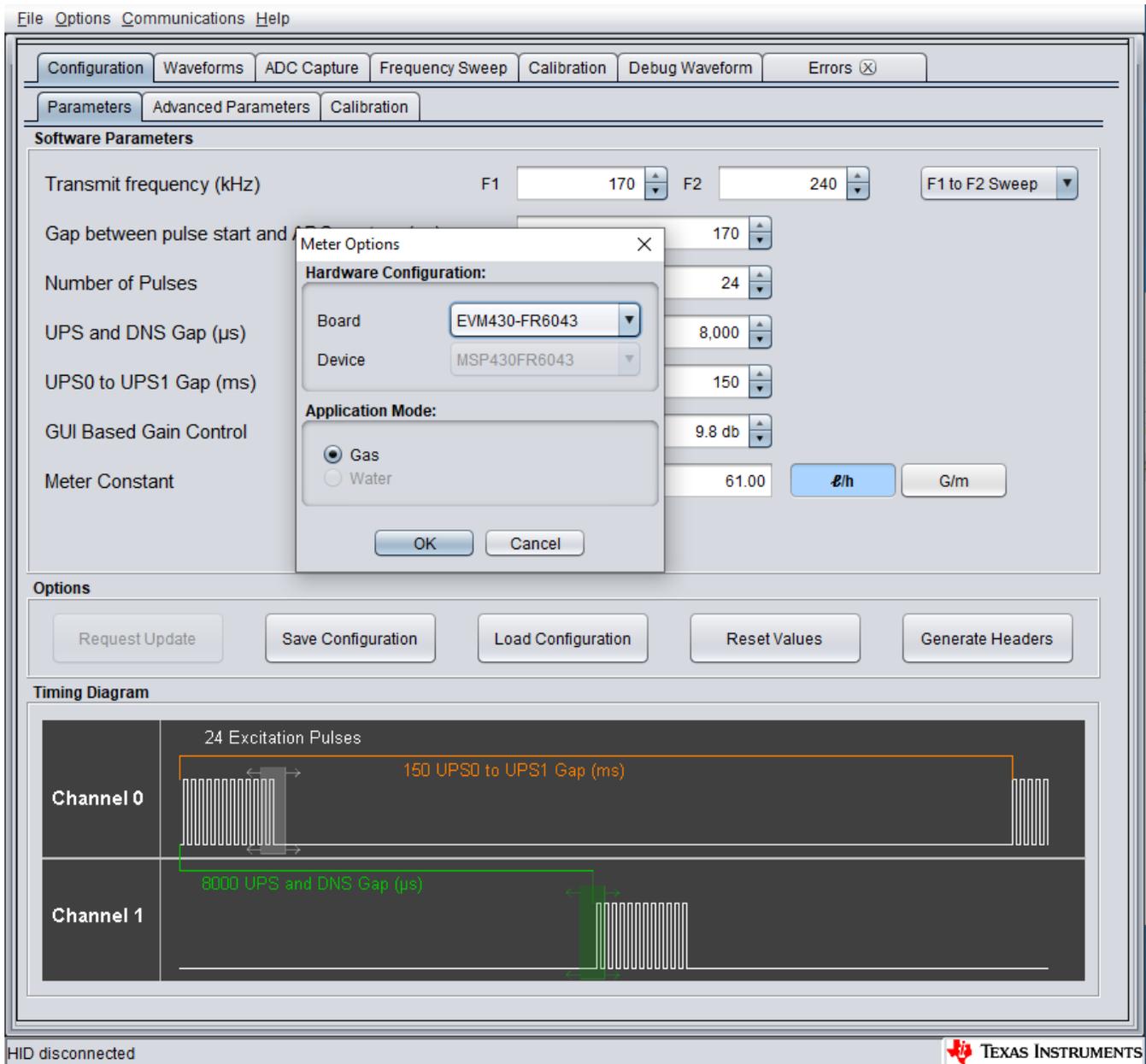


Figure 6. Selecting the EVM Configuration and Gas Application Mode

Connect to the platform by clicking "Connect" in the "Communications" menu. The GUI reports the connection as shown in [Figure 7](#).

The screenshot displays the USS GUI software interface. At the top, there is a menu bar with 'File', 'Options', 'Communications', and 'Help'. Below the menu bar are several tabs: 'Configuration', 'Waveforms', 'ADC Capture', 'Frequency Sweep', 'Calibration', and 'Debug Waveform'. The 'Configuration' tab is active, and within it, the 'Parameters' sub-tab is selected.

The 'Software Parameters' section contains the following settings:

- Transmit frequency (kHz): F1 is 180, F2 is 230, and 'F1 to F2 Sweep' is selected.
- Gap between pulse start and ADC capture (μ s): 150
- Number of Pulses: 24
- UPS and DNS Gap (μ s): 14,000
- UPS0 to UPS1 Gap (ms): 500
- GUI Based Gain Control: -0.8 db
- Meter Constant: 61.00, with buttons for 'l/h' and 'G/m'.
- Volume Flow Rate Calibration Ranges: 3

The 'Options' section includes buttons for 'Request Update', 'Save Configuration', 'Load Configuration', 'Reset Values', and 'Generate Headers'.

The 'Timing Diagram' section shows two channels:

- Channel 0:** Displays '24 Excitation Pulses' as a series of vertical lines. A horizontal orange line above it indicates a '500 UPS0 to UPS1 Gap (ms)'.
- Channel 1:** Shows a signal that starts after a '14000 UPS and DNS Gap (μ s)' (indicated by a green line) and then displays a series of vertical lines.

At the bottom left, a status bar indicates 'HID connected to MSP430FR6043 on Evaluation Module'. At the bottom right is the Texas Instruments logo.

Figure 7. USS GUI Connected to EVM

4.2 Configuration Parameters

4.2.1 Basic Configuration Parameters

Figure 8 shows the primary configuration parameters.

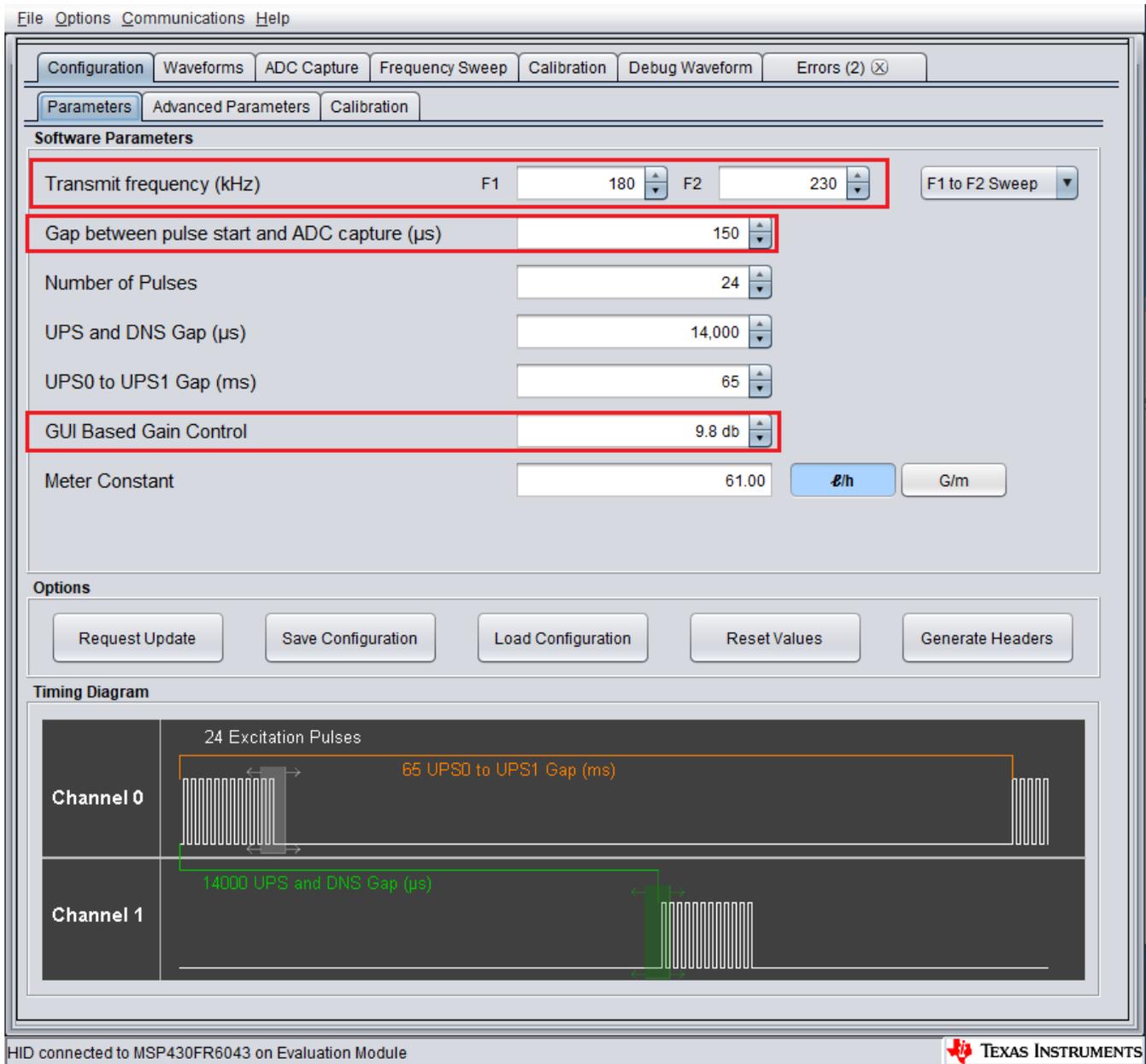


Figure 8. Parameters Tab

The F1, F2, Gap, and Gain parameters are the only parameters which should be initially adjusted. All other parameters should be set to their default values for 200 kHz transducers. These parameters control the excitation, amplification, and ADC capture time between the ultrasonic transducers connected to the platform.

