User's Guide
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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 water flow measurements.

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1 Design Center Introduction

Thank you for using the MSP430FR6047 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 water flow measurements.

2 Getting Started

2.1 Loading The Ultrasonic Sensing Design Center Example Project to the EVM430-FR6047

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 supports the MSP430™ MCU. The project developed for download has been tested with CCS and IAR.

Download CCSv6.2 or later (CCS-FREE) with support for the MSP430FR6047.

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 clicking on the TI Resource Explorer under the View drop-down menu. If not using CCS, make sure 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+ to be installed on the machine. If not already installed, the latest can be downloaded from the Java website.

2.3 GUI Launch

The Design Center is a graphical user interface (GUI) for the USS module of the MSP430FR6047 and is used to configure the application and USS library and to view the results. After installation, run USS.exe to open 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.

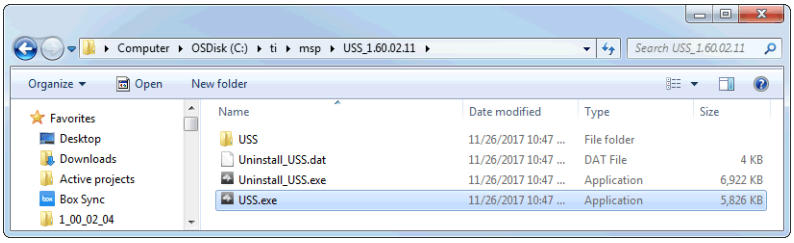

Figure 1. USS Design Center GUI Executable

Figure 2 shows the default screen of the GUI.

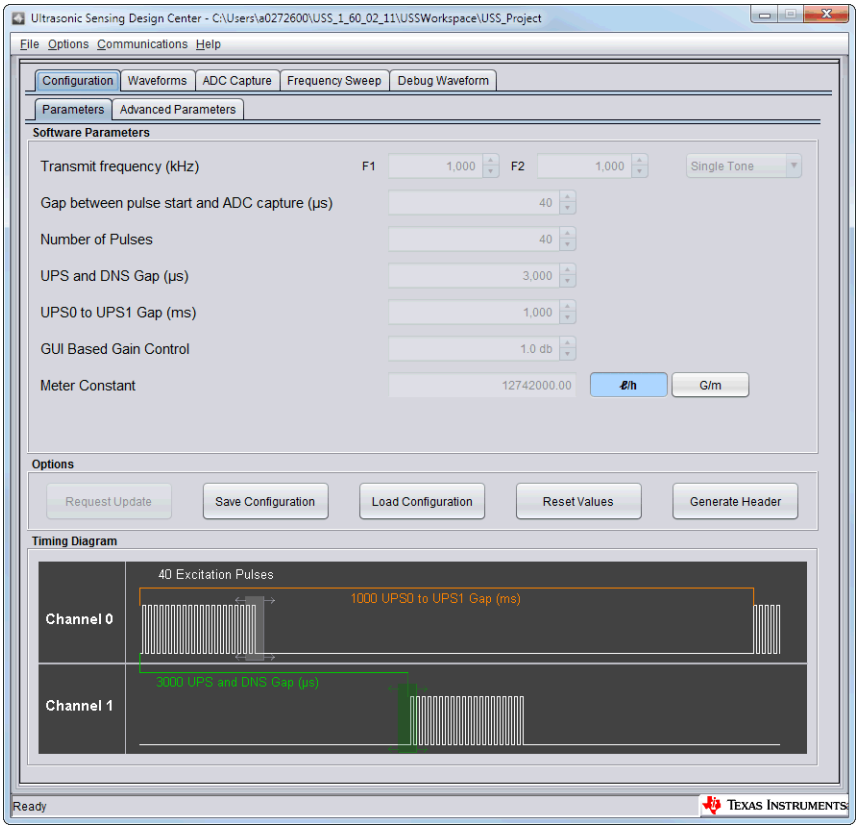

Figure 2. USS Design Center

3 Design Center Configuration Tab

3.1 Communicating With the MSP430FR6047 on the EVM430-FR6047

To confirm or start connection with the EVM430-FR6047, select *Connect* under the *Communications* drop-down option on the Design Center ribbon (see Figure 3) or press the F1 key. To disconnect, select *Disconnect* under the *Communications* drop-down option on the Design Center ribbon (see Figure 3) or press the F2 key .

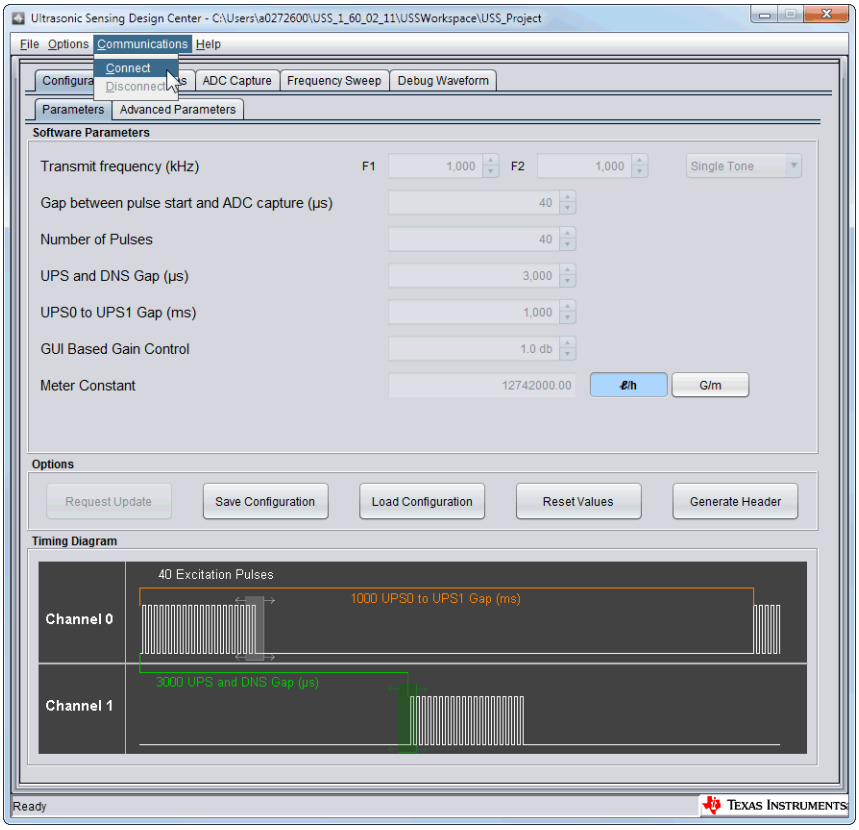

Figure 3. Connect to MSP430FR6047 on the EVM430-FR6047

After connecting to the target EVM430-FR6047, the Design Center displays *HID connected to MSP430FR6047 on Evaluation Module* at the bottom of the GUI (see Figure 4).

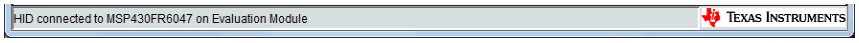

Figure 4. Confirmed Connection

The main configuration screen and the additional parameters screen are shown in Figure 5 and Figure 6. Details on these parameters and what are valid configurations can be found in Section 10 and Section 11.

