User's Guide

SLAU755–March 2018

MSP430FR6043 Ultrasonic Design Center

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ABSTRACT

This user's guide reviews the contents of the Design Center GUI and provides an overview on how to quickly get started with Ultrasonic Sensing (USS) Library and begin experimental flow measurements using the MSP430FR6043 MCU.

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1 Design Center Introduction

Thank you for using the MSP430FR6043 MCU and the Ultrasonic Sensing Design Center GUI. This user's guide reviews the contents of the Design Center GUI and provides an overview on how to quickly get started with Ultrasonic Sensing (USS) Library and begin experimental flow measurements with the MSP430FR6043 MCU.

2 Getting Started

2.1 Loading the Ultrasonic Sensing Design Center Example Project to the EVM430-FR6043

The EVM should have the program preloaded onto the device.

To run the provided programming example, the PC must have Code Composer Studio™ IDE (CCS), IAR Embedded Workbench™ IDE (IAR), or an IDE that works with the MSP430™ MCU. The project developed for download was used in CCS and IAR and is tested to work with only CCS and IAR.

By default, the GUI is installed in the C:/ti/msp directory.

After the downloaded project is imported into the workspace in CCS or IAR, build, load, and run the code. For help running a project in CCS, see the web resources link in the welcome menu on the resource explorer page. Find this by selecting the TI Resource Explorer on the View menu. If not using CCS, make sure that all the necessary files are in the workspace for the project to compile correctly.

2.2 GUI Installation: Java

The GUI tool requires Java version 1.7+. If Java is not already installed, download the latest version from the Java website.

2.3 GUI Launch

The Design Center is a graphical user interface (GUI) for the USS module of the MSP430FR6043 and is used to configure the application and USS library and to view the results. After proper installation, USS.exe is the application file that must be launched to run the Design Center (see Figure 1). The installation also adds the USS GUI app executable in the Windows start menu and places a shortcut on the desktop.

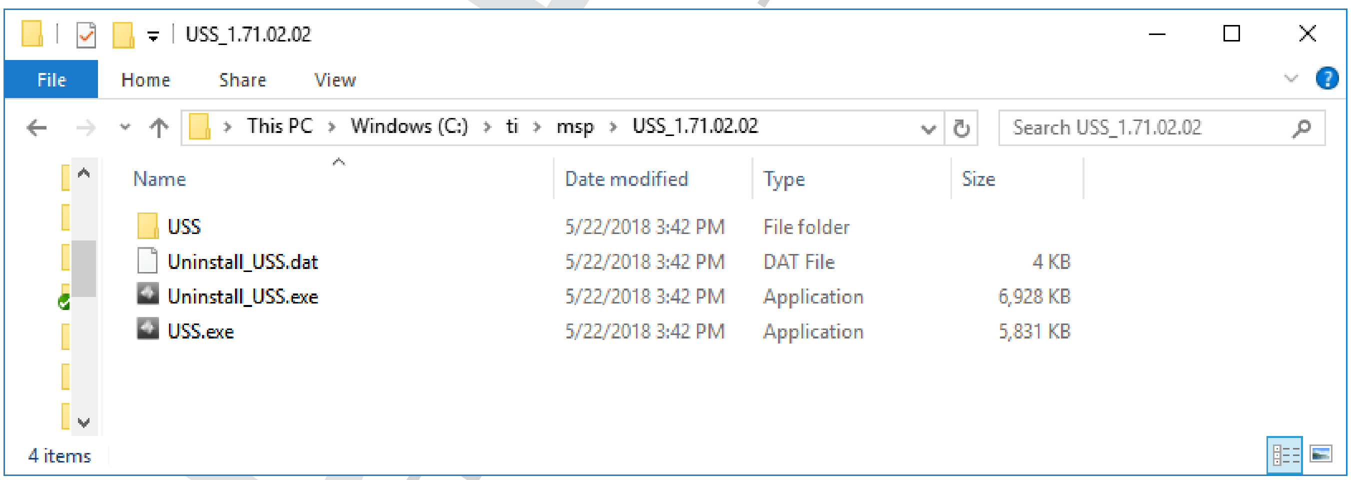

Figure 1. USS Design Center GUI Executable

Run "USS.exe" (see Figure 1) to launch the GUI. The window shown in Figure 2 opens.

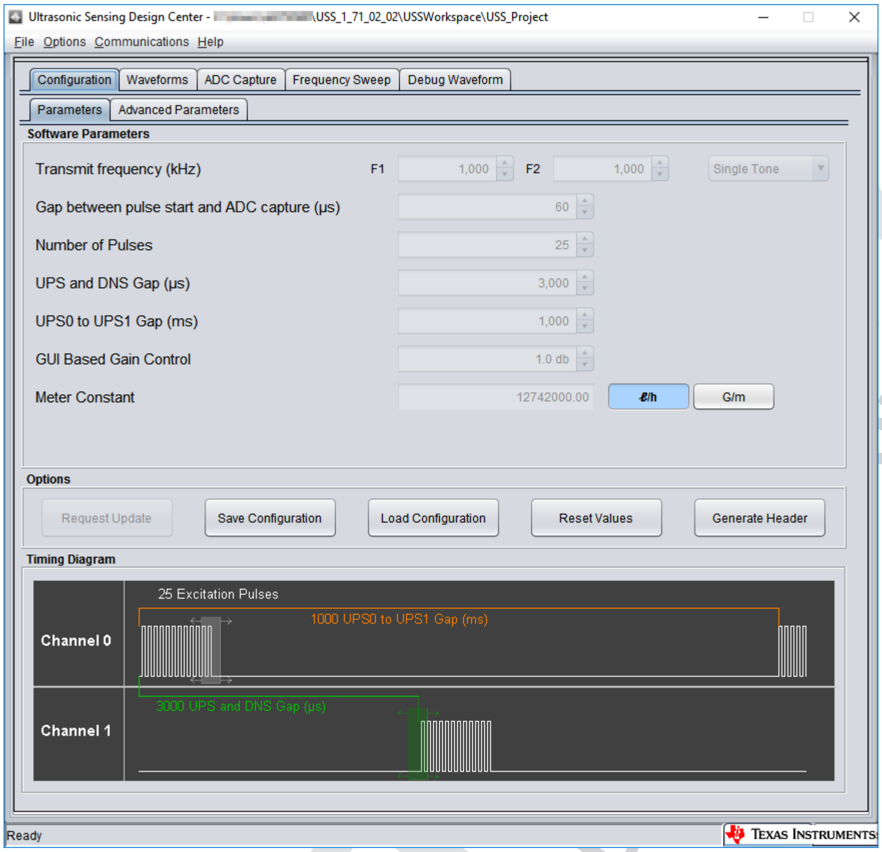

Figure 2. USS Design Center

3 Design Center Configuration Panel

3.1 Communicating With the MSP430FR6043 on the EVM430-FR6043

To confirm connection with the EVM430-FR6043, select "Connect" on the "Communications" menu on the Design Center menu (see Figure 3) or press the F1 key.

To disconnect, select "Disconnect" on the "Communications" menu on the Design Center menu (see Figure 3) or press the F2 key.

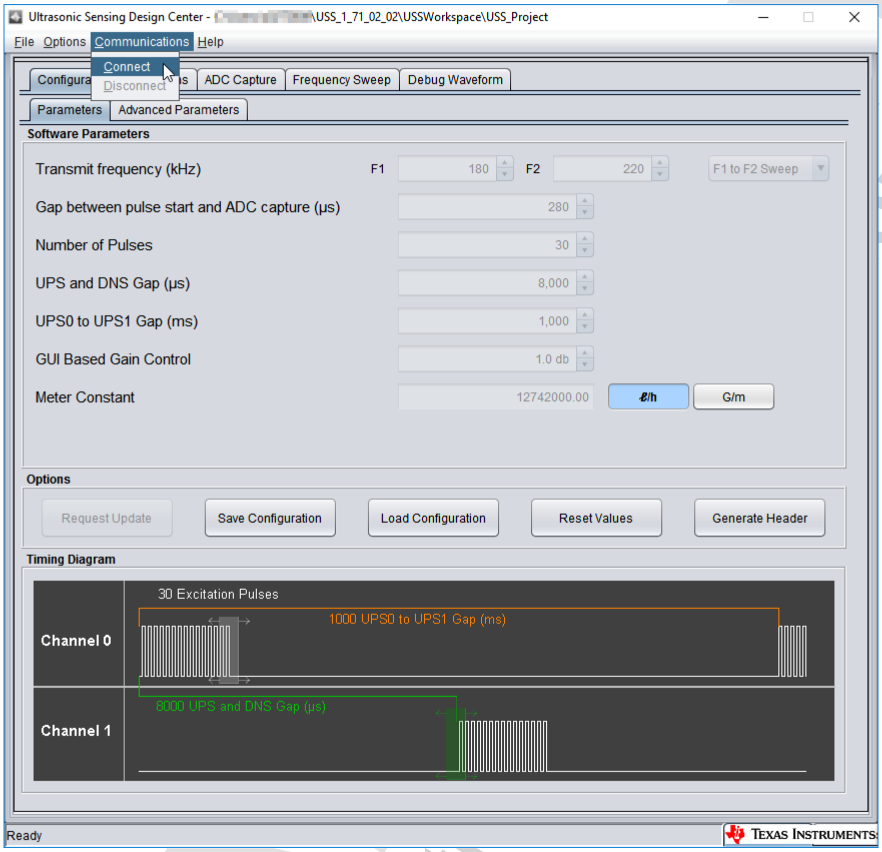

Figure 3. Connect to MSP430FR6043 on the EVM430-FR6043

After connecting the target EVM430-FR6043, the Design Center should display "HID connected to MSP430FR6043 on Evaluation Module" at the bottom of the GUI (see Figure 4).