Set the "Transmit Frequency" "F1" and "F2" to the lower end and higher end respectively of the nominal frequency of the transducers in kHz (for example, set to 180 and 230 for 200kHz transducers). Tune this parameter after the frequency sweep (described in [Section 4.5](#)) is conducted. After the other parameters have been properly determined, tune the transmit frequency to give a better signal response as described in [Section 4.3](#).

Set the "Gap between pulse start and ADC capture" based on the anticipated ultrasonic time of flight for a given flow tube with enough additional capture time to address signal shifts due to temperature variations.

The "GUI Based Gain Control" controls the gain of the integrated PGA. Set this parameter to give an ADC capture of no more than ± 900 ADC counts in the ADC capture tab. Although the system should be operable with signals down to ± 150 ADC counts, setting the gain to give higher ADC counts reduces the standard deviation in measurements.

For example, a 1" diameter pipe might have an ultrasonic path which corresponds to a time of flight of approximately 165 μ s. This is based on an ultrasonic path between transducers of approximately 5.5 cm and the speed of sound in air (330 m/s). An appropriate "Gap" that would ensure there is enough time before the signal to accommodate shifts due to temperature variations might therefore be 150 μ s. The ultrasonic distance between transducers will affect how much additional margin is required to address shifts in the signal due to temperature and flow variations. For example, a pipe with an ultrasonic path of 11 cm might require 30 μ s of additional capture time preceding the signal.

The "Number of Pulses" affects the strength of the signal and the standard deviation of the dToF waveform at zero flow. An increase in the number of pulses should give a lower standard deviation in dToF. There is also a tradeoff with respect to power consumption and interference. As the number of pulses is increased, earlier parts of the excitation signal can interfere with the latter part of the transmitted signal when traveling along alternative ultrasonic paths. The default setting for this parameter should be used as a starting point.

The "UPS and DNS gap" is the time between upstream and downstream measurements. The time required between measurements is governed by the ultrasonic propagation time. Larger pipes require a larger gap. There also needs to be enough time between UPS and DNS excitations to ensure the DNS signal does not have interference from residual reflections of the UPS signal. The default setting for this parameter should be used as a starting point.

The "UPS0 to UPS1 Gap" is the time between the end of a set of measurements and the beginning of the next set of measurements. Power consumption is directly affected by the measurement rate. A UPS0 to UPS1 gap of 1 second consumes roughly twice as much power as a UPS0 to UPS1 gap of 2 seconds. The default setting for this parameter should be used as a starting point. A value of 65 ms indicates a measurement rate of approximately 15 Hz (15 measurements each second) and allows to quickly obtain a single shot STD performance estimate. This can be increased to 1000 ms for a 1 Hz measurement rate.

Set the "Meter Constant" to give a volumetric result that is consistent with a reference meter under flow. The default setting for this parameter should be used as a starting point.

After the desired set of configuration parameters has been set, you should click the "Request Update" button to send these parameters to the platform. The "Save Configuration" button will save the current set of parameters to a file. The "Load Configuration" button loads a previously saved set of configuration parameters from a file. The timing diagram for the configuration can be seen at the bottom of the GUI screen (see [Figure 9](#)). The timing diagram represented in this figure is representative and is not exact.

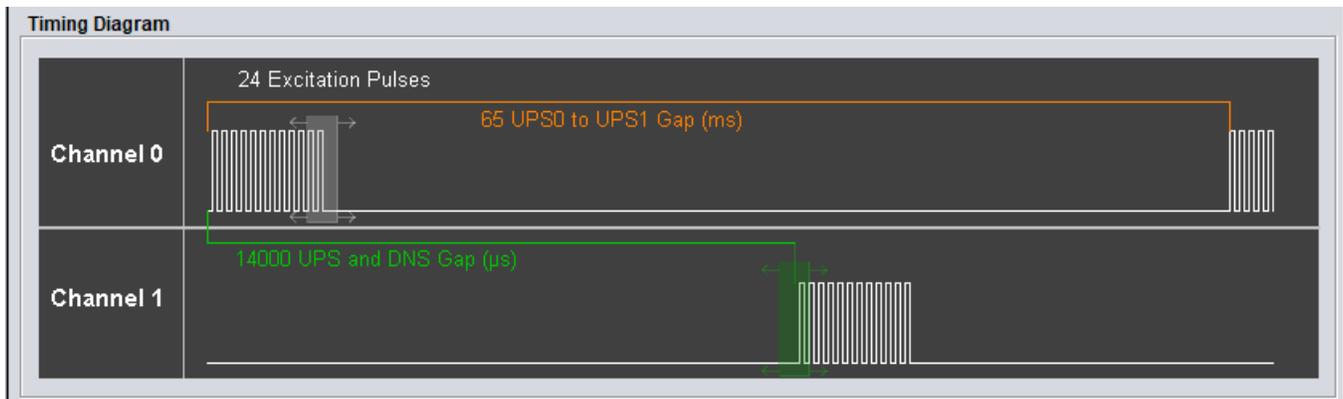


Figure 9. Configuration Timing Diagram

4.2.2 Advanced Configuration Parameters

The "Advanced Parameters" tab provides access to a variety of more advanced configuration parameters (see [Figure 10](#)).