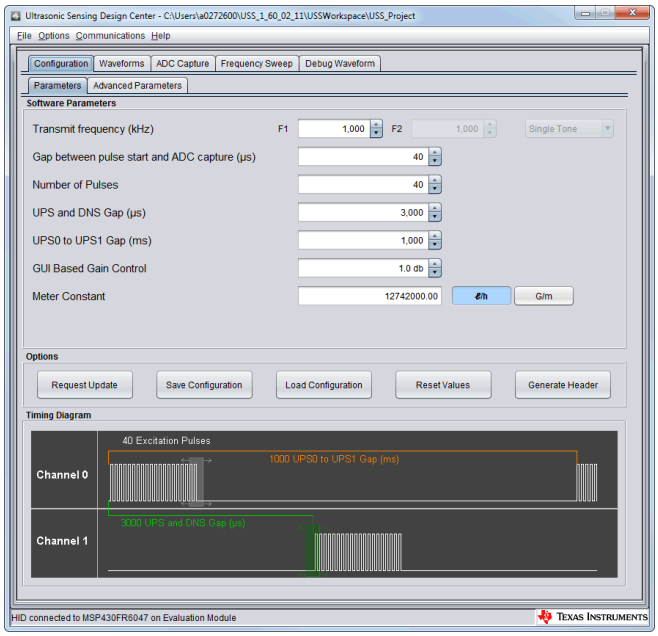

Figure 5. Design Center Input Parameters

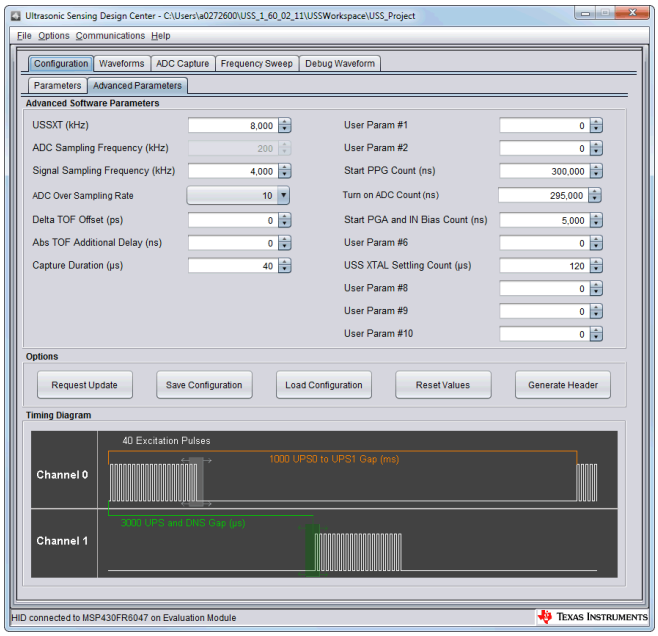

Figure 6. Design Center Input Advanced Parameters

3.2 Loading a Configuration

An existing meter configuration can be loaded using the “Load Configuration” button in the main tab as seen in Figure 7. Some example configurations are available in USS SW Library "example" directory.

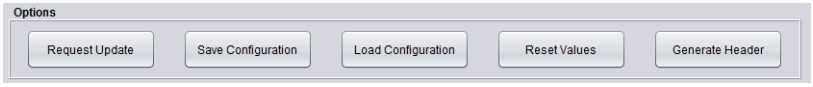

Figure 7. Design Center Configuration Option Buttons

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

3.3 Saving a Configuration

To save the parameters in the configuration tabs for later use, select the *Save Configuration* button in the main tab (see Figure 7).

Navigate to the desired location in the file system to save the configuration file and click *Save*.

3.4 Sending Configuration Parameters to MSP430 Device

The meter parameters in the configuration tabs are transmitted to the MSP430 device using the *Request Update* button in the main tab (see Figure 7).

3.5 Generating Source Code Header Files

To generate source files that can be integrated to a CCS or IAR project, select the *Generate Header* button in the main tab. These files determine the default configuration of the device.

4 Understanding the Design Center Waveforms Tab

The Waveforms tab shows 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 8).

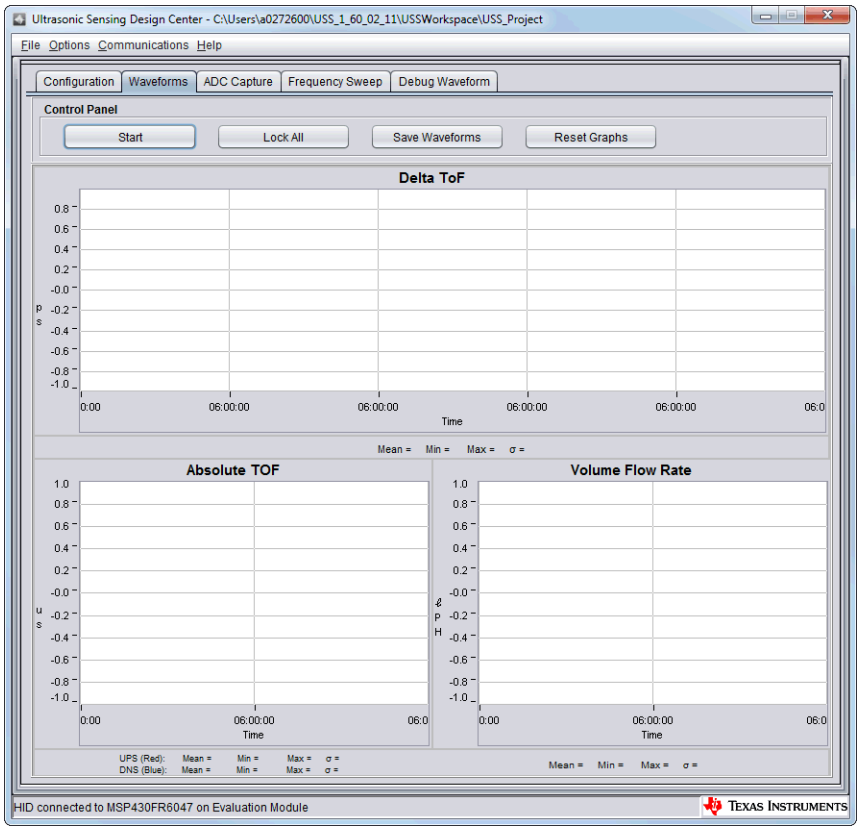

Figure 8. Waveforms Tab

When the start button is pressed, waveforms should begin to show up on each of the three graphs as shown in Figure 9. To Zoom in, click down with the right button on the mouse and drag from top left to bottom right. To Zoom out, click down with 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 click *Save*.

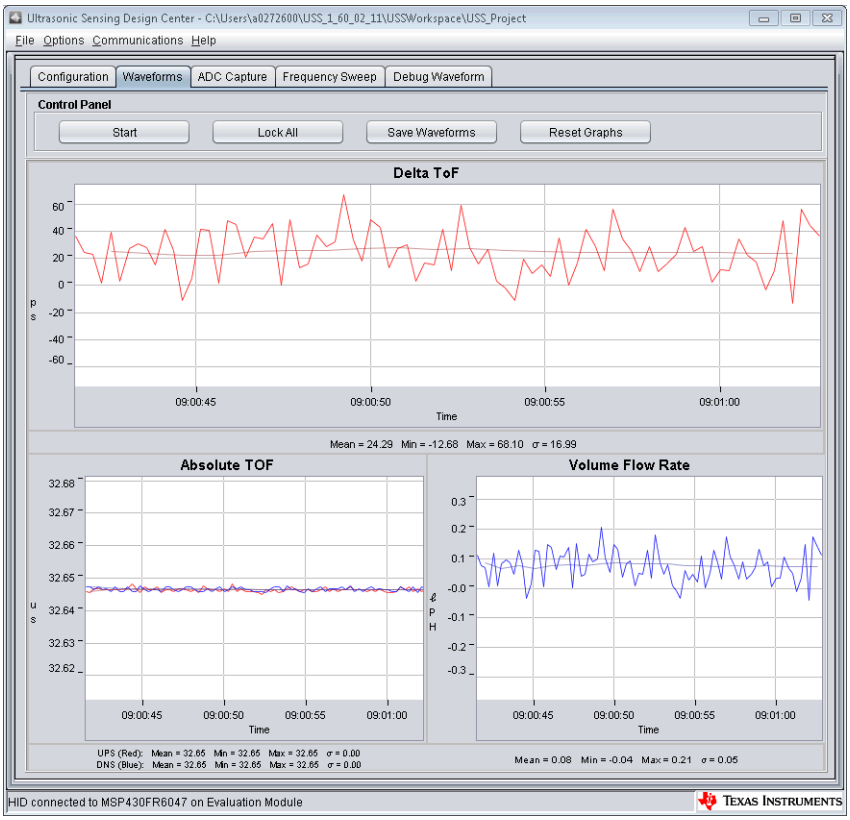

Figure 9. Waveforms Tab Running

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* (see Figure 10).