Figure 4. Confirmed Connection

The Design Center supports gas and water meter applications. Selecting the appropriate execution mode enables parameters and configurations that are pertinent to each application. To choose the execution mode, select "Meter Mode" on the "Options" menu, which opens the window shown in Figure 5.

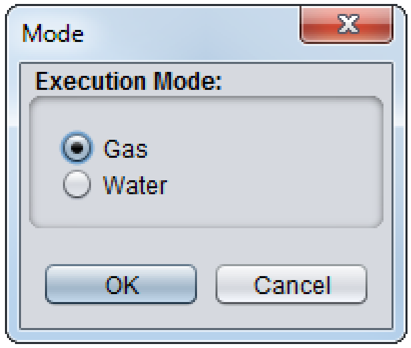

Figure 5. Selection of Execution Mode

This guide explains how to use Design Center for a gas application using MSP430FR6043, so the "Gas" execution mode must be selected.

3.2 Configuration Parameters

Figure 6 and Figure 7 show the main configuration screen and the additional parameters screen, respectively. Section 9 and Section 10 describe these parameters and the valid configurations.

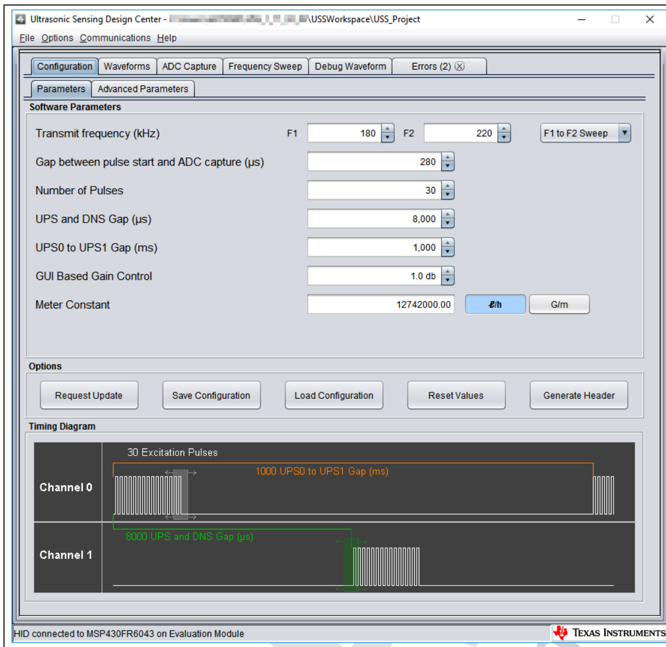

Figure 6. Design Center Input Parameters

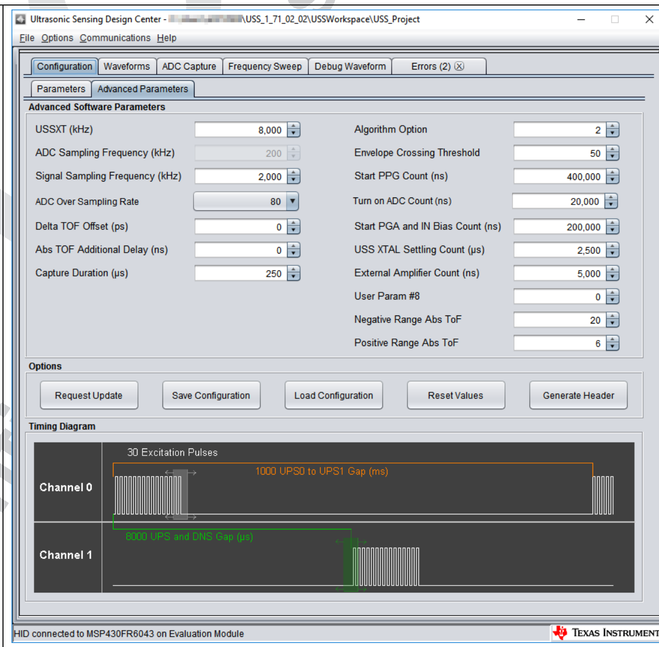

Figure 7. Design Center Advanced Parameters

3.3 Loading a Configuration

To load an existing meter configuration, select the "Load Configuration" button in the main panel (see Figure 8). Some example configurations are available in the Ultrasonic Gas example directory.

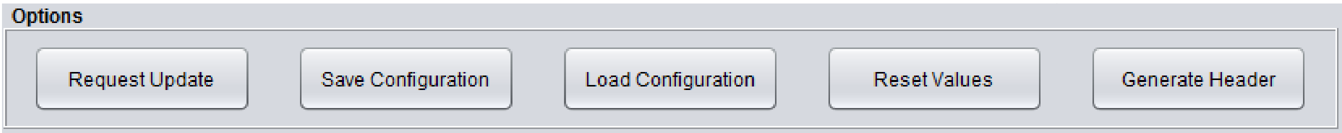

Figure 8. Design Center Configuration Option Buttons

Navigate to the desired Configuration file in the file system and click "Load".

3.4 Saving a Configuration

The parameters in the configuration panels can be saved to a file for later use by using the "Save Configuration" button in the main panel (see Figure 8).

Navigate to the desired location in the file system to save the configuration file and select "Save".

3.5 Sending Configuration Parameters to MSP430 Device

The meter parameters in the configuration panels are transmitted to the MSP430 device using the "Request Update" button in the main panel (see Figure 8).

3.6 Generating Source Code Header Files

Design Center can generate source files which can be integrated to an existing CCS or IAR project by pressing the "Generate Header" button in the main panel.

These files determine the default configuration of the device. More information about user configuration files is available in the Application Software (SW) Architecture for MSP430FR6043-Based Ultrasonic Gas Flow Meter User's Guide.

4 Understanding the Design Center Waveforms Panel

The Design Center's Waveforms panel allows the user to view the Absolute Time of Flight (TOF), Delta TOF, and Volume Flow Rate in real time of consecutive USS captures. To start viewing the waveforms click the "Start" button (see Figure 9).

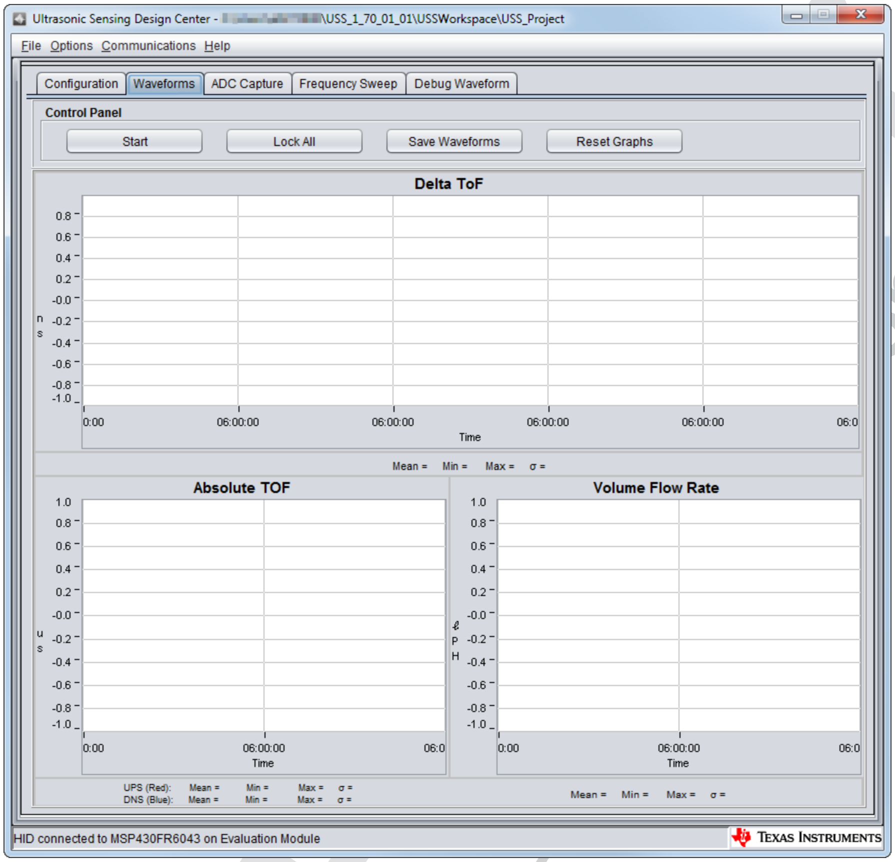

Figure 9. Waveforms Panel

When the start button is pressed, waveforms should begin to show up on each of the three graphs as shown in Figure 10.

- To zoom in, click and hold the right button on the mouse and drag from top left to bottom right.
- To zoom out, click and hold the right button on the mouse and drag from bottom right to top left.
- To save a capture of the graph, right click and select "Capture Image". Navigate to the desired location in the file system where the image should be saved and select "Save".