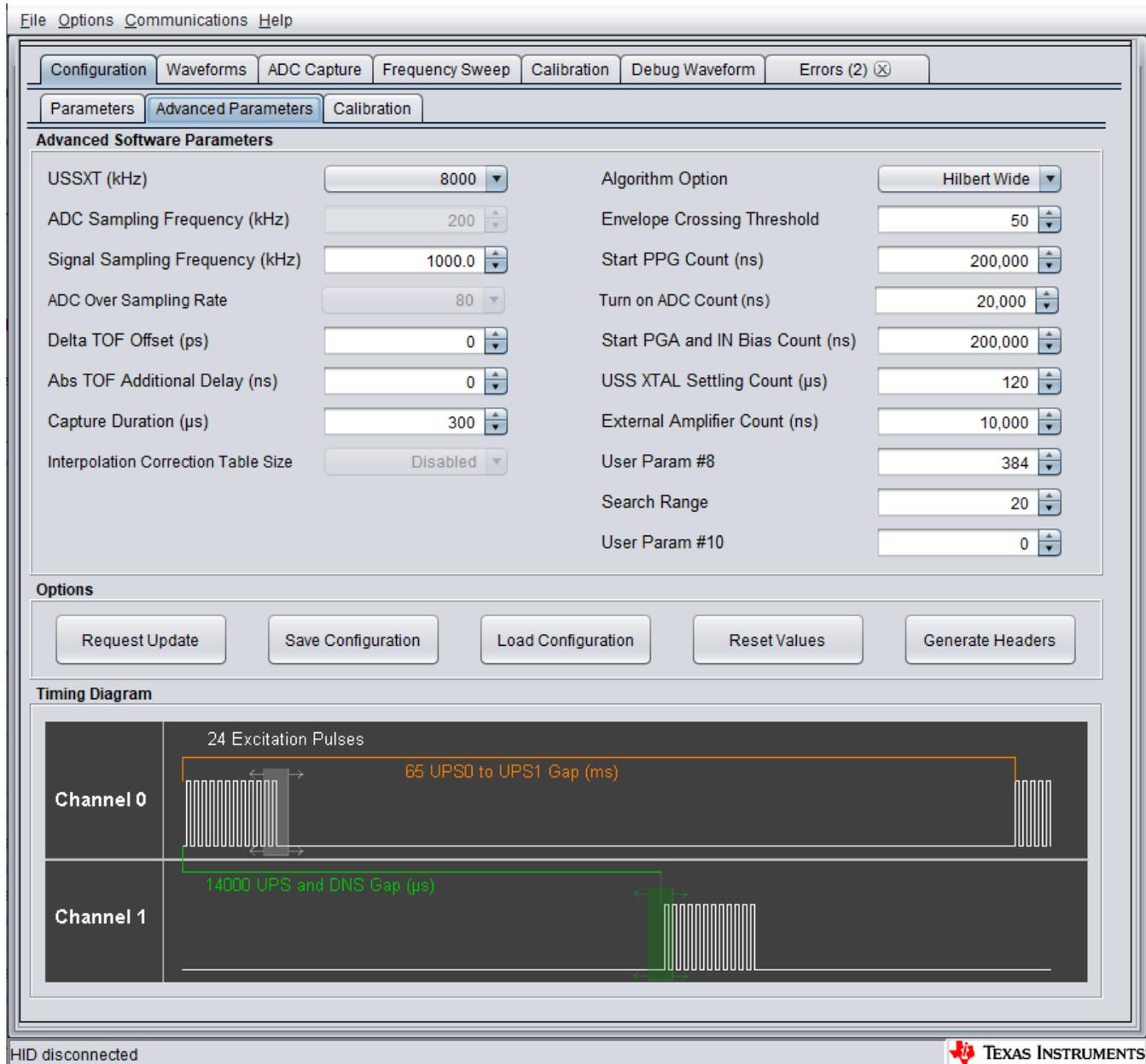


Figure 10. Advanced Parameters Tab

Set the "Signal Sampling Frequency" to 1 MHz (1000 kHz) for 200 kHz transducers and 2 MHz (2000 kHz) for 400 kHz or 500 kHz transducers. At this time, the SW releases do not support any other sampling frequencies.

The "Delta ToF Offset" is an adjustment to the differential ToF during the calculation of volume flow rate inside the ultrasonic flow meter library. Developers can optionally make their custom calculation of the volume flow rate based on the ToF values provided by the library.

The "Abs ToF Additional Delay" is an adjustment to the absolute ToF to account for any additional delays. The value depends on the shape of the signal and the envelope threshold. Developers can optionally set this value to zero and make their own adjustments of the absolute ToF in the application layer.

Increase the "Capture Duration" for configurations with a larger number of pulses, or decrease it for configurations with smaller number of pulses but ensure the signal is fully captured with enough margin for shifts over the intended operating temperature range.

The "Algorithm Option" determines which algorithm is used. Only the "Hilbert Wide" algorithm is currently available for gas metering. A detailed explanation of how this algorithm works can be found in the [Ultrasonic Sensing Subsystem Reference Design for Gas Flow Measurement design guide](#).

The "Envelope Crossing Threshold" determines at which amplitude level the AbsToF algorithm will lock onto. The threshold is the percentage of the amplitude compared to the peak amplitude. Set this threshold to lock onto the amplitude level that is in the middle of the steepest portion. In the example shown in [Figure 11](#), this lobe peak corresponds to a threshold of approximately 50%. This figure is shown for explanation of the concept of choosing the threshold. The actual threshold value internally uses the correlation output. We also recommend to not modify the 50% threshold setting.

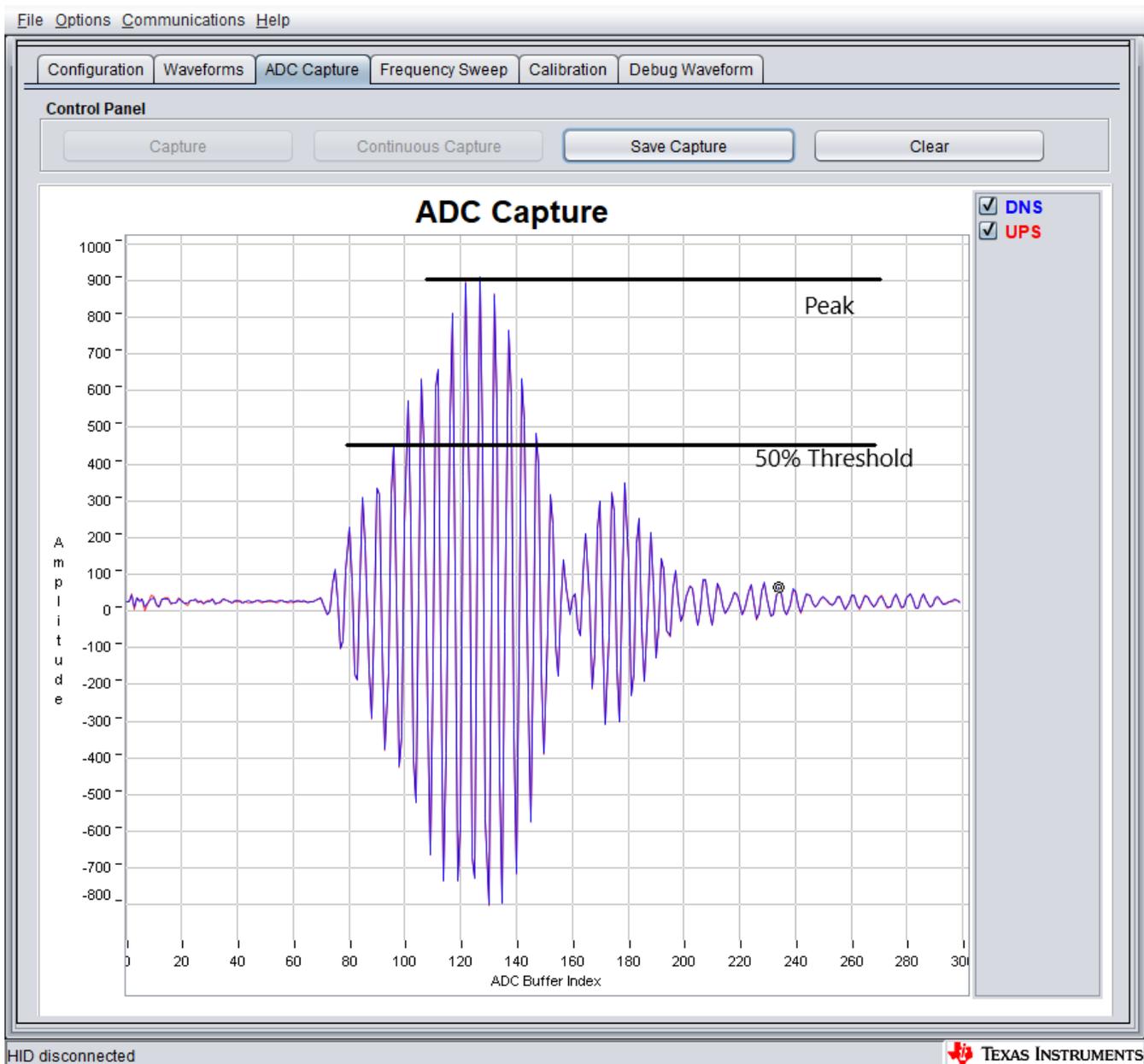


Figure 11. Representative Captured Waveform

The "Search Range" parameter can be used to control the maximum volume flow rate that can be supported by the system. This is equal to the difference of the upstream (UPS) and downstream (DNS) Absolute Time of Flight (AbsToF) expressed in terms of the number of samples. This also has a direct impact on the amount of time taken for algorithm processing as well as the current consumption which increases with increase in the value of the search range. We suggest keeping it at 20 or above for initial evaluation. This can be optimized later for reducing computation time and current consumption. This parameter limits the change in flow rate in tracking mode of AbsToF estimation. If the flow rate change exceeds this value, the algorithm switches to AbsToF acquisition mode.

"User Param #8" is used to enable or disable Additional Trill pulses that are used to excite the transducers at the end of the standard pulses. These are used to gracefully reduce the energy of the transducer response. A setting of "128" disables the Additional Trill pulses while a setting of "384" enables them. All other values are reserved for future use. We also recommend enabling these additional trill pulses.

"User Param #10" is reserved for future use.

4.2.3 Conditional Parameters

We recommend not modifying the default settings of these parameters for initial evaluation.

The "Start PPG Count" determines when the PPG is started. The timing diagrams for the operation of the ULP bias circuit can be found in the [MSP430FR58xx](#), [MSP430FR59xx](#), and [MSP430FR6xx Family User's Guide](#). For low current consumption, the recommended value is 200000 nanoseconds.

The "Turn on ADC Count" determines when the ADC is turned on. The relevant timing diagrams for the operation of the ULP bias circuit can be found in the [MSP430FR58xx](#), [MSP430FR59xx](#), and [MSP430FR6xx Family User's Guide](#). Do not modify this parameter.