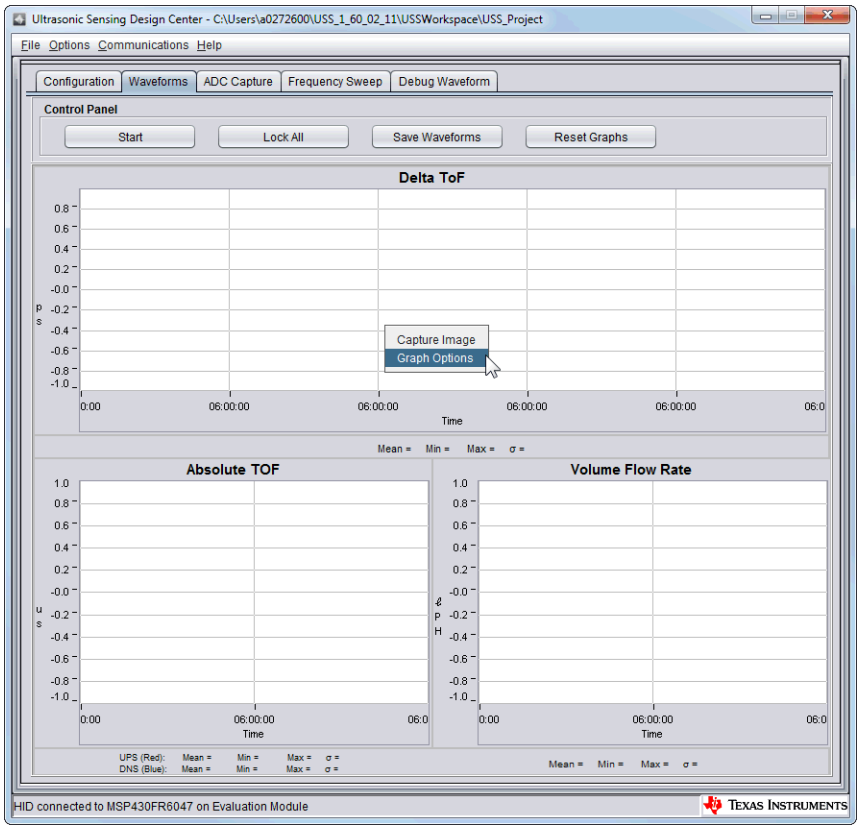

Figure 10. Right Click on Waveforms

Use the Graph Options window (see Figure 11) to edit the viewing options of the graphs and the number of samples used to calculate the statistics.

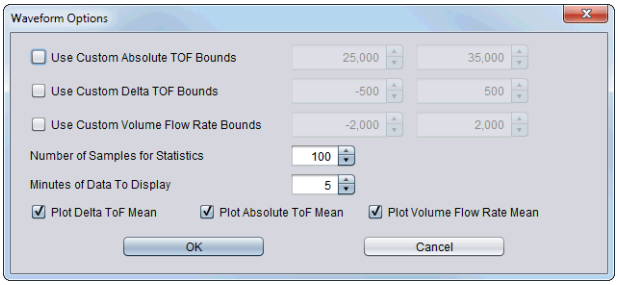

Figure 11. Graph Options Menu

5 Understanding the Design Center ADC Capture Tab

The ADC Capture tab shows a single USS ADC capture.

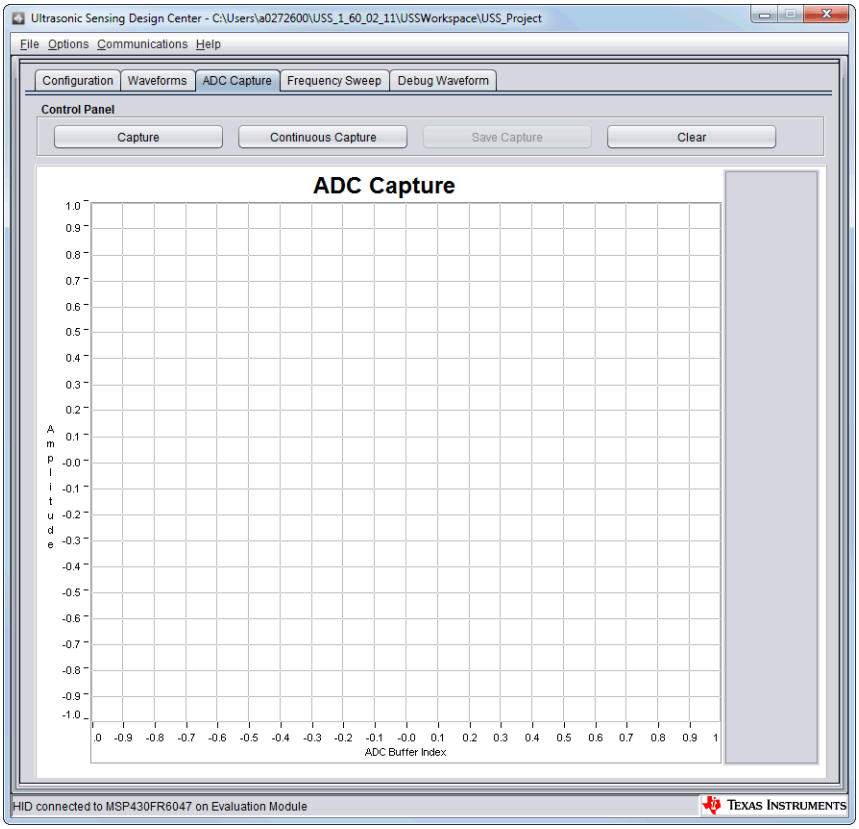

Figure 12. ADC Capture Tab

Pressing the 'Capture' Button takes the capture of the ADC waveform and the GUI will plot it on the graph. An example is shown in Figure 13. To zoom in, click down with the right button on the mouse and drag from top left to bottom right. To zoom out, click down with 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 click *Save*.

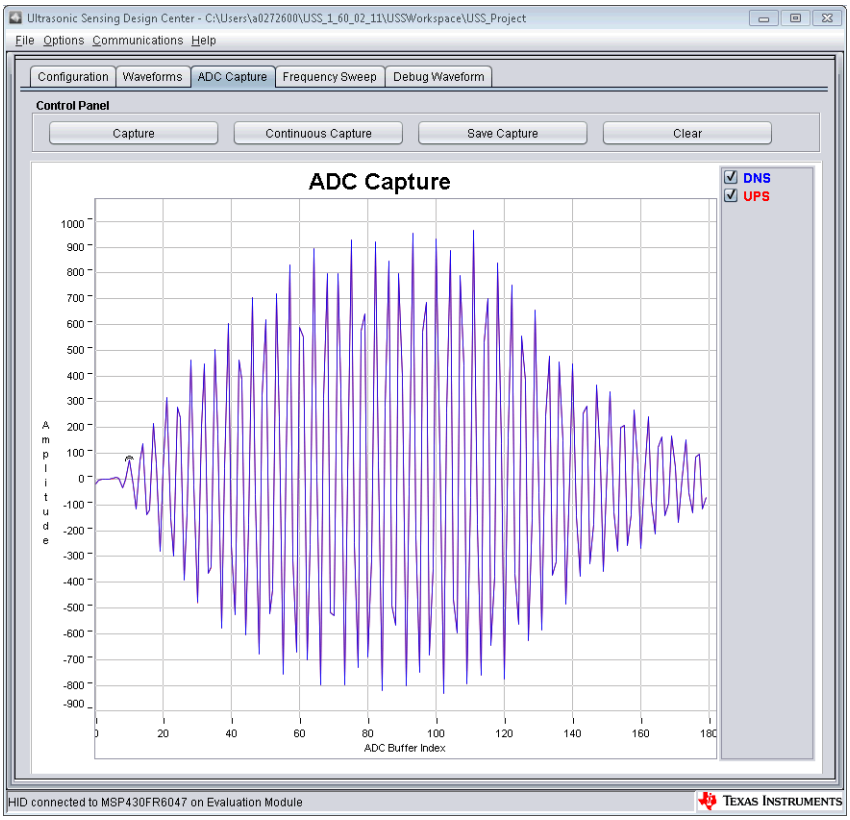

Figure 13. Single ADC Capture

5.1 Using Continuous Capture

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

6 Understanding the Design Center Frequency Sweep Tab

The Frequency Sweep Tab of the Design Center, shown in Figure 14, allows the user to 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 in which to sweep. Click the *Frequency Sweep* button, navigate to the desired location in the file system where the frequency sweep data should be saved, and click *Save*.