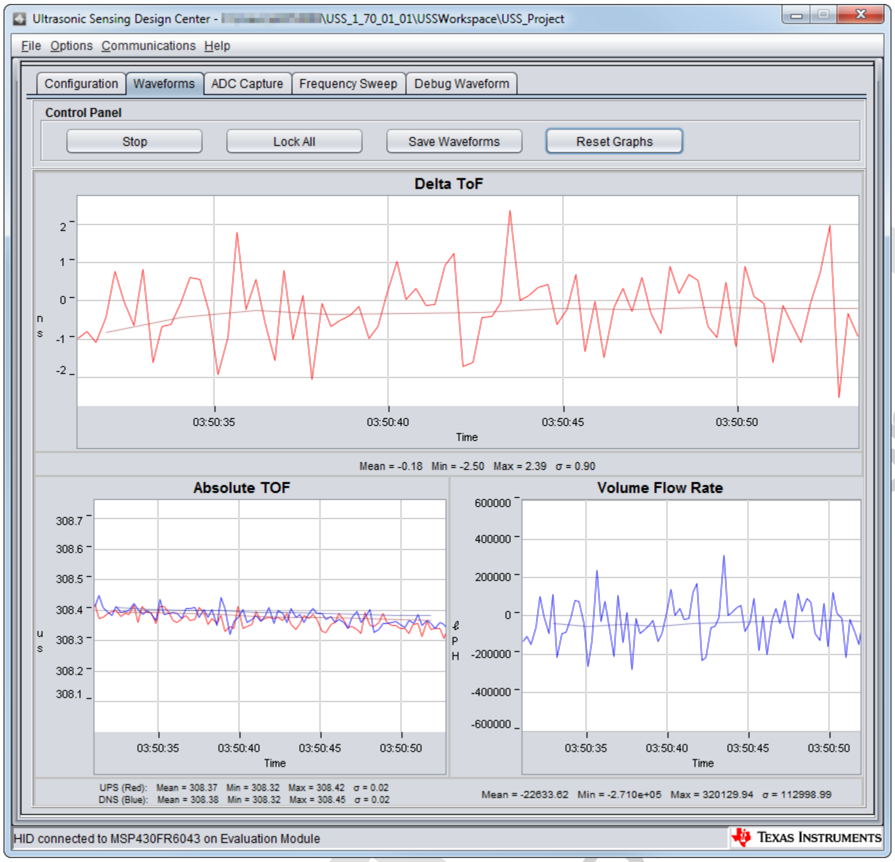

Figure 10. Waveforms Panel Running

In addition to the visual waveforms, the Design Center has the feature to be able to show statistics of the data on the graphs. Each graph displays the mean, minimum, maximum, and standard deviation of the data shown. The statistics can be adjusted using the graph options feature. To use the graph options feature, right click on the graph and select "Graph Options" as shown in Figure 11.

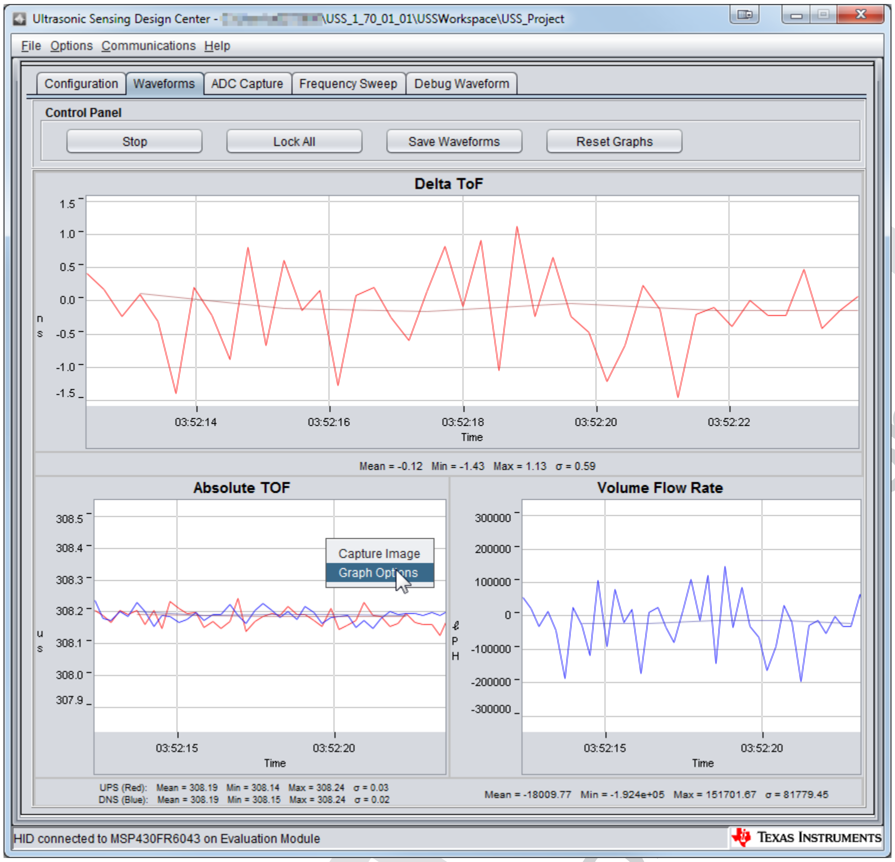

Figure 11. Right Click on Waveforms

Select "Graph Options" to open the window in Figure 12. Use this window to edit the viewing options of the graphs and the number of samples used to calculate the statistics.

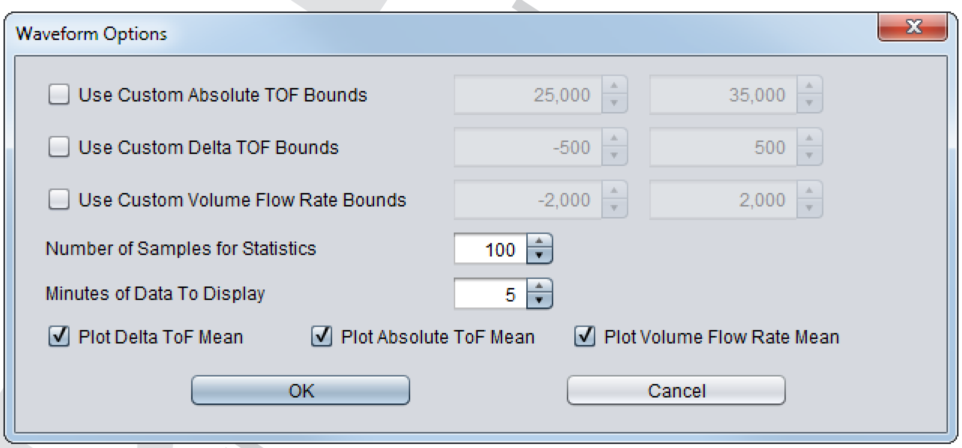

Figure 12. Graph Options Menu

5 Understanding the Design Center ADC Capture Panel

The Design Center ADC Capture panel can show a single USS ADC capture (see Figure 13).

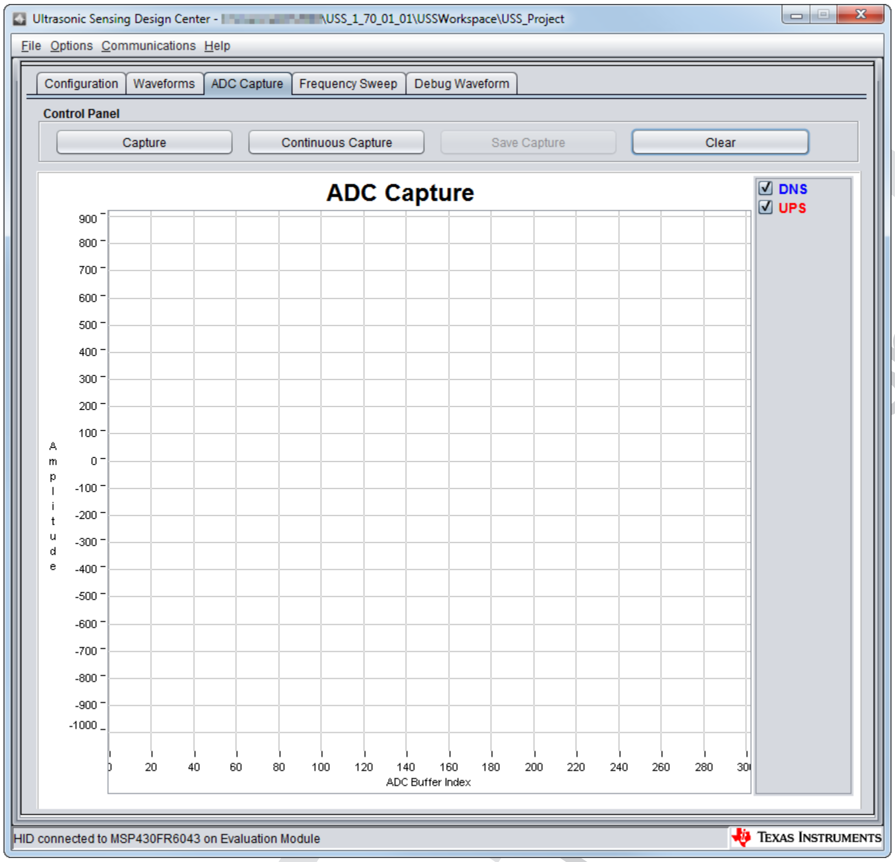

Figure 13. ADC Capture Panel

Select the "Capture" button to capture the ADC waveform and plot the graph on the GUI. An example is shown in Figure 14. To Zoom in, click and hold the right button on the mouse and drag from top left to bottom right. To Zoom out, click and hold the right button on the mouse and drag from bottom right to top left. To save a capture of the graph, right click on the mouse and select "Capture Image". Navigate to the desired location in the file system where the image should be saved and select "Save".