The "Start PGA and IN Bias Count" determines when the PGA and in Bias Circuit is turned on. The relevant timing diagrams for the operation of the ULP bias circuit can be found in the [MSP430FR58xx](#), [MSP430FR59xx](#), and [MSP430FR6xx Family User's Guide](#). Do not modify this parameter.

The "USS XTAL Settling Count" determines how much time is allowed for crystal or resonator settling. Based on internal experiments, 120 μ s is suggested for resonators, and 5000 μ s is suggested for crystals.

The "External Amplifier Count" parameter specifies when the external amplifier is enabled prior to starting the USS module timer. The default setting of 10 μ s (10000 ns) is suggested to be used with OPA838 or OPA836 on the EVM430-FR6043.

4.2.4 Configuration Tuning

After a working configuration has been set, you can experiment with changes to that working set to tune the system for optimum performance and power. [Table 1](#) indicates how changes in specific configuration parameters change system performance.

Table 1. Configuration Tuning

Parameter	Change to Parameter Affects...			
	Power Consumption	Flow Performance	Standard Deviation	Zero Flow Drift
Number of Pulses	✓	✓	✓	✓
UPS0 to UPS1 Gap	✓			
GUI Based Gain Control			✓	✓
Transmit Frequency		✓	✓	✓
Envelope Crossing Threshold		✓		
Capture Duration	✓	✓		✓

4.3 Capturing the ADC Signals

To capture the ADC signal, go to the "ADC Capture" tab and click the "Capture" button. If you are using the Jiakang 200 kHz transducers in a face-to-face configuration meter, you should see a signal that looks like [Figure 12](#) at zero flow.

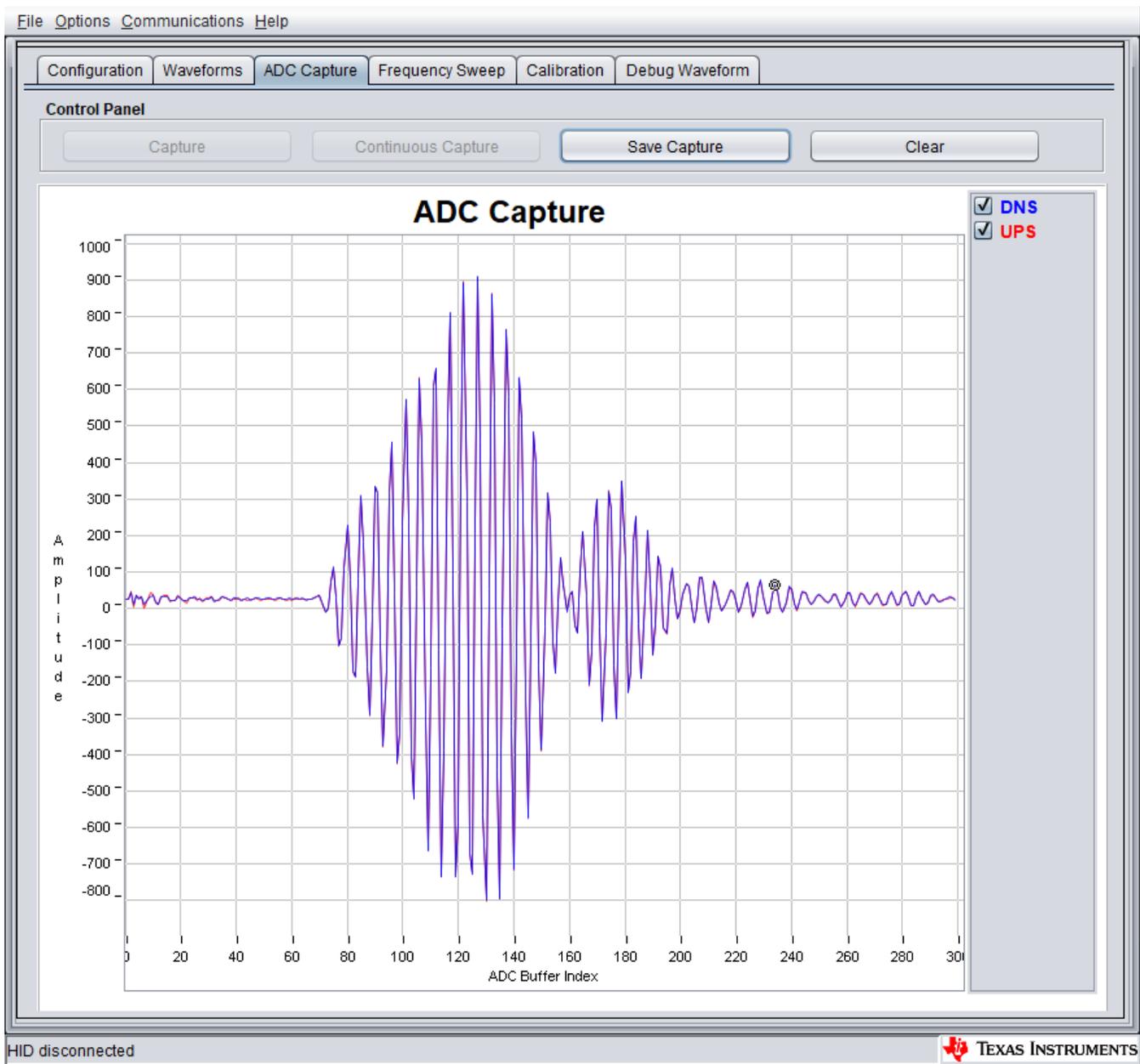


Figure 12. Captured ADC Signal

If the capture looks different, check these items first:

- Increase or reduce the "Gain Control" in your configuration parameters based on the observed ADC output codes
- Adjust the Gap between pulse start and ADC capture. [Figure 13](#) shows an example where the gap is set too long. [Figure 14](#) shows an example where the gap is set too short.