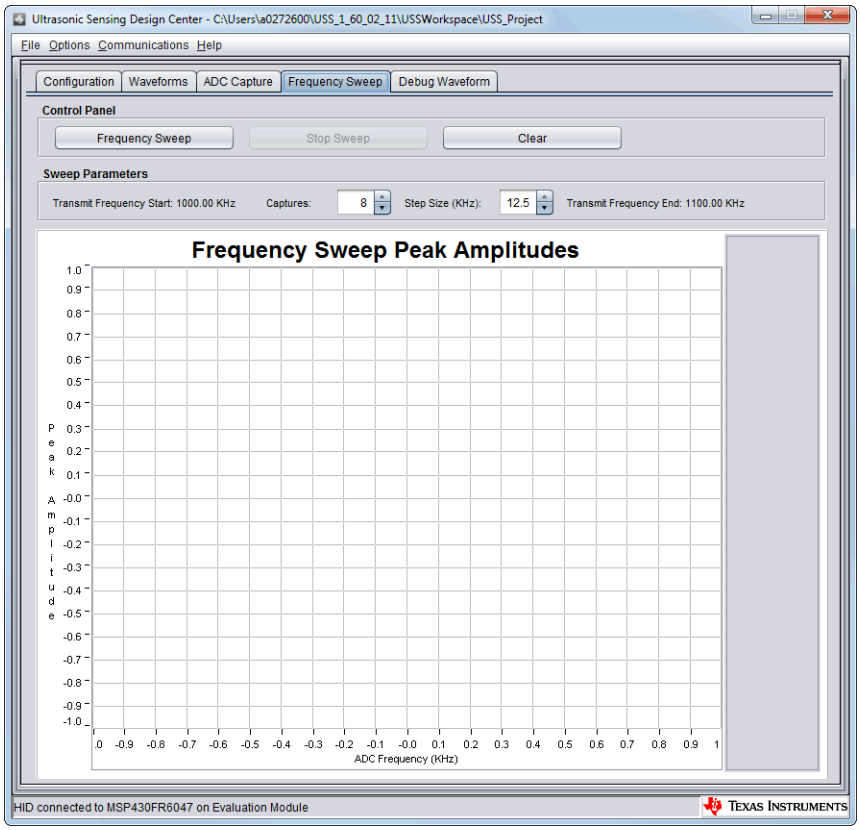

Figure 14. Frequency Sweep Tab

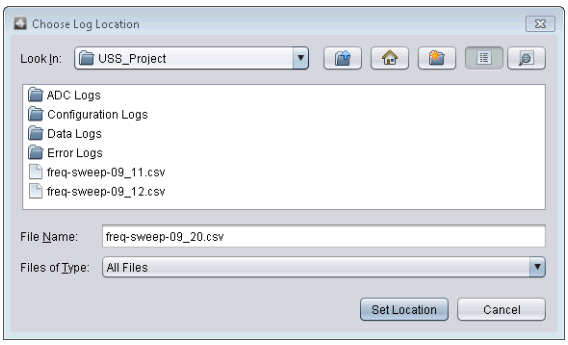

Figure 15. Save Frequency Sweep Location

The Frequency Sweep tool helps to determine at which transducer excitation frequency the ADC capture achieves the maximum amplitude. The frequency at which the peak amplitude is reached should be used as the new F1 parameter to achieve the strongest signal for the meter configuration. For the example in Figure 16, a value in the range of 920 to 1000 should be placed into the F1 parameter.

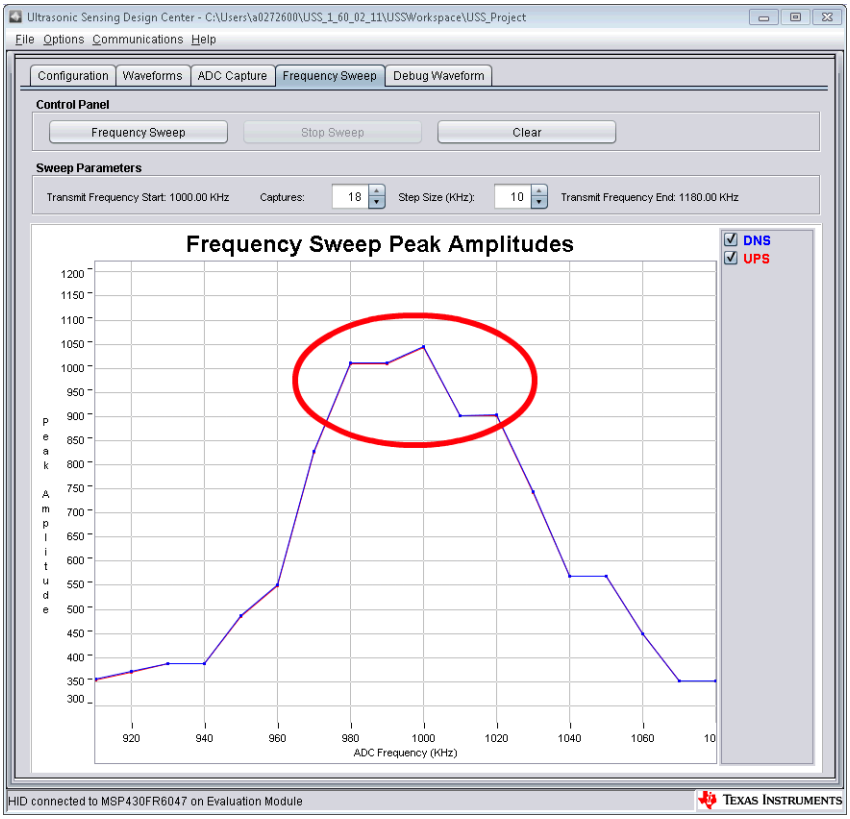

Figure 16. Frequency Sweep Showing Max Amplitude

7 Understanding the Design Center Debug Tab

The Debug tab shown in Figure 17 gives the user the ability to plot any data they may wish to view. To plot data on the graph simply navigate to the 'HMI_PostAlgorithm_Update' routine and modify the function 'CommandHandler_transmittDebugData(txPacket, (float)<your Data Here>)' to include the data in which you want to plot in the parameter. Make sure the function is un-commented. Rebuild, flash, and run the code then view the debug plot for the custom data.