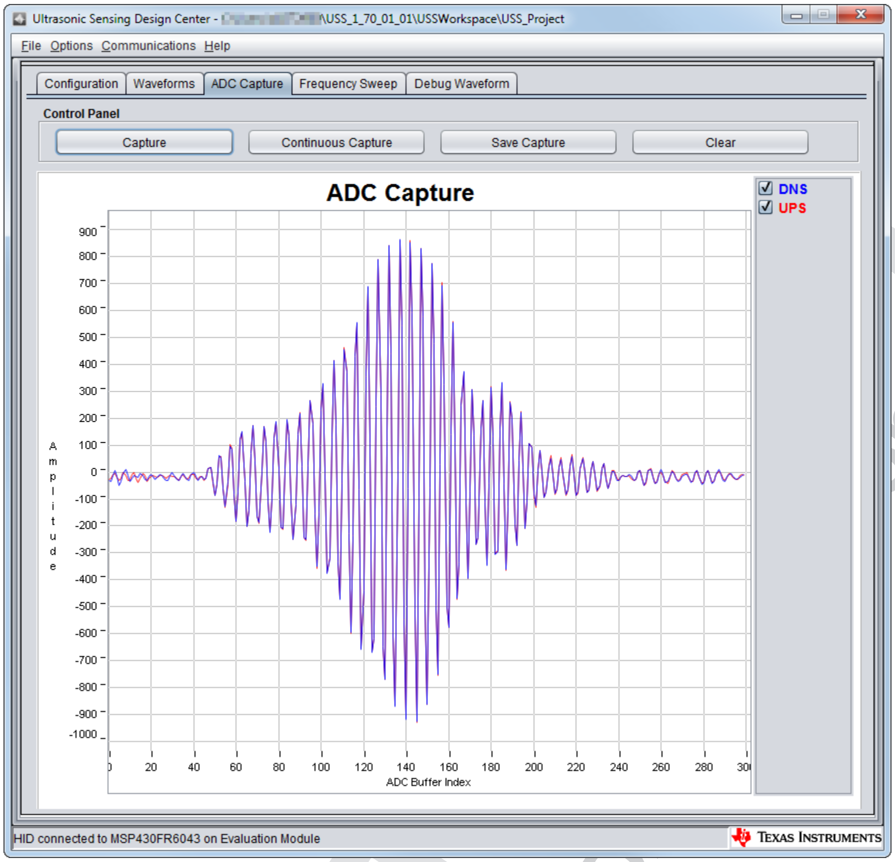

Figure 14. Single ADC Capture

5.1 Using Continuous Capture

Continuous Capture continuously sends the captured ADC waveform data from the GUI to a .csv file. To begin continuously capturing the ADC waveform data, select the "Continuous Capture" button. Navigate to the desired location in the file system where the .csv file should be saved and select "Set Location".

6 Understanding the Design Center Frequency Sweep Panel

The Frequency Sweep panel of the Design Center (see Figure 15) can sweep through a range of transmit frequencies. To start a sweep, set the F1 Parameter on the Configuration tab and then set the Number of Captures parameter in the Frequency Sweep tab to determine the range to sweep. Select the "Frequency Sweep" button and then navigate to the desired location in the file system where the Frequency Sweep data should be saved and select "Save".

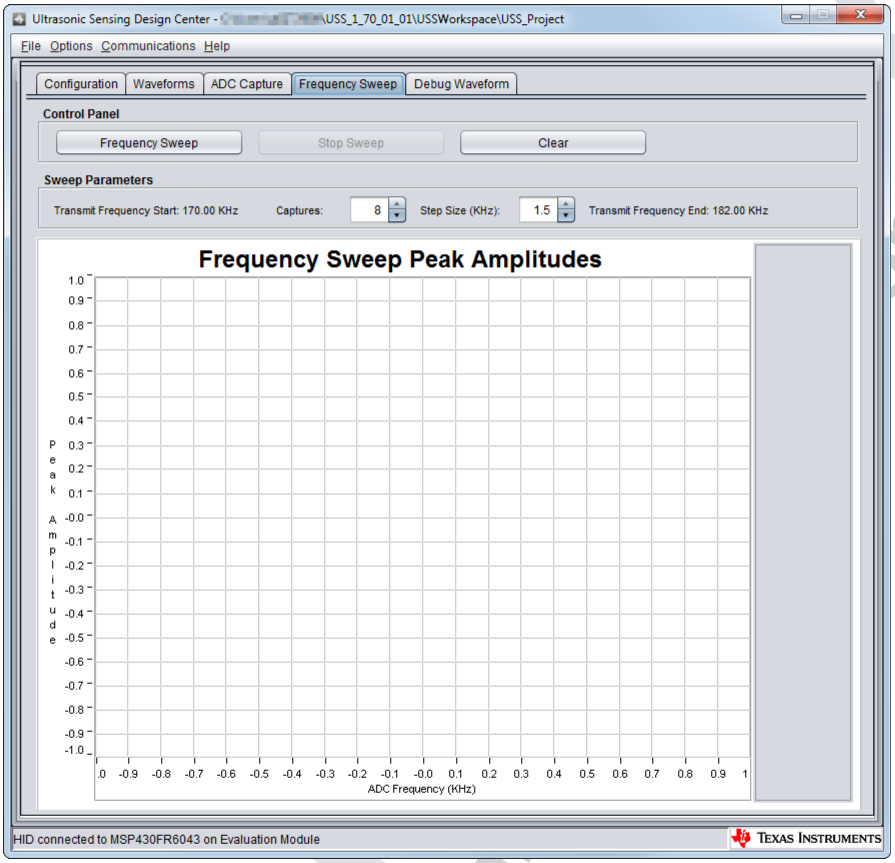

Figure 15. Frequency Sweep Panel

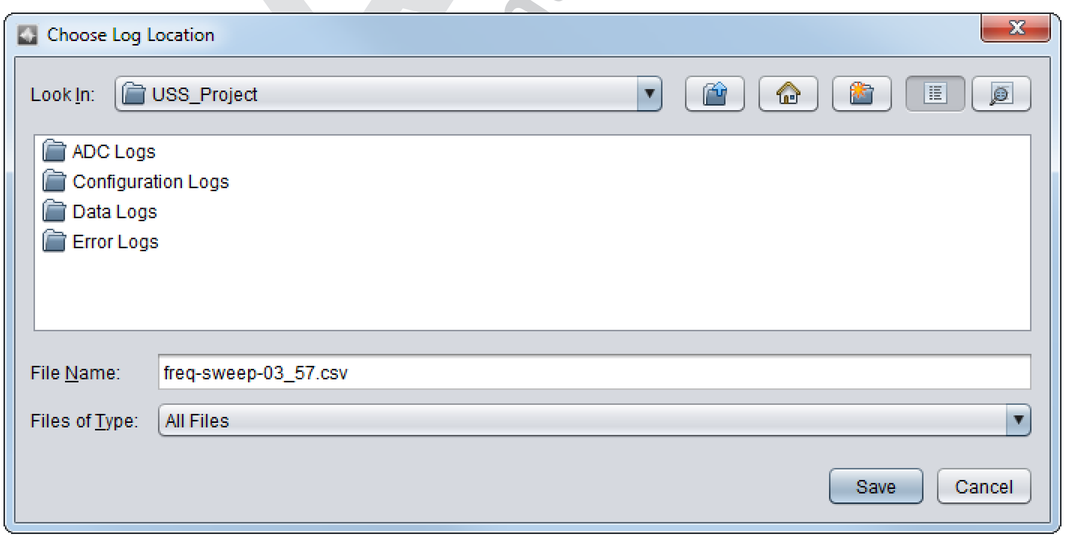

Figure 16. Save Frequency Sweep Location

The Frequency Sweep tool helps to determine the transducer excitation frequency at which the ADC capture achieves the maximum amplitude. The frequency at which the peak amplitude is reached should be used as the new F1 and F2 parameters to achieve the strongest signal for the meter configuration. For the example in Figure 17, the transducer has a good response between 320 kHz and 420 kHz. A frequency sweep between these frequencies could be used. TI recommendeds running frequency sweeps at different temperatures to observe the behavior of the transducer.

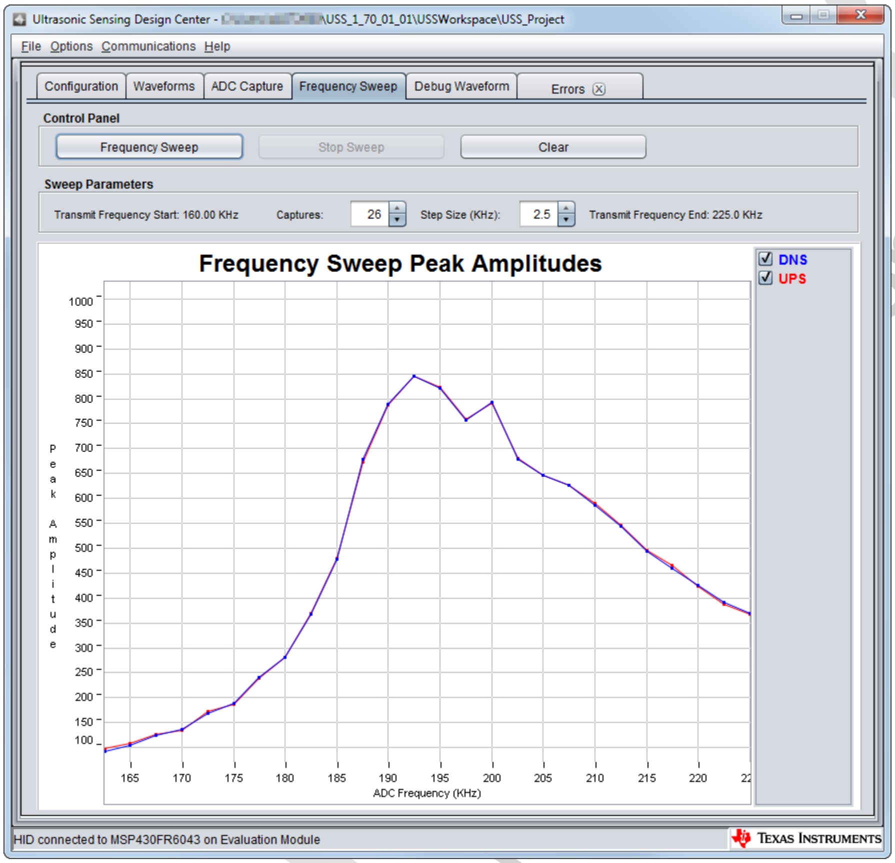

Figure 17. Frequency Sweep Showing Maximum Amplitude

7 Understanding the Design Center Debug Panel

The Debug Panel (see Figure 18) plots user-selected data. To plot data on the graph, navigate to the "HMI_PostAlgorithm_Update" routine and modify the function "CommandHandler_transmittDebugData(txPacket, (float)<your Data Here>)" to include the data to plot in the parameter. Rebuild, flash, and run the code then view the debug plot for the custom data.