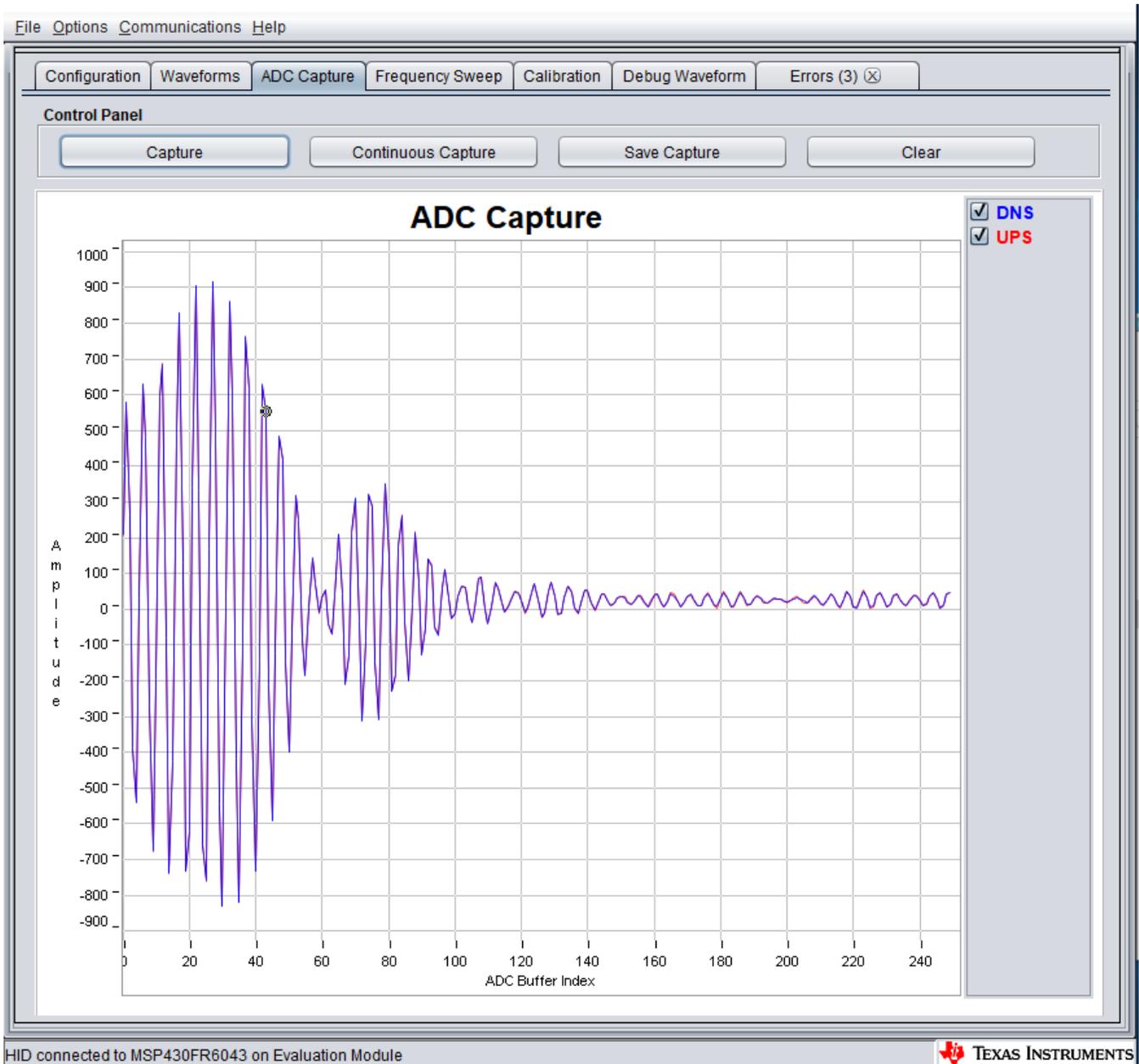


Figure 13. Gap Between Pulse Start and ADC Capture Set Too Long

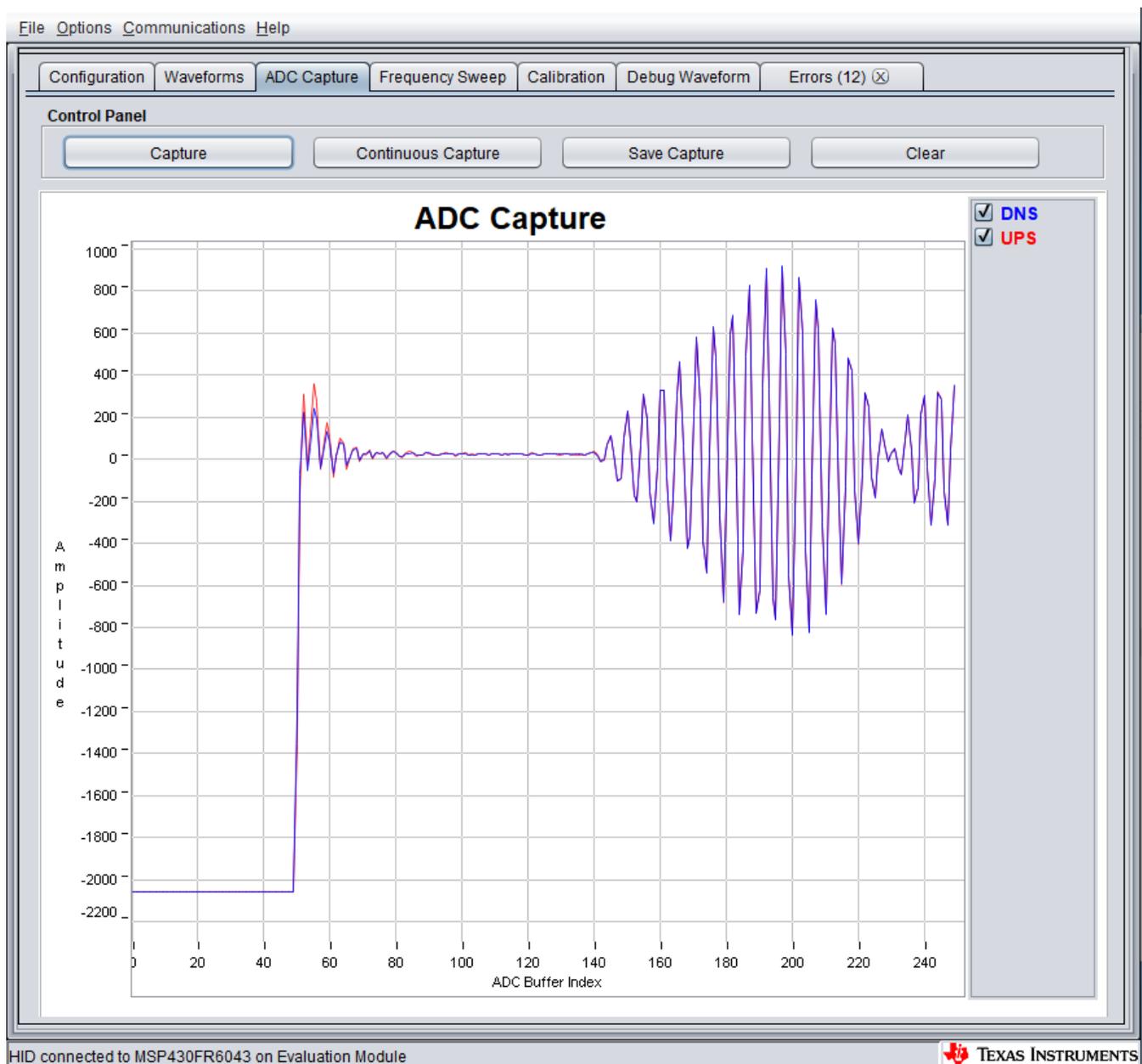


Figure 14. Gap Between Pulse Start and ADC Capture Set Too Short

- If no signal is observed, check the transducer connections to the platform. Connect the transducers as shown in [Section 2](#).
- If the transducers are not connected properly to the EVM, the captured signal may look similar to [Figure 15](#).

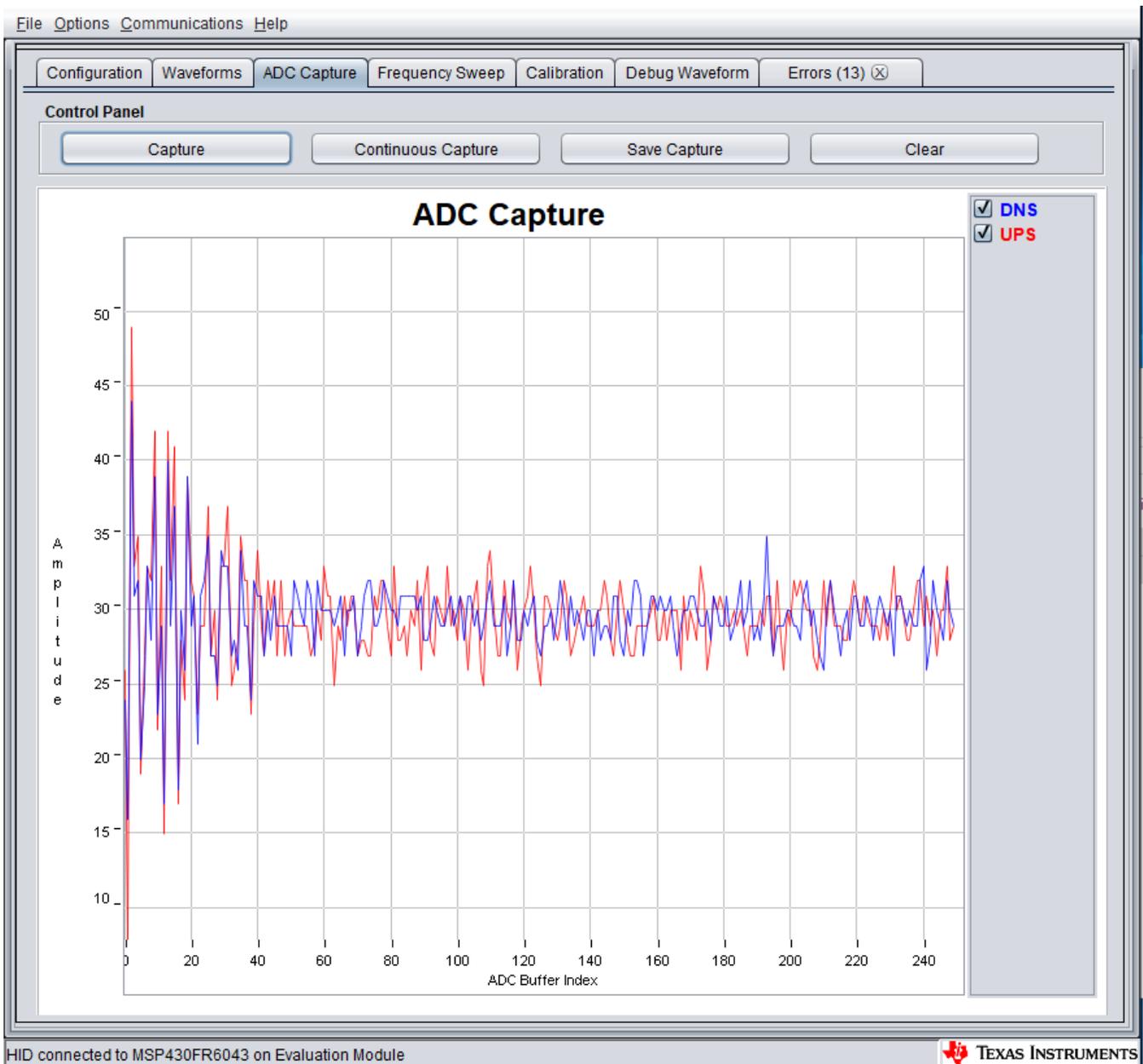


Figure 15. Captured ADC Signal With Bad Connection

To save the capture, click the "Save Capture" button and provide a filename. To continuously capture to a file, click the "Continuous Capture" button and provide a filename.