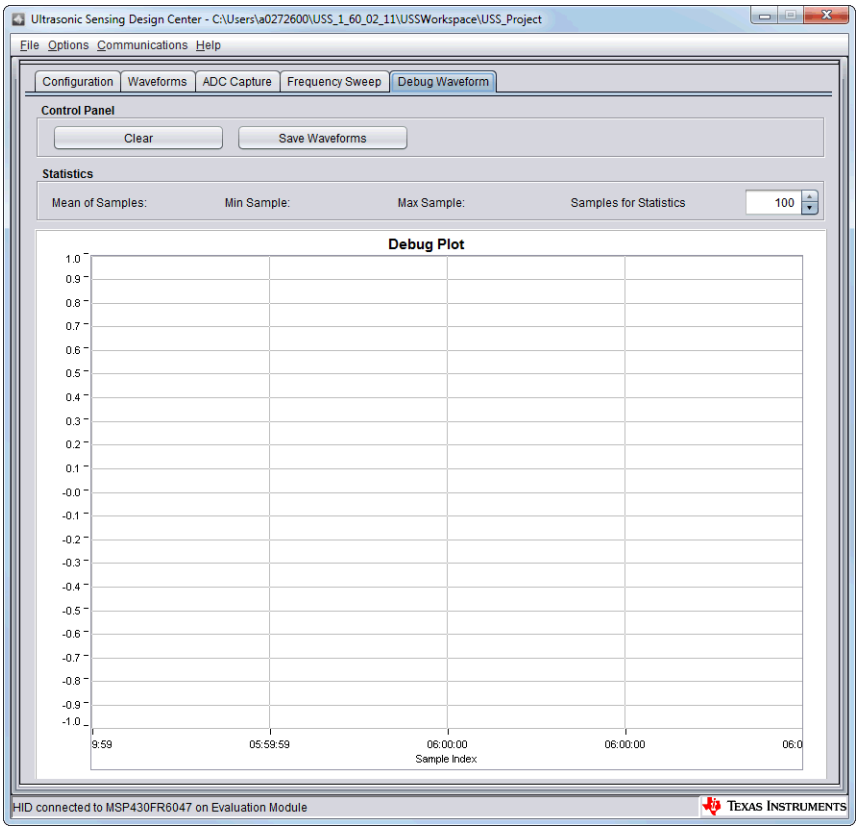

Figure 17. Debug Tab

8 Understanding the Design Center Errors Tab

The Design Center Errors tab shown in Figure 18 allows the user to view in detail any USS Lib errors that occur during a configuration of the library, measurement, or an algorithms update. There are eight different error types, each of which corresponds to a different type of error in USSLib. The error types are SAPH, HSPLL, SDHS, UUPS, Stop Error, Algorithm, ISTOP, Calibration, and Generic. For example, the following errors are caused by the transducer not being properly connected to the EVM.

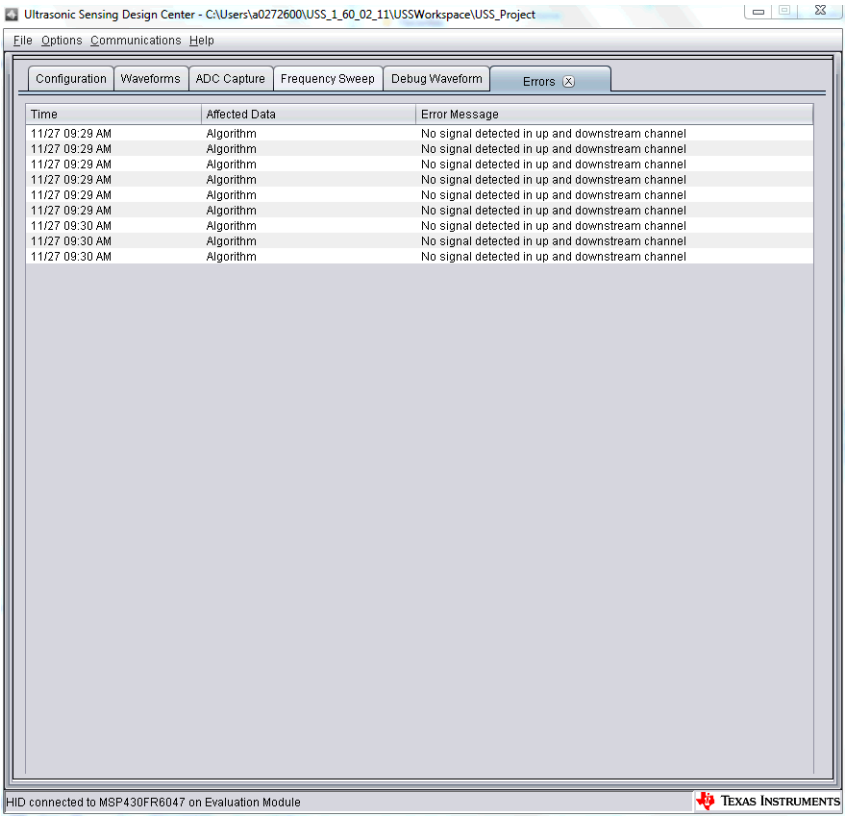

Figure 18. Errors Tab

9 Using The LCD

The LCD screen on the EVM430-FR6047 can be used when running the application without the GUI [(1)].

The LCD screen is disabled by default. To enable the LCD screen, press the top button on the EVM430-FR6047. To scroll between the enabled statistics, press the left and right buttons. The available statistics are:

- Delta TOF
- Average Delta TOF
- Standard Deviation Delta TOF
- Flow Rate in Liters/Hour or Gallons/Minute
- Average Flow Rate in Liters/Hour or Gallons/Minute
- Volume in Liters or Gallons
- Date and Time (currently disabled)
- Temperature (currently disabled)
- Battery Voltage

Press the middle button to continuously scroll through the enabled statistics on the LCD. Press the middle button again to return to viewing a single statistic.

(1) The LCD screen on the EVM430-FR6047 can also be used when running the application with the GUI. However, the LCD routines can disrupt communication between the device and the GUI, and the timing between captures. These disruptions affect the data displayed on the GUI.

10 Design Center Parameters

Table 1 describes the parameters available in the Design Center. Each parameter maps to a member of the Command Handler data structure (see Section 12).

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
F2	N/A for water applications
Pattern	N/A for water applications
Gap between pulse start and ADC capture: (µs)	The value represents 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)	Crystal frequency. This is fixed at 8 MHz, as TI does not specify performance at another frequency.
ADC Sampling Frequency (kHz)	N/A for water applications
Signal Sampling Frequency (kHz)	Sampling frequency in kHz
ADC Over Sampling Rate	Over-sampling rate of ADC
Delta TOF Offset (ps)	Delta time of flight offset (entered in ps)
Abs TOF Additional Delay (ns)	Additional capture delay (entered in ns)
Capture Duration (µs)	Duration of samples
User Param #1	Reserved
User Param #2	Reserved
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 the PGA and input biasing in ns
User Param #6	Reserved
USS XTAL Settling Count (µs)	Settling time for USSXT in µs
User Param #8	Reserved
User Param #9	Reserved
User Param #10	Reserved

11 Detailed Description of Design Center Parameters

The following tables describe each parameter available in the Design Center. Each parameter also maps to one or more of the USS Library data structures (see Section 12). The Range column of each table lists the values that have been tested.

11.1 F1

Table 2 lists the details of the F1 parameter.

Table 2. Details for F1

Parameter	Description	Command Handler Struct	USS Library Struct And Members		Range	Example
F1	Pulse output frequency	transFreq1	meterConfig	transducerFreq	772 kHz to 2.5 MHz	F1 = 1000

11.2 F2

Table 3 lists the details of the F2 parameter.

Table 3. Details for F2

Parameter	Description	Command Handler Struct	USS Library Struct And Members		Range	Example
F2	N/A for water applications	transFreq2	N/A for water applications	N/A for water applications	N/A for water applications	N/A for water applications

11.3 Pattern Option

Table 4 lists the details of the Pattern Option parameter.

Table 4. Details for Pattern Option

Parameter	Description	Command Handler Struct	USS Library Struct And Members		Range	Example
Pattern Option	N/A for water applications	patternOption	N/A for water applications	N/A for water applications	N/A for water applications	Single tone

11.4 Gap Between Pulse Start and ADC Capture (µs)

Table 5 lists the details of the Gap Between Pulse Start and ADC Capture parameter.

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

Parameter	Description	Command Handler Struct	USS Library Struct And Members		Range	Example
Gap between pulse start and ADC capture (µs)	The time in µs to start ADC acquisition from PPG pulse	gap_pls_adc_start	measurementConfig	startADCsamplingCount	3 to 9000	62

11.5 Number of Pulses

Table 6 lists the details of the Number of Pulses parameter.