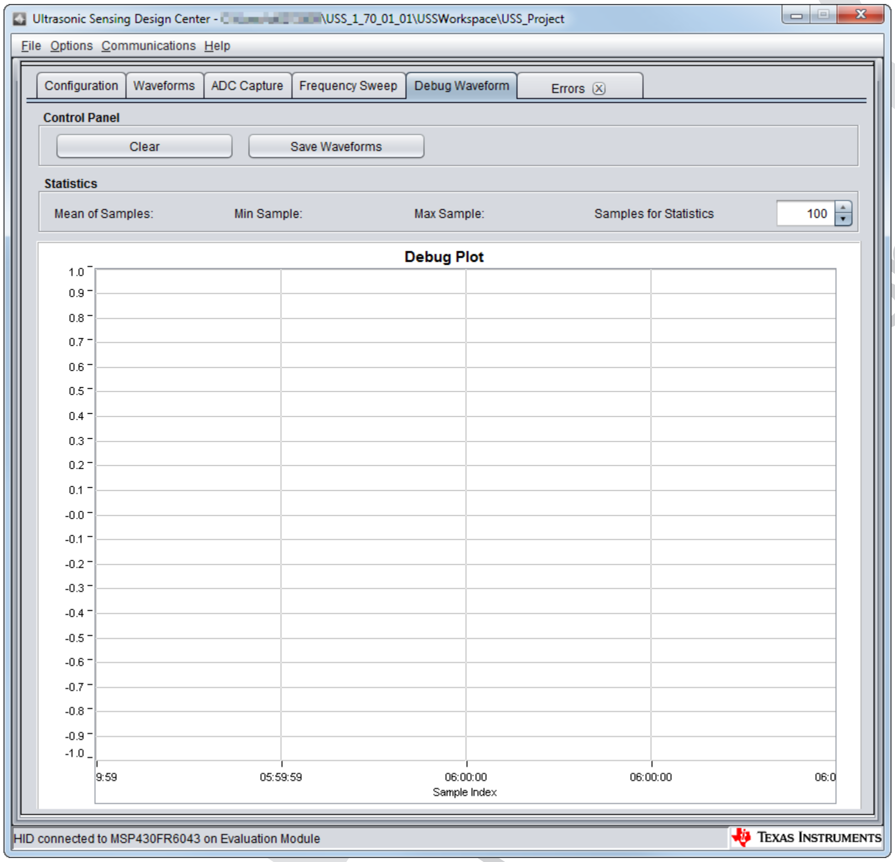

Figure 18. Debug Panel

8 Understanding the Design Center Errors Panel

The Design Center Errors panel (see Figure 19) shows Lib errors that occur during the execution of the application, configuration of the library, measurement, or algorithm execution.

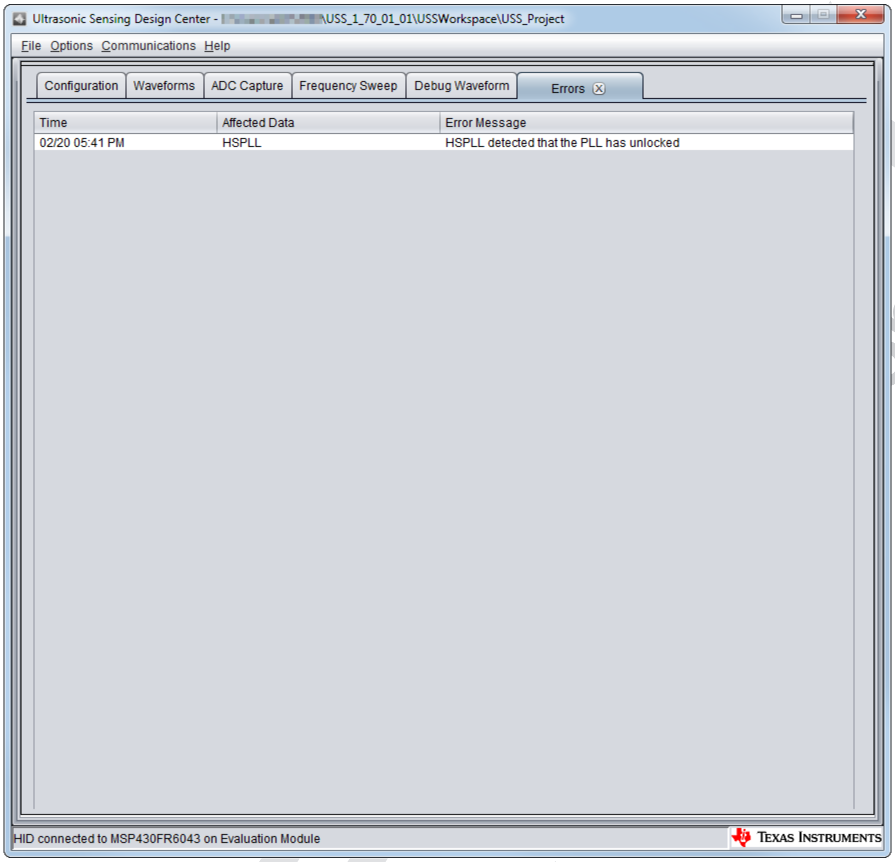

Figure 19. Errors Panel

9 Design Center Parameters Overview and Specifications

Table 1 describes the parameters that are available in the Design Center. Each parameter directly maps to a member of the Command Handler data structure.

Section 10 includes a more detailed description of each parameter.

NOTE: Hovering the cursor over the parameter in the GUI shows a description.

Table 1. Design Center Key Parameter Specifications

Design Center Label	Description
F1	Pulse output frequency 1
F2	Pulse output frequency 2
Pattern	Defines the output pattern mode: single tone, dual tone, or F1 to F2 sweep
Gap between pulse start and ADC capture: (µs)	The time in µs to start ADC acquisition from PPG pulse
Number of Pulses	Number of excitation pulses
UPS and DNS Gap (µs)	Time between captures in a sequence (that is, from upstream to downstream)
UPS0 to UPS1 Gap (ms)	Time between sequences of captures (that is, from previous captures upstream pulse to next captures upstream pulse)
GUI Based Gain Control	PGA gain value
Meter Constant	Volume scale factor
USSXT (kHz)	USS crystal frequency
ADC Sampling Frequency (kHz)	N/A
Signal Sampling Frequency (kHz)	Sampling frequency in kHz
ADC Over Sampling Rate	Oversampling rate of ADC
Delta TOF Offset (ps)	Delta TOF offset in ps
Abs TOF Additional Delay (ns)	Additional absolute TOF delay in ns
Capture Duration (µs)	Duration of ADC capture
Algorithm Option	Selects the gas metrology algorithm option
Envelope Crossing Threshold	Envelope crossing threshold of correlation output for calculation of absolute TOF
Start PPG Count (ns)	Time to start PPG pulse trigger in ns
Turn on ADC Count (ns)	Time to turn on the ADC in ns
Start PGA and IN Bias Count (ns)	Time to turn on the PGA and input biasing in ns
USS XTAL Settling Count (µs)	Settling time for USSXT in µs
External Amplifier Count (ns)	Time to turn on the external amplifier
User Param #8	Parameter available for user. Demo application uses the parameter to enable/disable application features.
Negative Range Abs ToF	Adjusts the maximum negative index to search across correlation value of UPS/DNS and TX pulse for matching signal
Positive Range Abs ToF	Adjusts the maximum positive index to search across correlation value of UPS/DNS and TX pulse for matching signal

10 Detailed Description of Design Center Parameters

The following sections describe each parameter in the Design Center. Each parameter also maps to one or more of the USS Library data structures directly or indirectly. The tested range for each parameter is provided.

10.1 F1

This parameter specifies pulse output frequency 1.

The pattern of the output pulses also depends on pattern mode as explained in Section 10.3.

The pulse output frequency should be selected according to the transducer's frequency response.

This parameter affects the size of TX pattern. The device will generate an error if the calculated TX pattern size exceeds the allocated maximum size.

Table 2. Details for F1

Parameter	Description	Command Handler Struct	USS Library Struct And Members		Range	Example
F1	Pulse output frequency 1	transFreq1	meterConfig	transducerFreq	134 kHz to 600 kHz	F1 = 200
			measurementConfig.pulseConfig	F1Frequency		

10.2 F2

This parameter specifies pulse output frequency 2.