4.4 Capturing Waveforms

After you have a good ADC capture, go to the "Waveforms" tab to capture some waveforms. In the "Waveforms" tab, click the "Start" button to start capturing waveforms. The GUI displays the Delta ToF, Absolute ToF, and Volume Flow Rate waveforms (see Figure 16). Real time statistics are also available below each waveform. A typical standard deviation value of Delta ToF can be seen in the red box shown in Figure 16.

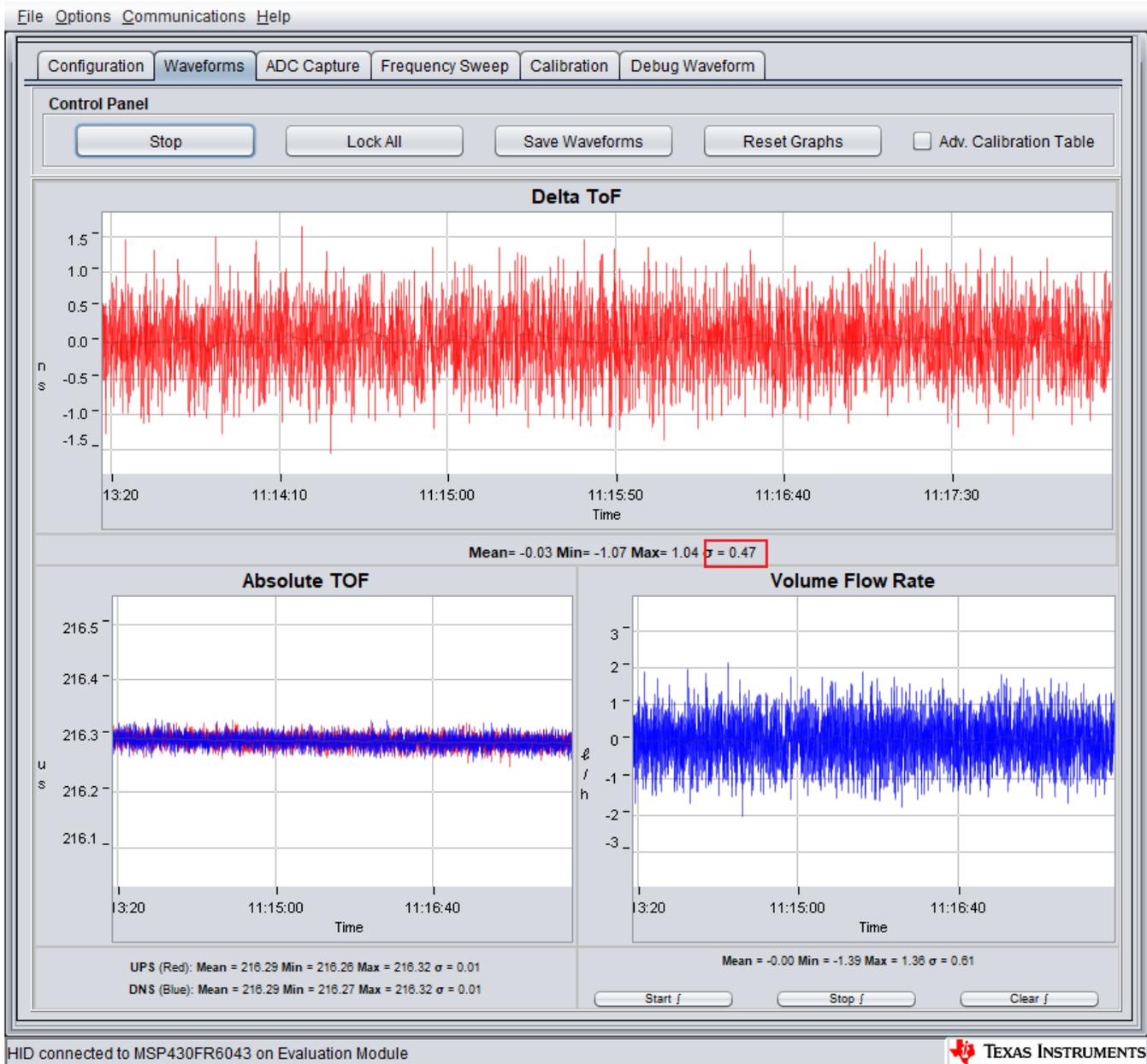


Figure 16. Capturing Waveforms

The frequency of measurement updates can be increased (or decreased) by reducing (increasing) the "UPS0 to UPS1 Gap" in the "Configuration" tab.

After capturing waveforms for some time, you can save them to a file using the "Save Waveforms" button. The "Lock All" button stops updates, and the "Reset Graphs" button erases all previously captured data.

4.5 Frequency Response

The frequency response of the meter can be determined in the GUI to ensure the excitation frequency is optimal. A "Frequency Sweep" is initiated by first setting the desired starting excitation frequency in the "Configuration" tab. The F1 frequency should be selected to be lower than the nominal lower frequency edge of the transducer. For the Jiakang 200 kHz transducers, 160 kHz is suggested. F2 frequency should be 2 kHz above F1. This ensures that during the frequency sweep procedure, the excitation frequency for each of the captures is very close to a single frequency value.

CAUTION

Please ensure F1 is not less than 160 kHz. This is necessary due to device limitations on the lowest possible excitation frequency.

The example setting can be see in [Figure 17](#).

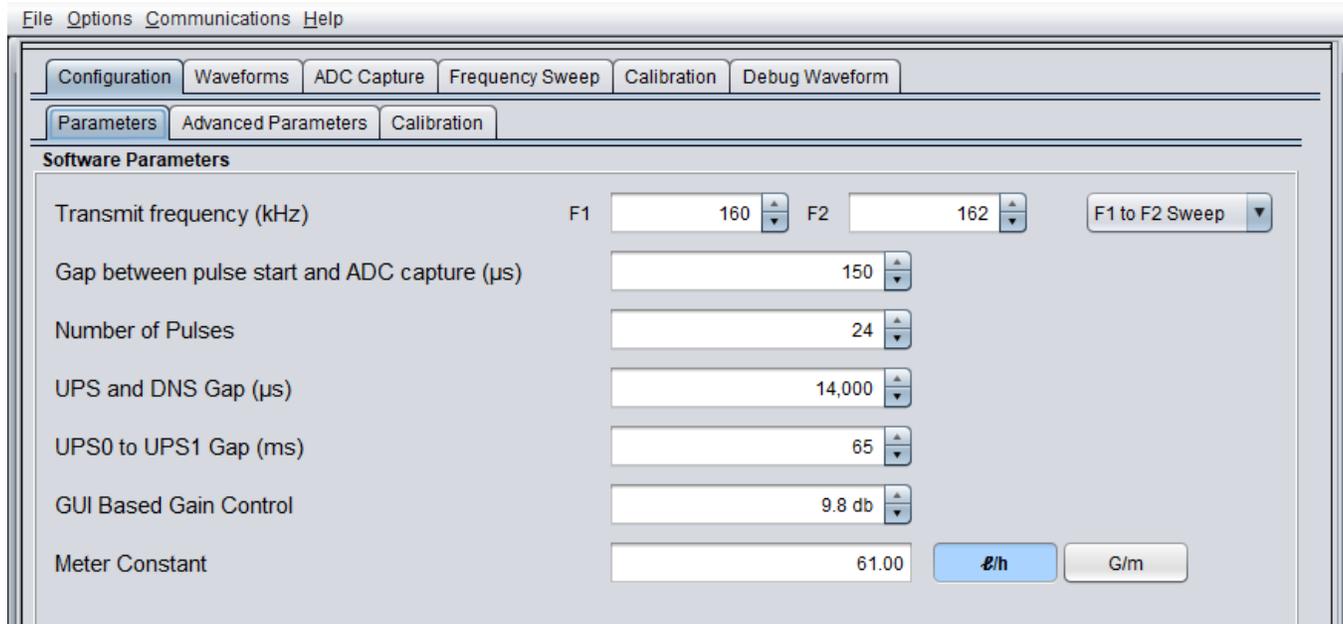


Figure 17. Frequency sweep Configuration setting

After this has been set, set the number of "Captures" and "Step Size" to cover the band of interest. In [Figure 18](#), the sweep is configured for 4 kHz step sizes and 32 captures spanning from 160 kHz to 286 kHz. The "Frequency Sweep" button requests a file name and then initiates the sweep. A smaller step size and larger # of captures can also be used but the procedure would take longer and can be used for better resolution.