Table 6. Details for the Number of Pulses

Parameter	Description	Command Handler Struct	USS Library Struct And Members		Range	Example
Number of Pulses	Number of excitation pulses	num_pls	measurementConfig	numOfExcitationPulses	0 to 63	20

11.6 UPS and DNS Gap (µs)

Table 7 lists the details of the UPS and DNS Gap parameter.

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

Parameter	Description	Command Handler Struct	USS Library Struct And Members		Range	Example
UPS and DNS Gap (µs)	Time between captures in a sequence (that is, from upstream to downstream)	gap_ups_dns	measurementConfig	restartCaptureCount	100 to 9000	3000

NOTE: UPS and DNS Gap + UPS0 to UPS1 Gap must be greater than 20.1 ms.

11.7 UPS0 to UPS1 Gap (ms)

Table 8 lists the details of the UPS0 to UPS1 Gap parameter.

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

Parameter	Description	Command Handler Struct	USS Library Struct And Members		Range	Example
UPS0 to UPS1 Gap (ms)	Time between sequences of captures (that is, from previous captures upstream pulse to next captures upstream pulse)	gap_ups_ups	See (1)	See (1)	20 to 2000	100

(1) Currently the USS Lib application implements the UPS0 to UPS1 parameter as a delay routing between captures. This is better described as DNS0 to UPS1, or the previous captures downstream pulse to the next captures upstream pulse. In a future versions of the application, this will be a true UPS0 to UPS1 delay.

NOTE: UPS and DNS Gap + UPS0 to UPS1 Gap must be greater than 20.1 ms.

11.8 GUI Based Gain Control

Table 9 lists the details of the GUI Based Gain Control parameter.

Table 9. Details for GUI Based Gain Control

Parameter	Description	Command Handler Struct	USS Library Struct And Members		Range	Example
GUI Based Gain Control	PGA gain value to register	gain_control	captureConfig	gainRange	–6.5 dB to 30.8 dB	1.4 dB

11.9 Meter Constant

Table 10 lists the details of the Meter Constant parameter.

Table 10. Details for Meter Constant

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

11.10 USSXT (kHz)

Table 11 lists the details of the USSXT parameter.

Table 11. Details for USSXT (kHz)

Parameter	Description	Command Handler Struct	USS Library Struct And Members		Range	Example
USSXT (kHz)	Crystal frequency. This should be fixed to 8 MHz as TI does not specify performance at any other frequency	ussxt_freq	measurementConfig	startADCsamplingCount	8000	8000
				restartCaptureCount		
				restartLowPowerCaptureCount		
			pllConfiguration	pllXtalFreq_inKHz		

11.11 ADC Sampling Frequency (kHz)

Table 12 lists the details of the ADC Sampling Frequency parameter.

Table 12. Details for ADC Sampling Frequency (kHz)

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

11.12 Signal Sampling Frequency (kHz)

Table 13 lists the details of the Signal Sampling Frequency parameter.

Table 13. Details for Signal Sampling Frequency (kHz)

Parameter	Description	Command Handler Struct	USS Library Struct And Members		Range	Example
Signal Sampling Frequency (kHz)	Sampling frequency in kHz	sig_samp_freq	measurementConfig	pulseLowPhasePeriod	3400 to 8000, where sampling frequency = PLL frequency / oversampling rate. PLL frequency = 68 MHz to 80 MHz, and oversampling rate = 10, 20, 40, 80, or 160}	4000
				pulseHighPhasePeriod		
				startPPGCount		
				turnOnADCCount		
				startPGAandINBiasCount		
				startADCsamplingCount		
				restartCaptureCount		
				restartLowPowerCaptureCount		
			pllConfiguration	pllOutputFreq		
			captureConfig	sampleSize		

11.13 ADC Oversampling Rate

Table 14 lists the details of the ADC Oversampling Rate parameter.

Table 14. Details for ADC Oversampling Rate

Parameter	Description	Command Handler Struct	USS Library Struct And Members		Range	Example
ADC Over Sampling Rate	Over-sampling Rate of ADC	over_sampling_rate	measurementConfig	pulseLowPhasePeriod	10, 20, 40, 80, or 160	20
				pulseHighPhasePeriod		
				startPPGCount		
				turnOnADCCount		
				startPGAandINBiasCount		
				startADCsamplingCount		
				restartCaptureCount		
				restartLowPowerCaptureCount		
			pllConfiguration	pllOutputFreq		
			captureConfig	overSampleRate		

11.14 Delta TOF Offset (ps)

Table 15 lists the details of the Delta TOF Offset parameter.

Table 15. Details for Delta TOF Offset (ps)

Parameter	Description	Command Handler Struct	USS Library Struct And Members		Range	Example
Delta TOF Offset (ps)	Delta Time of Flight offset (entered in ps)	delta_tof_offset	algorithmsConfig	DcOffset		0

11.15 Abs TOF Additional Delay (ns)

Table 16 lists the details of the Abs TOF Additional Delay parameter.

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

Parameter	Description	Command Handler Struct	USS Library Struct And Members		Range	Example
Abs TOF Additional Delay (ns)	Additional Capture delay (entered in ns)	abs_tof_additional	algorithmsConfig	ADCAdditionalCaptureDelay		0

11.16 Capture Duration (µs)

Table 17 lists the details of the Capture Duration parameter.

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	40

11.17 User Param #1

Table 18 lists the details of the Details for User Param #1 parameter.

Table 18. Details for User Param #1

Parameter	Description	Command Handler Struct	USS Library Struct And Members		Range	Example
User Param #1	Reserved	user_param1	Reserved	Reserved	–2000000000 to 2000000000	0

11.18 User Param #2

Table 19 lists the details of the User Param #2 parameter.

Table 19. Details for User Param #2

Parameter	Description	Command Handler Struct	USS Library Struct And Members		Range	Example
User Param #2	Reserved	user_param2	Reserved	Reserved	–2000000000 to 2000000000	0

11.19 Start PPG Count (ns)

Table 20 lists the details of the Start PPG Count parameter.

Table 20. Details for Start PPG Count (ns)

Parameter	Description	Command Handler Struct	USS Library Struct And Members		Range	Example
Start PPG Count (ns)	Time to start PPG Pulse trigger in ns	param3_comp_option_start_ppg	measurementConfig	startPPGCount	0 to 10^6	300000

11.20 Turn on ADC Count (ns)

Table 21 lists the details of the Turn on ADC Count parameter.

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

Parameter	Description	Command Handler Struct	USS Library Struct And Members		Range	Example
Turn on ADC Count (ns)	Time to turn ON the ADC in ns	param4_env_crossing_turn_on_adc	measurementConfig	turnOnADCCount	0 to 10^6	295000

11.21 Sart PGA and IN Bias Count (ns)

Table 22 lists the details of the Sart PGA and IN Bias Count parameter.

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

Parameter	Description	Command Handler Struct	USS Library Struct And Members		Range	Example
Sart PGA and IN Bias Count (ns)	Time to turn the PGA and Input biasing in ns	param5_start_pga_in_bias	measurementConfig	startPGAandINBiasCount	0 to 10^6	5000

11.22 User Param #6

Table 23 lists the details of the User Param #6 parameter.

Table 23. Details for User Param #6

Parameter	Description	Command Handler Struct	USS Library Struct And Members		Range	Example
User Param #6	Reserved	user_param6	Reserved	Reserved	–2000000000 to 2000000000	0

11.23 USS XTAL Settling Count (ns)

Table 24 lists the details of the USS XTAL Settling Count parameter.

Table 24. Details for USS XTAL Settling Count (ns)

Parameter	Description	Command Handler Struct	USS Library Struct And Members		Range	Example
USS XTAL Settling Count (ns)	N/A	param7_uss_xtal_settling_count	pllConfiguration	ussXTALsettling Count		120

11.24 User Param #8

Table 25 lists the details of the User Param #8 parameter.