The pattern of the output pulses also depends on the pattern mode as explained in Section 10.3.

The pulse output frequency should be selected according to the transducer's frequency response.

This parameter affects the size of TX pattern. The device will generate an error if the calculated TX pattern size exceeds the allocated maximum size.

Table 3. Details for F2

Parameter	Description	Command Handler Struct	USS Library Struct And Members		Range	Example
F2	Pulse output frequency 2	transFreq2	meterConfig	transducerFreq	134 kHz to 600 kHz	F2 = 200
			measurementConfig.pulseConfig	F2Frequency		

10.3 Pattern Option

This parameter selects the output pattern option. The possible options are:

- Single Tone: Pulses are generated at F1 frequency. transducerFreq = F1
- Dual Tone: Half the pulses are generated at F1 frequency and half at F2 frequency. transducerFreq = (F1 + F2) / 2
- F1 to F2 Sweep: Pulses are generated starting at F1 frequency and incrementing to F2 frequency. transducerFreq = (F1 + F2) / 2

Select the pattern option according to the transducer characteristics: Single-tone provides good performance if the transducer frequency response is constant across temperature and flow conditions. Dual Tone provides good performance for transducers with bi-modal distribution of frequency response. F1 to F2 Sweep provides more robust response with transducer variation.

This parameter affects the TX pattern. The device will generate an error if the calculated TX pattern size exceeds the allocated maximum size.

Table 4. Details for Pattern Option

Parameter	Command Handler Struct	USS Library Struct And Members		Range	Example
Pattern Option	patternOption	meterConfig	transducerFreq	Single tone, Dual Tone, F1 to F2 Sweep	F1 to F2 Sweep
		measurementConfig. pulseConfig	pulseGenMode		

10.4 Gap Between Pulse Start and ADC Capture (µs)

This parameter defines the amount of time between the generation of pulses and the ADC capture.

The time for the signal to travel from a transmitting transducer to a receiving transducer is directly proportional to the dimension of the pipe; however, it is also affected by the medium (for example, temperature and gas composition).

This parameter should be used to make sure the signal is received properly by the ADC after it travels from one transducer to the other, and it should also be adjusted to allow for signal variations.

Table 5. Details for Gap Between Pulse Start and ADC Capture (µs)

Parameter	Command Handler Struct	USS Library Struct And Members		Range	Example
Gap between pulse start and ADC capture (µs)	gap_pls_adc_start	measurementConfig	startADCsamplingCount	3 to 9000	200

10.5 Number of Pulses

This parameter defines the number of pulses generated during tone generation.

The number of pulses must be even in Dual Tone and F1 to F2 Sweep modes.

This parameter affects the TX pattern. The device will generate an error if the calculated TX pattern size exceeds the allocated maximum size.

Table 6. Details for Number of Pulses

Parameter	Command Handler Struct	USS Library Struct And Members		Range	Example
Number of Pulses	num_pls	measurementConfig.pulseConfig .pToneConfig	pToneConfig(1)	0 to 63	20

(1) In Single Tone, pToneConfig points to singDualToneConfig, and the parameter singDualToneConfig.numOfF1Cycles is updated with num_pls.
In Dual Tone, pToneConfig points to singDualToneConfig, and the parameters singDualToneConfig.numOfF1Cycles and singDualToneConfig.numOfF2Cycles are updated with num_pls/2.
In F1 to F2 Sweep, pToneConfig points to multiToneConfig, and the parameter multiToneConfig.numOfTrillcycles is updated with num_pls/2.

10.6 UPS and DNS Gap (µs)

This parameter defines the time between an upstream capture (from transducer 1 to transducer 2) and a downstream capture (from transducer 2 to transducer 1).

Adjust this parameter according to transducer and pipe characteristics to allow enough time for a signal to settle.

Table 7. Details for UPS and DNS Gap (µs)

Parameter	Command Handler Struct	USS Library Struct And Members		Range	Example
UPS and DNS Gap (µs)	gap_ups_dns	measurementConfig	restartCaptureCount	100 to 16000	8000

10.7 UPS0 to UPS1 Gap (ms)

This parameter defines the time between sequences of captures, that is a upstream capture followed by a downstream capture. As such, it defines the time from one upstream capture to the next.

This parameter is implemented at the application layer instead of the USS library and it should be adjusted according to the application requirements. For example, if the application requires 1 measurement per second, the parameter should be set to 1000. Faster measurements are possible at the expense of higher power consumption.

Table 8. Details for UPS0 to UPS1 Gap (ms)

Parameter	Command Handler Struct	USS Library Struct And Members		Range	Example
UPS0 to UPS1 Gap (ms)	gap_ups_ups	None	None	20 to 2000	1000

10.8 GUI Based Gain Control

This parameter defines the internal amplifier gain setting. Allowed values depend on the configurations supported by the MSP430FR6043 internal amplifier.

The GUI Based Gain Control should be adjusted to allow sufficient amplitude without saturating the ADC. Recommended maximum amplitude is around ±1000 ADC counts.

Table 9. Details for GUI Based Gain Control

Parameter	Command Handler Struct	USS Library Struct And Members		Range	Example
GUI Based Gain Control	gain_control	captureConfig	gainRange	-6.5 dB to 30.8 dB	1.4 dB

10.9 Meter Constant

The meter constant is used to calculate the flow rate. This parameter depends on the meter/pipe characteristics and it can also be used to change the output units (for example, LPH or GPM).

A recommended approach to approximate this value is to provide a constant flow to the pipe and adjust the parameter accordingly based on the calculated flow rate.

Table 10. Details for Meter Constant

Parameter	Command Handler Struct	USS Library Struct And Members		Range	Example
Meter Constant	meter_constant	meterConfig	volumeScaleFactor	0 to 22742000	15500

10.10 USSXT (kHz)

This parameter defines the USS crystal frequency.

The possible values are 8 MHz and 4 MHz. The EVM430-FR6043 includes an 8-MHz oscillator.

Table 11. Details for USSXT (kHz)

Parameter	Command Handler Struct	USS Library Struct And Members		Range	Example
USSXT (kHz)	ussxt_freq	pllConfiguration	pllXtalFreq_inKHz	4000 or 8000	8000

10.11 ADC Sampling Frequency (kHz)

This parameter is not used by gas meter application using MSP430FR6043.

Table 12. Details for ADC Sampling Frequency (kHz)

Parameter	Command Handler Struct	USS Library Struct And Members		Range	Example
ADC Sampling Frequency (kHz)	adc_samp_freq	N/A	N/A	N/A	N/A

10.12 Signal Sampling Frequency (kHz)

This parameter defines the signal sampling frequency.

The recommended Signal Sampling Frequency is at least 3.5 times the transducer frequency; however, developers can adjust this parameter as a tradeoff between power consumption and signal resolution.

This parameter affects the PLL frequency which is defined as signal sampling frequency x oversampling rate. The PLL output frequency must be between 68 MHz and 80 MHz. Modifying the PLL frequency affects other timing-related parameters.

This parameter affects the TX pattern and the total number of ADC samples. The device will generate an error if their calculated size exceeds the allocated maximum size.

Table 13. Details for Signal Sampling Frequency (kHz)

Parameter	Command Handler Struct	USS Library Struct And Members		Range	Example
Signal Sampling Frequency (kHz)	sig_samp_freq	pllConfiguration	pllOutputFreq	1000 to 8000	2000
Signal Sampling Frequency (kHz)	sig_samp_freq	captureConfig	sampleSize	1000 to 8000	2000

10.13 ADC Over Sampling Rate

This parameter defines the ADC over sampling rate. The values supported by MSP430FR6043 are: 10, 20, 40, 80 and 160.

This parameter affects the PLL frequency which is defined as signal sampling frequency x oversampling rate. The PLL output frequency must be between 68 MHz and 80 MHz. Modifying the PLL frequency will affect other timing-related parameters.

Table 14. Details for ADC Over Sampling Rate

Parameter	Command Handler Struct	USS Library Struct And Members		Range	Example
ADC Over Sampling Rate	over_sampling_rate	pllConfiguration	pllOutputFreq	10,20, 40, 80, or 160	20
ADC Over Sampling Rate	over_sampling_rate	captureConfig	overSampleRate	10,20, 40, 80, or 160	20

10.14 Delta TOF Offset (ps)

This parameter compensates for any offsets in the delta TOF calculation. The reported delta TOF is simply the result of adding this offset to the calculated delta TOF.

Table 15. Details for Delta TOF Offset (ps)

Parameter	Command Handler Struct	USS Library Struct And Members		Range	Example
Delta TOF Offset (ps)	delta_tof_offset	algorithmsConfig	DcOffset	int32	0

10.15 Abs TOF Additional Delay (ns)

This parameter compensates for any offsets in the Absolute TOF calculation. The reported Absolute TOF is the result of adding this offset to the calculated Absolute TOF.

Table 16. Details for Abs TOF Additional Delay (ns)

Parameter	Command Handler Struct	USS Library Struct And Members		Range	Example
Abs TOF Additional Delay (ns)	abs_tof_additional	algorithmsConfig	ADCAdditionalCaptureDelay	int32	0

10.16 Capture Duration (µs)

This parameter defines the duration of the ADC capture. It should be defined based on the transducer characteristics and the shape of the received signal.

Developers should adjust this parameter to ensure that a complete signal is received considering fluctuations over temperature and flow conditions.

This parameter affects the total number of captures. The device will generate an error if the calculated number of captures exceeds the allocated maximum size.