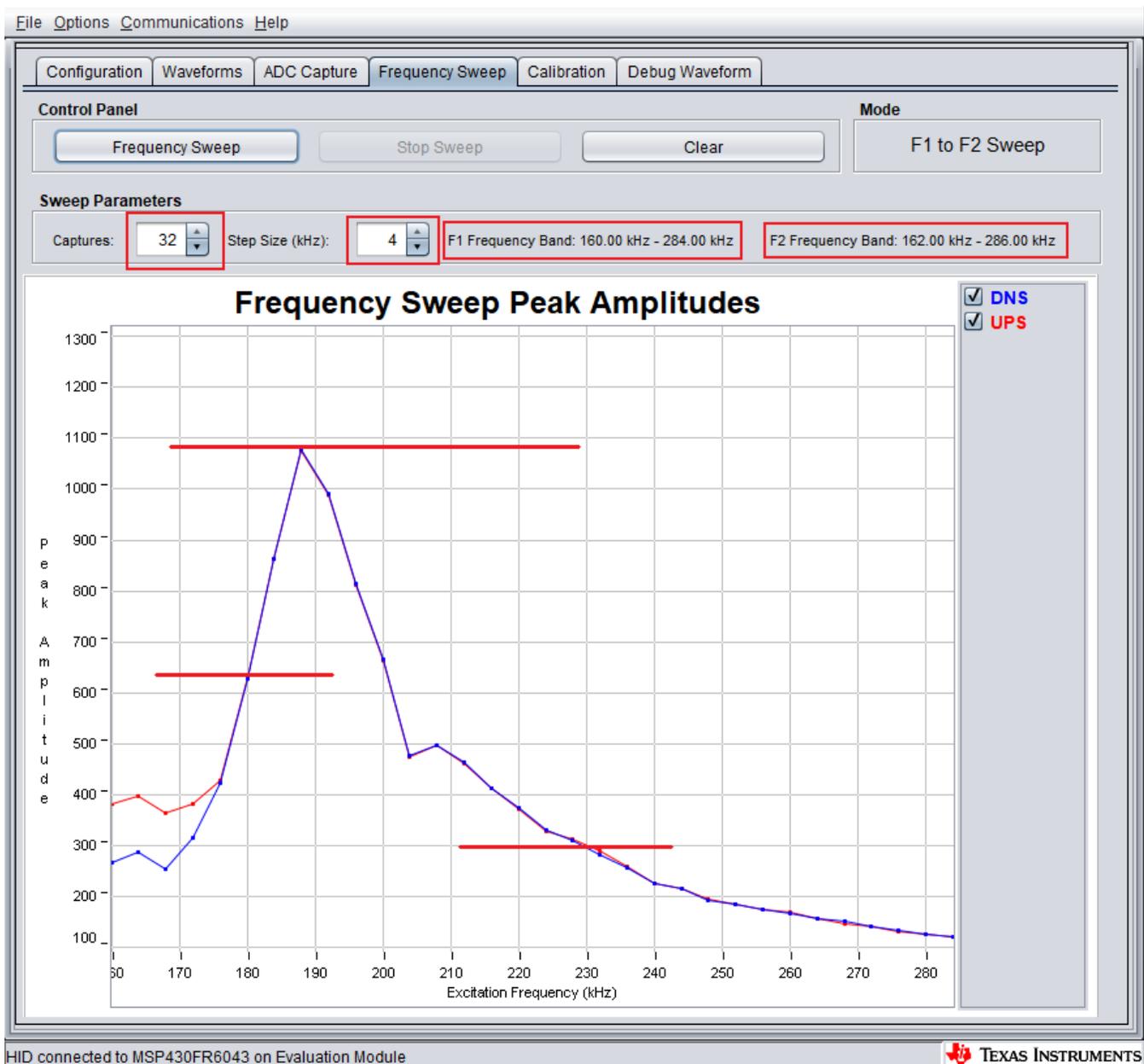


Figure 18. Frequency Sweep Peak Amplitudes

The lower F1 frequency can be picked where the amplitude of the frequency sweep is at 50% of frequency that had the peak amplitude, on the lower frequency edge. Ideally, this should be based on the response at the highest required operating temperature, say +55°C in the case of gas meters. For initial configuration, frequency sweep at room temperature should be sufficient.

The higher F2 frequency can be picked where the amplitude of the frequency sweep is at 50% of frequency that had the peak amplitude, on the higher frequency edge. Ideally, this should be based on the response at the lowest required operating temperature, say -35°C in the case of gas meters. As before, for initial configuration, frequency sweep at room temperature should be sufficient.

From this sweep, F1 of 180 kHz and F2 of 230 kHz appear to be a good excitation frequency bad for this meter. The process for tuning the configuration to an optimal value can be summarized as follows:

NOTE: Steps 1 to 3 should have already been completed in [Section 4.3](#).

1. Set the "Transmit Frequency" F1 to the nominal frequency of the transducer.
2. Set F2 to 2 kHz above F1.
3. Adjust the "Gap between pulse start and ADC capture" and "Capture Duration" parameters to capture the complete signal in the "ADC Capture" window.
4. Adjust the "Gain" setting to get a signal which has an amplitude of ± 900 ADC counts.
5. Set the "Transmit Frequency" F1 to a frequency lower than the nominal lower frequency edge of the transducer. Conduct a frequency sweep which ends at a frequency sufficiently higher than the nominal higher frequency edge of the transducer. For example, a 200 kHz transducer can have nominal band between 170 kHz - 230 kHz.
6. Identify the 50% amplitudes of the "Frequency Sweep" on the lower and higher frequency band edges and set the F1, F2 "Transmit Frequency" to these values.

Please note that after the initial evaluation is complete, for further system optimization and production, there should be at least two sweeps conducted: one at -35°C and one at 55°C . F1 should then be set around the 6dB from peak at 55°C . The frequency response is expected to shift to the left (lower frequency) at 55°C . At -35°C , the frequency response is expected to shift to the right (higher frequency). F2 should be set to $\sim 15\text{kHz}$ greater than the 6dB point for this sweep. The additional 15kHz of excitation is used to reduce the ring down of the transducer. If the transducer still has significant ring down excitation, F2 should be increased further. Also, the choice of -35°C and 55°C depends on the gas meter requirements.

5 Meter Characterization

Meter characterization comprises standard deviation, zero flow drift, and flow testing.

5.1 Single Shot Standard Deviation

The standard deviation in dToF (and volume) is often used as a measure for the accuracy with which flow measurements can be made. Although it is possible to average across several measurements, the amount of time and power required to do this may not meet application requirements.

Standard deviation testing is typically conducted at room temperature over a period of 30 minutes with a 1 measurement per second rate to ensure a statistically valid average. It is also acceptable to increase the measurement rate to a higher value to obtain the statistics using a larger number of measurements within a given time period. As in [Figure 16](#), the standard deviation is reported along with the mean in the "Waveform Tab" of the GUI. [Figure 19](#) shows the single-shot STD of blocks of 200 measurements. Each plot represents single-shot STD of 200 measurements. The plot clearly shows the variation of single-shot STD is just ± 50 ps, and the average is < 500 ps. These measurements were taken at 15 measurements per second.



Figure 19. Single Shot Standard Deviation

5.2 Zero Flow Drift Testing

Zero flow drift testing is often used as a measure of the minimum detectable flow of a meter and accuracy in low flow. The minimum detectable flow of a meter is related to the zero flow drift and the sensitivity of the meter. A meter with higher sensitivity and lower zero flow drift will have a smaller minimum detectable flow. The minimum detectable flow is limited by the drift in dToF over temperature. This test is typically conducted in an oven with a temperature profile ranging from -35°C to 55°C over a period of 12 to 24 hours, depending on the robustness of the required test. These tests are conducted with both the meter and electronics in the oven. More detailed information on zero flow drift testing can be found in the [Ultrasonic Sensing Metrology Subsystem Reference Design for Gas Flow Measurement design guide](#).

5.3 Flow Testing

Flow testing is typically conducted with a reference meter and a temperature controlled air or gas circulation system. ACE60 12V DC fan (Micronel D301L-012GK-2) is used to blow air and can be connected to one end of the pipe for basic flow testing. The fan can be found at https://www.micronel.com/products/d-line/?tx_micronel_products%5Bserie%5D=8&tx_micronel_products%5Baction%5D=show&tx_micronel_products%5Bcontroller%5D=Serie&cHash=5cd082d813f1624d9d7858e9f2029aad. It is important to choose a fan that has a linear relationship between Voltage & flow rate. Figure 20 shows a such a basic flow test setup. This setup includes the 12V DC fan, and the Device Under Test (DUT). Flow is recorded at various flow rates by the DUT. The DToF of the test gas pipe (DUT) needs to be calibrated against a reference meter connected in series. Please note that the air is pulled out of the pipe.