Table 25. Details for User Param #8

Parameter	Description	Command Handler Struct	USS Library Struct And Members		Range	Example
User Param #8	Reserved	user_param8	Reserved	Reserved	–2000000000 to 2000000000	0

11.25 User Param #9

Table 26 lists the details of the User Param #9 parameter.

Table 26. Details for User Param #9

Parameter	Description	Command Handler Struct	USS Library Struct And Members		Range	Example
User Param #9	Reserved	user_param9	Reserved	Reserved	–2000000000 to 2000000000	0

11.26 User Param #10

Table 27 lists the details of the User Param #10 parameter.

Table 27. Details for User Param #10

Parameter	Description	Command Handler Struct	USS Library Struct And Members		Range	Example
User Param #10	Reserved	user_param10	Reserved	Reserved	–2000000000 to 2000000000	0

12 USS Library Parameters

The following sections describe the USS Library and which library members are updated with the Design Center GUI. In addition, it will show which Design Center parameters are used in updating each of the USS library members. For more details on the USS Library, see the USS Software Library User's Guide.

12.1 System Configuration Parameters

- **Structure:** USS_SW_Library_configuration
- **Application Definition:** gUssSWConfig.systemConfig=ussSystemConfig

Table 28. USS Library System Configuration Parameters

Member	Description	Modifiable In Design Center
mCLKkFrequency	System (MCLK) Clock Frequency in Hz	No
LFXTFrequency	LF crystal frequency in Hz	No
timerBaseAddress	Base address of timer used for delays	No
diagMode	Enables diagnostic modes	No

12.2 Meter Configuration Parameters

- **Structure:** USS_Meter_Configuration
- **Application Definition:** gUssSWConfig.meterConfig=ussMeterConfig

Table 29. USS Library Meter Configuration Parameters

Member	Description	Modifiable In Design Center (By Which Command Handler Struct)
volumeScaleFactor(1)	Volume scale factor	Yes (meter_constant)
acousticLength	Acoustic length in us at room temperature	No
transducerFreq(1)	Transducer Frequency in Hz	Yes (transFreq1)

(1) See Section 13 for detailed calculations.

12.3 Measurement Configuration Parameters

- **Structure:** USS_Measurement_Configuration
- **Application Definition:** gUssSWConfig.measurementConfig = ussMeasurementConfig

Table 30. USS Library Measurement Configuration Parameters

Member	Description	Modifiable In Design Center (By Which Command Handler Struct)
sequenceSelection	USS capture sequence	No
eofSequenceState	End of sequence state	No
ch0DriveStrength	Strength for CH0	No
ch1DriveStrength	Strength for CH1	No
pauseState	State before and after pulse generation	No
pulsePolarity	Polarity of pulse	No
ulpBiasDelay	ULP bias delay during USS Power up.	No
biasImpedance	Control RX/TX bias impedance during acquisition sequence.	No
muxChargePumpMode	Control the PGA input multiplexer during capture sequence.	No
pulseLowPhasePeriod(1)	Low period of generated pulse frequency	Yes (sig_samp_freq, over_sampling_rate)
pulseHighPhasePeriod(1)	High period of generated pulse frequency	Yes (sig_samp_freq, over_sampling_rate)
numOfExcitationPulses(1)	Number of pulses	Yes (num_pls)
numOfStopPulses	Number of stop pulses	No
startPPGCount(1)	Time to start PPG Pulse	Yes (sig_samp_freq, over_sampling_rate, param3_comp_option_start_ppg)
turnOnADCCount(1)	Time to turn on ADC	Yes (sig_samp_freq, over_sampling_rate, param4_env_crossing_turn_on_adc)
startPGAandINBiasCount(1)	Time to start PGA and input biasing	Yes (sig_samp_freq, over_sampling_rate, param5_start_ppg_in_bias)
startADCsamplingCount(1)	Time to start ADC acquisition	Yes (sig_samp_freq, over_sampling_rate, gap_pls_adc_start, ussxt_freq)
restartCaptureCount(1)	Time to trigger next capture	Yes (sig_samp_freq, over_sampling_rate, gap_ups_dns, ussxt_freq)
restartLowPowerCaptureCount(1)	Time to trigger next capture for low power modes	Yes (sig_samp_freq, over_sampling_rate, gap_ups_dns, ussxt_freq)

(1) See Section 13 for detailed calculations.

Table 30. USS Library Measurement Configuration Parameters (continued)

Member	Description	Modifiable In Design Center (By Which Command Handler Struct)
captureTimeOutCount	Time from start to ACK of data complete	No

12.4 PLL Configuration Parameters

- **Structure:** USS_HSPLL_Configuration
- **Application Definition:** gUssSWConfig.pllConfiguration=ussPLLConfig

Table 31. USS Library PLL Configuration Parameters

Member	Description	Modifiable In Design Center (By Which Command Handler Struct)
pllXtalFreq_inKHz(1)	PLL crystal frequency	Yes (ussxt_freq)
HSPLLInputCLKType	PLL Input clock type	No
pllOutputFreq(1)	PLL Output frequency	Yes (sig_samp_freq, over_sampling_rate)
outputPLLXtal	true = outputs HSPLL crystal , false = does not outputs HSPLL crystal	No
hspllTolerance	PLL variance tolerance	No
ussXTALsettlingCount(1)	Specifies the number of LFXT cycles needed to allow USS XT to settle.	Yes (param7_uss_xtal_settling_count)

(1) See Section 13 for detailed calculations.

12.5 Capture Configuration

- **Structure:** USS_Capture_Configuration
- **Application Definition:** gUssSWConfig.captureConfig=ussCaptureConfig

Table 32. USS Library Capture Configuration Parameters

Member	Description	Modifiable In Design Center (By Which Command Handler Struct)
overSampleRate(1)	Oversampling rate	Yes (over_sampling_rate)
sampleSize(1)	Number of samples per capture	Yes (capture_duration, sig_samp_freq)
gainRange(1)	PGA range	Yes (gain_control)
enableWindowHiComp	Enables high window comparator	No
enableWindowLoComp	Enables low window comparator	No
windowHighThreshold	Threshold for high window comparator	No
windowLowThreshold	Threshold for low window comparator	No
mismatchDeltaValues	Mismatch delta values	No
delta1	Mismatch correction value for ±2	No
delta2	Mismatch correction value for ±1	No
agcConstant	Gain amplifier setting	No
pCapturesBuffer	Pointer to LEA memory buffer	No
pAccCapturesBuffer	Pointer to LEA buffer for capture accumulation	No
maxCapture	Maximum capture size	No
isCapAccumulationEnabled	Enables sample accumulation	No

(1) See Section 13 for detailed calculations.

12.6 Trigger Configuration

- **Structure:** USS_Trigger_Configuration
- **Application Definition:** gUssSWConfig.triggerConfig=ussTriggerConfig

Table 33. USS Library Trigger Configuration Parameters

Member	Description	Modifiable In Design Center
triggerConfig	Trigger configuration	No

12.7 Algorithms Configuration

- **Structure:** USS_Algorithms_User_Configuration
- **Application Definition:** gUssSWConfig.algorithmsConfig=ussAlgConfig