Table 17. Details for Capture Duration (µs)

Parameter	Description	Command Handler Struct	USS Library Struct And Members		Range	Example
Capture Duration (µs)	Duration of samples	capture_duration	captureConfig	sampleSize	4 to 400	300

10.17 Algorithm Option

Algorithm used by the library to calculate absolute and delta time-of-flights. Possible values are:

- 2 (Lobe-Wide):
  - The downstream and upstream absolute TOF are obtained based on a calculation performed on the corresponding signal. The algorithm has optimized power consumption because it does not rely on a complete search for the absolute time of flight but instead narrows the search based on the last result.
  - dTOF is calculated by a window search on the cross correlation between the received upstream and downstream signal.
- 3 (Hilbert-Wide):
  - Absolute TOF is obtained similarly to option 2, except that a Hilbert envelope is used.
  - dTOF is calculated by a window search on the cross correlation between the received upstream and downstream signal.

Other values are reserved for future use.

The performance of both algorithms is similar; however, developers might observe differences depending on the transducers and signal shape.

Table 18. Details for Algorithm Option

Parameter	Command Handler Struct	USS Library Struct And Members		Range	Example
Algorithm Option	param1_computation_mode	algorithmsConfig	absToFOption	2 or 3	2

10.18 Envelope Crossing Threshold

This parameter defines the crossing threshold of the calculated envelope used to detect the time-of-flight.

The threshold should be high enough to avoid noise. It is typically set to 50% of the maximum signal amplitude; however, it can be adjusted according to the signal characteristics resulting in an adjustment to the calculated time-of-flight.

Table 19. Details for Envelope Crossing Threshold

Parameter	Command Handler Struct	USS Library Struct And Members		Range	Example
Envelope Crossing Threshold	param2_env_cross_threshold	algorithmsConfig	crossThreshold[1]	0 to 100	50
			ratioOfTrackLobeToPeak[1]		

(1) algorithmsConfig->crossThreshold is modified for Hilbert Wide algorithm, algorithmsConfig->ratioOfTrackLobeToPeak is modified for Lobe Wide algorithm.

10.19 Start PPG Count (ns)

Defines the time from the start of sequence to the trigger to generate output pulses. This is defined as TMA or TIMEMARK_A in the MSP430FR58xx, MSP430FR59xx, and MSP430FR6xx Family User's Guide.

This parameter, together with other timemarks, can be adjusted to allow enough settling time for the ADC, amplifiers, and bias voltages.

Table 20. Details for Start PPG Count (ns)

Parameter	Command Handler Struct	USS Library Struct And Members		Range	Example
Start PPG Count (ns)	param3_TM_A_start_ppg	measurementConfig	startPPGCount	0 to $<10^{6}$	300000

10.20 Turn on ADC Count (ns)

Defines the time from the start of sequence to the moment the ADC is turned on. This is defined as TMB or TIMEMARK_B in the MSP430FR58xx, MSP430FR59xx, and MSP430FR6xx Family User's Guide.

This parameter, together with other timemarks, can be adjusted to allow enough settling time for the ADC.

Table 21. Details for Turn on ADC Count (ns)

Parameter	Command Handler Struct	USS Library Struct And Members		Range	Example
Turn on ADC Count (ns)	param4_TM_B_adc_on	measurementConfig	turnOnADCCount	0 to 10^{6}	295000

10.21 Start PGA and IN Bias Count (ns)

Defines the time from the start of sequence to the moment the internal bias for signal reception is applied. This is defined as TMC or TIMEMARK_C in the MSP430FR58xx, MSP430FR59xx, and MSP430FR6xx Family User's Guide.

This parameter, together with other timemarks, can be adjusted to allow enough settling time for the internal RX bias.

Table 22. Details for Start PGA and IN Bias Count (ns)

Parameter	Command Handler Struct	USS Library Struct And Members		Range	Example
Start PGA and IN Bias Count (ns)	param5_TM_C_pga_bias	measurementConfig	startPGAandINBiasCount	0 to 10^6	5000

10.22 USS XTAL Settling Count (ns)

This parameter defines the settling time of the USS XTAL.

The settling time depends on the type of oscillator used (resonator or crystal) and the characteristics of the oscillator. Developers should ensure that enough settling time is allowed to provide a stable clock source.

Table 23. Details for USS XTAL Settling Count (ns)

Parameter	Command Handler Struct	USS Library Struct And Members		Range	Example
USS XTAL Settling Count (ns)	param6_uss_xtal_settling_count	pllConfiguration	pllXtalFreq_inKHz	0 to 10000	120

10.23 External Amplifier Count (ns)

Defines the time from the start of sequence to the moment the external amplifier is enabled. Developers should provide enough time for the amplifier to settle before the ADC measurement.

Table 24. Details for External Amplifier Count (ns)

Parameter	Command Handler Struct	USS Library Struct And Members		Range	Example
External Amplifier Count (ns)	param7_ext_amp_count	measurementConfig	startRxEnCount	1 to 10E6	5,000

10.24 User Param #8

This parameter is used by the demo as a command to enable application features.

The functionality of this parameter is defined bit-wise as follows:

- Bits [7:0]: Enables the command only if the value is 128 (0x80). Possible values:
  - 128: enables the command and enables the rest of functionality for bits[31:8].
  - 0-127, 129-255: disables the command. All bits are ignored.
- Bits [11:8]: Additional TX Sequence mode ("detuning"). This feature sends an additional pattern at the end of the TX sequence which can be used to reduce the ringing ("detune") the transducers. Possible values:
  - 0: disables detuning.
  - 1: sends a predefined sequence of 1 pulse at 300kHz, 1 pulse at 400kHz, 2 pulses at 500kHz, 3 pulses at 800kHz.
  - 2-15: reserved for future use.
- Bits [15:12]: reserved for future use.
- Bits [19:16]: Amplitude Gain Calibration (AGC) interval. This feature enables an automatic gain calibration of the signal. Possible values:
  - 0: Disables AGC.
  - 1-15: Performs AGC every 1-15 measurements.
- Bits [23:20]: DC Offset estimation and cancellation. This feature calculates the DC offset of the signal and removes it. Possible values:
  - 0: Disables DC Offset estimation.
  - 1-15: Performs DC offset estimation every 1-15 measurements.
- Bits [27:24]: Resonator calibration interval. This feature enables a resonator calibration routine using LFXT to calculate and compensate for the drift on USSXT. Possible values:
  - 0: Disables resonator calibration.
  - 1-15: Performs resonator calibration every 1-15 measurements.
- Bits [31:28]: reserved for future use

For example, a value of 84,148,608 (0x504 0180) will: 1)enable the command, 2) enable detuning feature, 3) enable AGC calibration every 4 measurements, 5) disable DC Offset estimation, and 5) enable resonator calibration every 5 measurements.

Table 25. Details for Positive Range Delta ToF

Parameter	Command Handler Struct	USS Library Struct And Members		Range	Example
User Param #8	user_param8	N/A	N/A	Signed 32-bits	384

10.25 Negative Range Abs ToF

This parameter adjusts the negative range of a window used to search for Absolute TOF match. The algorithm tracks the index of the previous Absolute TOF calculation and adjusts a search window based on the positive and negative absolute TOF range values.

If the reduced search fails, the algorithm attempts a search over the complete signal. This parameter can be used to reduce the power consumption of absolute TOF calculation, but it should be adjusted to allow for sudden changes in the signal.

Table 26. Details for Negative Range Abs ToF

Parameter	Command Handler Struct	USS Library Struct And Members		Range	Example
Negative Range Abs ToF	param9_negRngTracking	algorithmsConfig	negSearchRange	0 to 32768	20

10.26 Positive Range Abs ToF

This parameter adjusts the positive range of a window used to search for Absolute TOF match. The algorithm tracks the index of the previous absolute TOF calculation and adjusts a search window based on the positive and negative absolute TOF range values.

If the reduced search fails, the algorithm attempts a search over the complete signal. This parameter can be used to reduce the power consumption of absolute TOF calculation, but it should be adjusted to allow for sudden changes in the signal.

Table 27. Details for Positive Range Abs ToF

Parameter	Command Handler Struct	USS Library Struct And Members		Range	Example
Positive Range Abs ToF	param10_posRngTracking	algorithmsConfig	posSearchRange	0 to 32768	6

11 USS Library Parameters

The following sections provide information on the USS Library and which library members and parameters get updated with the Design Center GUI. For more details, see the USS Library User's Guide.

11.1 System Configuration Parameters

- **Structure:** USS_SW_Library_configuration
- **Application Definition:** gUssSWConfig.systemConfig = ussSystemConfig
- **Parameters updated by Design Center:** None

11.2 Meter Configuration Parameters

- **Structure:** USS_Meter_Configuration
- **Application Definition:** gUssSWConfig.meterConfig = ussMeterConfig
- **Parameters updated by Design Center:**

Table 28. USS Library Meter Configuration Parameters Updated by Design Center

Member	Description	Parameter in Design Center
volumeScaleFactor (1)	Volume scale factor	Meter Constant
transducerFreq (2)	Transducer frequency in Hz	F1, F2, Pattern Option

(1) volumeScaleFactor = Meter Constant

(2) If (Pattern Option == Single-tone), transducerFreq = F1 (in Hz).
If (Pattern Option == Dual-tone or F1 to F2 Sweep), transducerFreq = [F1 (in Hz) + F2(in Hz)] / 2.