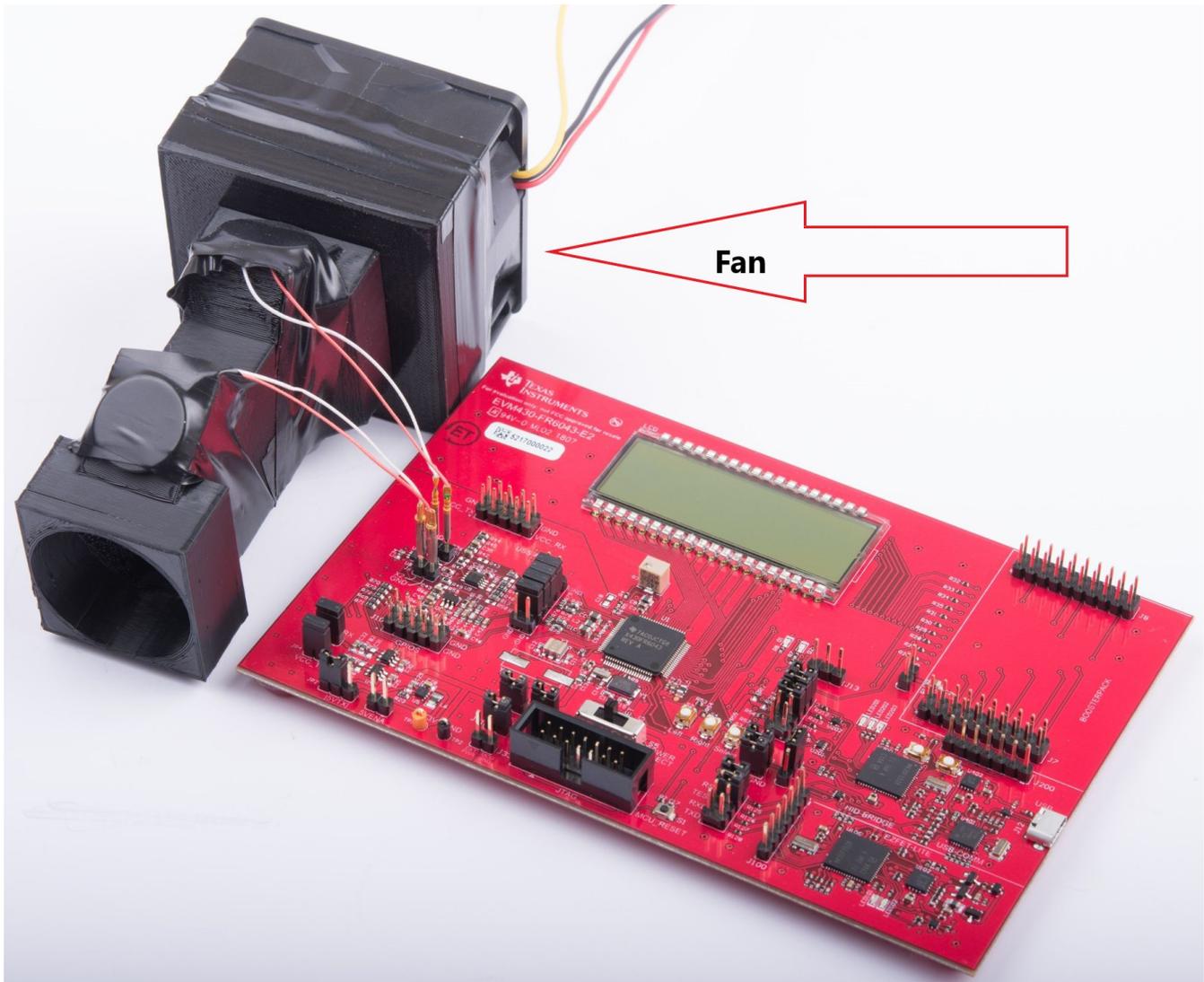
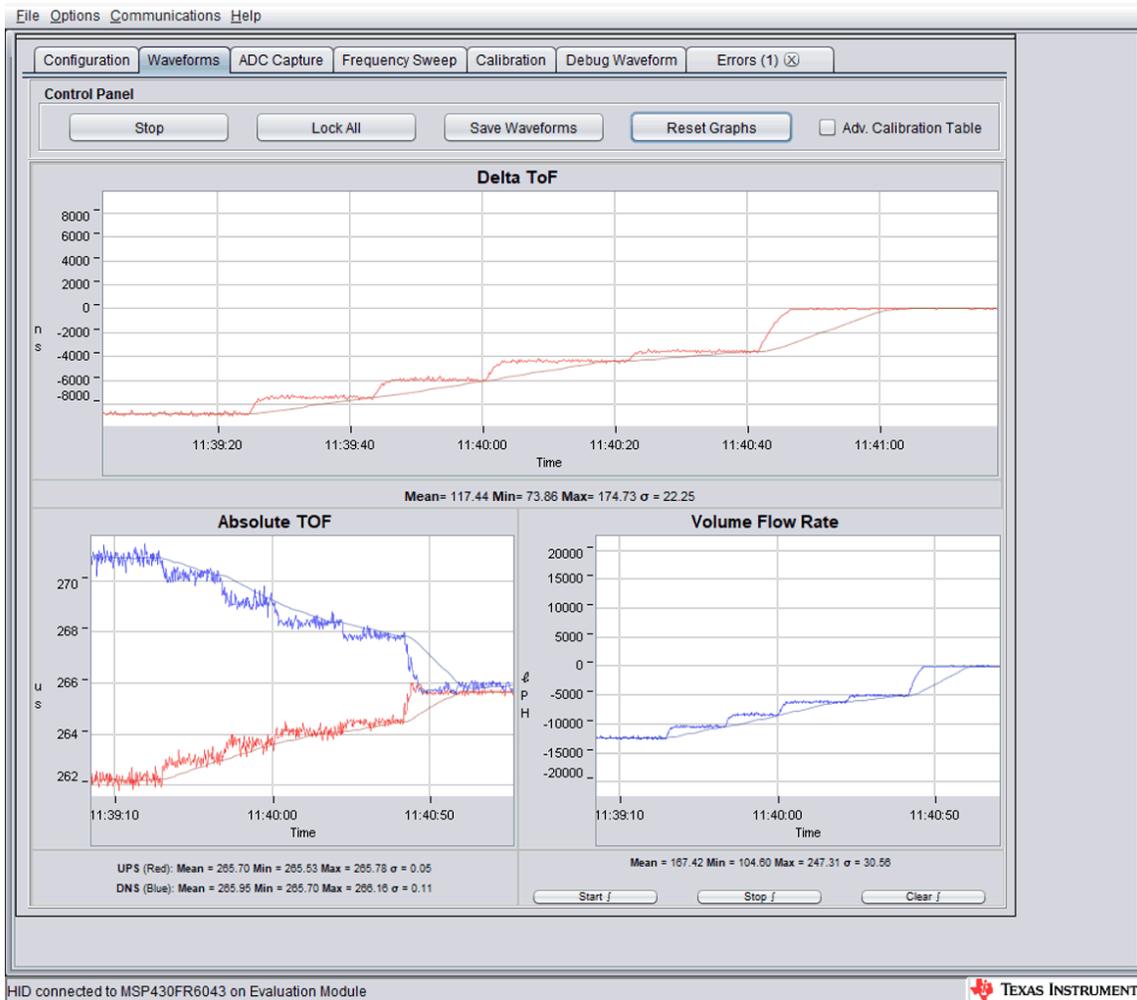


Figure 20. Flow Test Setup

Flows are typically captured over several minutes and averaged over multiple measurements. Figure 21 shows flow tests results including differential ToF (DToF), absolute ToF (AToF) and Volume Flow Rate (VFR) at various flows rates ranging from 12000 LPH to 0 LPH in decreasing steps of 2000 LPH. The flow rates appear negative because air was pulled (instead of pushed) through the pipe. Also, the last step of nearly 5000 lph is due to limitation of the smallest voltage setting of the fan.



NOTE: Measurements at room temperature

Figure 21. Flow Rate Testing

For more details on gas flow testing, see the section 3.2.2.5 Flow Measurements in the TI Design [Ultrasonic Sensing Metrology Subsystem Reference Design for Gas Flow Measurement design guide](#).

IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATASHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES "AS IS" AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, or other requirements. These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you will fully indemnify TI and its representatives against, any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI's products are provided subject to TI's Terms of Sale (www.ti.com/legal/termsofsale.html) or other applicable terms available either on ti.com or provided in conjunction with such TI products. TI's provision of these resources does not expand or otherwise alter TI's applicable warranties or warranty disclaimers for TI products.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2020, Texas Instruments Incorporated