Table 34. USS Library Algorithms Configuration Parameters

Member	Description	Modifiable In Design Center (By Which Command Handler Struct)
absTOFInterval	Interval to calculate time of flight	No
numSamplesPerCycle	Number of samples in one cycle	No
ADCSamplePeriod	ADC sampling period ($1/f_s$)	No
ADCStartCaptureInstant	Time from start of pulse and ADC capture	No
ADCAdditionalCaptureDelay(1)	Additional time during firing and capturing data	Yes (abs_tof_additional)
volumeScaleFactor	Volume scale factor	No
DcOffset(1)	Constant calibrated at zero flow	Yes (delta_tof_offset)
ratioOfTrackLobeToPeak	Ratio of side lobe closest to threshold and peak lobe amplitudes	No
NumPulsesBeforeThreshold	Number of pulses before selected threshold	No
EnableWindowing	Enables windowing	No
SignalValueThresholdCheck	Signal value check parameter which has to be crossed for valid signal	No
numCycleSearchCorrPeak	Number of cycles to search for correlation peak before setting overrun	No
searchLobeSampleSteps	Number of samples to increment/decrement while searching side lobe	No
maxRatioPeak2PeakVariation	Maximum ratio of allowed P2P variation from one measurement to another	No
WinStartIndexBackOffNumCycles	Number of cycles to back off from start of received pulse	No
WinTrapzRampOverNumCycles	Number of cycles over which the trapezoid window should ramp	No
CorrValueThresholdCheckFactor	Factor of maximum lobe energy which has to be crossed for valid correlation	No
isInitAlgorithms	Indicates if the algorithms need to be initialized	No
calibratedDCOffsetUPS	Constant subtracted to UPS captures.	No
calibratedDCOffsetDNS	Constant subtracted to DNS captures.	No
dtofVolInterval	Interval to calculate dTOF and volume.	No
pNvMemBuffer	Pointer to NVM memory for algorithm computations.	No
pWinCoef	Pointer to LEA memory for window coefficients.	No
highFlowOption	If true, enables high flow rates > 5GPM	No
cycleSlipThreshold	Threshold for cycle slip when using high flow mode.	No
thresholdX1X3	Threshold for X1-X3 coefficients	No
clockRelativeError	Relative error of clock to be corrected for AbsTOF calculation	No
winNumCycles(1)	Controls window length when windowing is enabled	Yes (num_pls)
enableFilter	Enable signal filtering before running algorithms	No
filterCoeffs	Pointer to filter coefficients	No
filterLength	Length of filter	No

(1) See Section 13 for detailed calculations.

12.8 Interrupt Configuration

- **Structure:** USS_Interrupt_Configuration
- **Application Definition:** gUssSWConfig.interruptConfig=ussInterruptConfig

Table 35. USS Library Interrupt Configuration Parameters

Member	Description	Modifiable In Design Center
enableUUPSPREQIGInterrupt	Enables PREQIQ interrupt	No
enableSAPHPingTransmitDoneInterrupt	Enables SAPH PNGDN interrupt	No

13 USS Library Parameters Detailed Calculations

The following sections highlight how each of the USS Library parameters are calculated with the inputs from the USS Design Center GUI

13.1 volumeScaleFactor

volumeScaleFactor equals meter_constant.

Return to Measurement Configuration Parameters.

13.2 transducerFreq

transducerFreq is calculated by transFreq1 × 1000 (transFreq1 in Hz)

Return to Measurement Configuration Parameters.

13.3 pulseLowPhasePeriod

If the USS ASQ prescalar is disabled, then the pulseLowPhasePeriod is calculated by ((1 – USS_PULSE_DUTYPERCENT) × ((sig_samp_freq (in Hertz) × over_sampling_rate) / transducerFreq)

If the USS ASQ prescaler is enabled, then the pulseLowPhasePeriod is calculated by ((1 – USS_PULSE_DUTYPERCENT) × (((sig_samp_freq (in Hertz) × over_sampling_rate) / 4) / transducerFreq)

Return to Measurement Configuration Parameters.

13.4 pulseHighPhasePeriod

If the USS measurement prescalar is disabled then the pulseLowPhasePeriod is calculated by (USS_PULSE_DUTYPERCENT × ((sig_samp_freq (in Hertz) × over_sampling_rate) / transducerFreq)

If the USS measurement prescalar is enabled then the pulseLowPhasePeriod is calculated by (USS_PULSE_DUTYPERCENT × (((sig_samp_freq (in Hertz) × over_sampling_rate) / 4) / transducerFreq)

Return to Measurement Configuration Parameters.

13.5 numOfExcitationPulses

numOfExcitationPulses equals num_pls.

Return to Measurement Configuration Parameters.

13.6 startPPGCount

startPPGCount is calculated by (param3_comp_option_start_ppg (in seconds) × (sig_samp_freq (in Hertz) × over_sampling_rate)) / 16

Return to Measurement Configuration Parameters.

13.7 turnOnADCCount

turnOnADCCount is calculated by (param4_env_crossing_turn_on_adc (in seconds) × (sig_samp_freq (in Hertz) × over_sampling_rate)) / 16

Return to Measurement Configuration Parameters.

13.8 startPGAandINBiasCount

startPGAandINBiasCount is calculated by (param5_start_ppg_in_bias (in seconds) × (sig_samp_freq (in Hertz) × over_sampling_rate)) / 16

Return to Measurement Configuration Parameters.

13.9 startADCsamplingCount

startADCsamplingCount is calculated by startPPGCount + ((gap_pls_adc_start (in seconds) × ussxt_freq (in Hz))/2)× ((sig_samp_freq (in Hertz) × over_sampling_rate) / 1000000) / (ussxt_freq / 8)

Return to Measurement Configuration Parameters.

13.10 restartCaptureCount

restartCaptureCount is calculated by ((gap_ups_dns (in seconds) × ussxt_freq (in Hz))/2)× ((sig_samp_freq (in Hertz) × over_sampling_rate) / 1000000) / (ussxt_freq / 128)

Return to Measurement Configuration Parameters.

13.11 restartLowPowerCaptureCount

restartLowPowerCaptureCount is calculated by ((gap_ups_dns (in seconds) × ussxt_freq (in Hz))/2)× ((USS_LFXT_FREQ_IN_HZ × 2) / (ussxt_freq)

Return to Measurement Configuration Parameters.

13.12 pllXtalFreq_inKHz

pllXtalFreq_inKHz equals ussxt_freq.

Return to PLL Configuration Parameters.

13.13 pllOutputFreq

pllOutputFreq is calculated by (sig_samp_freq (in Hertz) × over_sampling_rate) / 1000000. The resulting value must be between 68 MHz and 80 MHz.

Return to PLL Configuration Parameters.

13.14 ussXTALsettlingCount

ussXTALsettlingCount is calculated by (param7_uss_xtal_settling_count × LFXTFrequency + 500000) / 1000000

Return to PLL Configuration Parameters.

13.15 overSampleRate

overSampleRate equals over_sampling_rate, with possible values of 10, 20, 40, 80, or 160.

Return to Capture Configuration.

13.16 sampleSize

sampleSize is calculated by capture_duration (in seconds) × sig_samp_freq.

Return to Capture Configuration.

13.17 gainRange

gainRange equals gain_control

Return to Capture Configuration.

13.18 ADCAdditionalCaptureDelay

ADCAdditionalCaptureDelay equals abs_tof_additional.

Return to Capture Configuration.

13.19 DcOffset

DcOffset equals delta_tof_offset.

Return to Capture Configuration.

13.20 winNumCycles

winNumCycles equals num_pls.

Return to Capture Configuration.

14 USS Library Documentation

The USS Library documentation is installed as [INSTALL_DIR]\USSLib-ApiGuide.html.

15 Terminology

- UPS = upstream
- DNS = downstream
- UPS0 = previous upstream pulse
- UPS1 = next upstream pulse
- DNS0 = previous downstream pulse
- DNS1 = next downstream pulse
- MCU = microcontroller
- USS = ultrasonic sensing
- TOF = time of flight

16 References

1. Quick Start Guide for MSP430FR6047-Based Ultrasonic Water Flow Meter
2. EVM430-FR6047 Hardware Guide
3. Application Software (SW) Architecture for MSP430FR6047-Based Ultrasonic Water Flow Meter
4. MSP430FR6047 and Ultrasonic Software Based Water Flow Meter Measurement Results

Revision History

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

Changes from February 3, 2018 to March 5, 2018 **Page**

- Changed from "less than" to "greater than" in the note "UPS and DNS Gap + UPS0 to UPS1 Gap must be greater than 20.1 ms." in Section 11.6, *UPS and DNS Gap (µs)* 19
- Changed from "less than" to "greater than" in the note "UPS and DNS Gap + UPS0 to UPS1 Gap must be greater than 20.1 ms." in Section 11.7, *UPS0 to UPS1 Gap (ms)* 19

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