11.3 Measurement Configuration Parameters

- **Structure:** USS_Measurement_Configuration
- **Application Definition:** gUssSWConfig.measurementConfig = ussMeasurementConfig
- **Parameters updated by Design Center:**

Table 29. USS Library Measurement Configuration Parameters Updated by Design Center

Member	Description	Parameter in Design Center
pulseConfig	Pointer to pulse configuration	See Section 11.3.1
startPPGCount (1)	Time to start PPG Pulse	Start PPG Count
turnOnADCCount (2)	Time to turn on ADC	Turn on ADC Count
startPGAandINBiasCount (3)	Time to start PGA and input biasing	Start PGA and IN Bias Count
startADCsamplingCount (4)	Time to start ADC acquisition	Gap Between Pulse Start and ADC Capture
restartCaptureCount (5)	Time to trigger next capture	UPS and DNS Gap
restartLowPowerCaptureCount (6)	Time to trigger next capture for low-power modes	UPS and DNS Gap

(1) startPPGCount = (Start PPG Count(in seconds) × PLL_Frequency) / 16 where PLL_Frequency = Signal Sampling Frequency × ADC Over Sampling Rate

(2) turnOnADCCount= (Turn on ADC Count (in seconds) × PLL_Frequency) / 16 where PLL_Frequency = Signal Sampling Frequency × ADC Over Sampling Rate

(3) startPGAandINBiasCount = (Start PGA and IN Bias Count (in seconds) × PLL_Frequency) / 16.Where PLL_Frequency = Signal Sampling Frequency × ADC Over Sampling Rate

(4) startADCsamplingCount = startPPGCount + [Gap Between Pulse Start and ADC Capture(in seconds) × PLL_Frequency] / 16.Where PLL_Frequency = Signal Sampling Frequency × ADC Over Sampling Rate

(5) restartCaptureCount = (UPS and DNS Gap(in seconds) × PLL_Frequency) / 256.Where PLL_Frequency = Signal Sampling Frequency × ADC Over Sampling Rate

(6) restartLowPowerCaptureCount = (UPS and DNS Gap (in seconds) × USS_LFXT_FREQ_IN_HZ) where USS_LFXT_FREQ_IN_HZ = 32768

11.3.1 Pulse Configuration Parameters

- **Structure:** USS_Pulse_Configuration
- **Application Definition:** gUssSWConfig.measurementConfig.pulseConfig = ussPulseConfig
- **Parameters updated by Design Center:**

Table 30. USS Library Pulse Configuration Parameters Updated by Design Center

Member	Description	Parameter in Design Center
F1Frequency (1)	Pulse frequency 1	F1
F2Frequency (2)	Pulse frequency 2	F2
pulseGenMode (3)	Pulse generation mode	Pattern Option
pToneConfig (4)	Pointer to tone configuration	Pattern Option

(1) F1Frequency = F1 (in kHz) × 1000
(2) F2Frequency = F2(in kHz) × 1000
(3) pulseGenMode = Pattern Option
(4) If (Pattern Option == Single-tone or Dual-tone), pToneConfig = singDualToneConfig
If (Pattern Option == F1 to F2 Sweep mode), pToneConfig = multiToneConfig

11.3.2 Single-Dual Tone Configuration Parameters

- **Structure:** USS_Pulse_Single_Dual_Tone_Configuration
- **Application Definition:** gUssSWConfig.measurementConfig.pulseConfig.pToneConfig = singDualToneConfig
- **Parameters updated by Design Center:**

Table 31. USS Library Single-Dual Tone Configuration Parameters Updated by Design Center

Member	Description	Parameter in Design Center
numOfF1Cycles (1)	Number of F1 pulses	Pattern Option, Number of Pulses
numOfF2Cycles (2)	Number of F2 pulses	Pattern Option, Number of Pulses

(1) If (Pattern Option == Single-tone), numOfF1Cycles = Number of Pulses
If (Pattern Option == Dual-tone), numOfF1Cycles = Number of Pulses / 2
(2) If (Pattern Option == Dual-tone), numOfF2Cycles = Number of Pulses / 2

11.3.3 Multi-Tone Configuration Parameters

- **Structure:** USS_Pulse_Multitone_Configuration
- **Application Definition:** gUssSWConfig.measurementConfig.pulseConfig.pToneConfig = multiToneConfig
- **Parameters updated by Design Center:**

Table 32. USS Library Multi Tone Configuration Parameters Updated by Design Center

Member	Description	Parameter in Design Center
numOfTrillcycles (1)	Number of trill cycles	Pattern Option, Number of Pulses

(1) If (Pattern Option == F2 Sweep), numOfTrillcycles =Number of Pulses / 2

11.4 PLL Configuration Parameters

- **Structure:** USS_HSPLL_Configuration
- **Application Definition:** gUssSWConfig.pllConfiguration = ussPLLConfig
- **Parameters updated by Design Center:**

Table 33. USS Library PLL Configuration Parameters

Member	Description	Parameter in Design Center
pllXtalFreq_inKHz (1)	PLL crystal frequency	USSXT
pllOutputFreq (2)	PLL output frequency	Signal Sampling Frequency, ADC Over Sampling Rate
ussXTALsettlingCount (3)	The number of LFXT cycles to allow USS XT to settle	USS XTAL Settling Count

(1) pllXtalFreq_inKHz = USSXT
(2) pllOutputFreq = [Signal Sampling Frequency (in Hertz) × ADC Over Sampling Rate] / 1000000
(3) ussXTALsettlingCount = [USS XTAL Settling Count (in sec) × LFXTFrequency] + 0.5 where LFXTFrequency = 32768 Hz

11.5 Capture Configuration

- **Structure:** USS_Capture_Configuration
- **Application Definition:** gUssSWConfig.captureConfig = ussCaptureConfig
- **Parameters updated by Design Center:**

Table 34. USS Library Capture Configuration Parameters Updated by Design Center

Member	Description	Parameter in Design Center
overSampleRate (1)	Oversampling rate	ADC Over Sampling Rate
sampleSize (2)	Number of samples per capture	Capture Duration, Signal Sampling Frequency
gainRange (3)	PGA range	Gain Control

(1) overSampleRate = ADC Over Sampling Rate with possible values of 10, 20, 40, 80, or 160
(2) sampleSize = Capture Duration (in seconds) × Signal Sampling Frequency (in Hz)
(3) gainRange = Gain Control

11.6 Trigger Configuration

- **Structure:** USS_Trigger_Configuration
- **Application Definition:** gUssSWConfig.triggerConfig = ussTriggerConfig
- **Parameters updated by Design Center:** None

11.7 Algorithms Configuration

- **Structure:** USS_Algorithms_User_Configuration
- **Application Definition:** gUssSWConfig.algorithmsConfig = ussAlgConfig
- **Parameters updated by Design Center:**

Table 35. USS Library Algorithms Configuration Parameters Updated by Design Center

Member	Description	Parameter in Design Center
ADCAdditionalCaptureDelay (1)	Additional time during firing and capturing data	Abs TOF Additional Delay
algorithmOption (2)	Selects the gas metrology algorithm option	Algorithm Option
pAlgorithmUserConfig (3)	Pointer to user configuration of Algorithm	See Table 36

(1) ADCAdditionalCaptureDelay = Abs TOF Additional Delay (in seconds)
(2) algorithmOption = Algorithm Option with possible values of 82 for algorithm 2 and 85 for algorithm 5
(3) pAlgorithmUserConfig = ussAlgGasConfig for gas metering

11.7.1 Gas Algorithms User Configuration Parameters

- **Structure:** USS_Algorithms_Gas_User_Configuration
- **Application Definition:** gUssSWConfig.algorithmsConfig.ussAlgConfig = ussAlgGasConfig
- **Parameters updated by Design Center:**

Table 36. USS Library Gas Algorithms User Configuration Parameters Updated by Design Center

Member	Description	Parameter in Design Center
dcOffset (1)	Delta time of flight offset	Delta TOF Offset
envCrossThreshold (2)	Selects the gas metrology algorithm option	Envelope Crossing Threshold
negSearchRange (3)	Adjusts the maximum negative index to search across correlation value of UPS/DNS and TX pulse for matching signal	Negative Range Abs ToF
posSearchRange (4)	Adjusts the maximum positive index to search across correlation value of UPS/DNS and TX pulse for matching signal	Positive Range Abs ToF

(1) dcOffset = Deta TOF Offset (in seconds)
(2) envCrossThreshold = Envelope Crossing Threshold
(3) negSearchRange = Negative Range Abs ToF (in seconds)
(4) posSearchRange = Positive Range Abs ToF (in seconds)

11.8 Interrupt Configuration

- **Structure:** USS_Interrupt_Configuration
- **Application Definition:** gUssSWConfig.interruptConfig = ussInterruptConfig
- **Parameters updated by Design Center:** None

12 USS Library Documentation

The USS Library documentation can be found at <INSTALL_DIR>\USSLib-ApiGuide.html. It documents all the APIs available to the user.

13 Terminology

AbsTOF	absolute time of flight
dTOF	delta (differential) time of flight
DNS	downstream
DNS0	previous downstream pulse
DNS1	next downstream pulse
MCU	microcontroller
PGA	programmable gain amplifier
TOF	time of flight
UPS	upstream
UPS0	previous upstream pulse
UPS1	next upstream pulse
USS	ultrasonic sensing
XTAL	crystal

14 References

1. Quick Start Guide for MSP430FR6043-Based Ultrasonic Gas Flow Meter
2. EVM430-FR6043 Hardware Guide
3. Application Software (SW) Architecture for MSP430FR6043-Based Ultrasonic Gas Flow Meter User's Guide

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