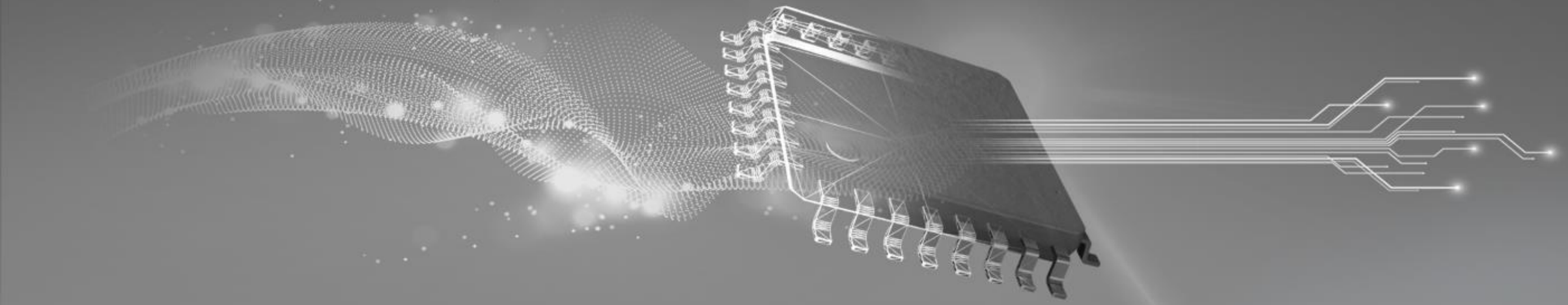
TI TECH DAYS



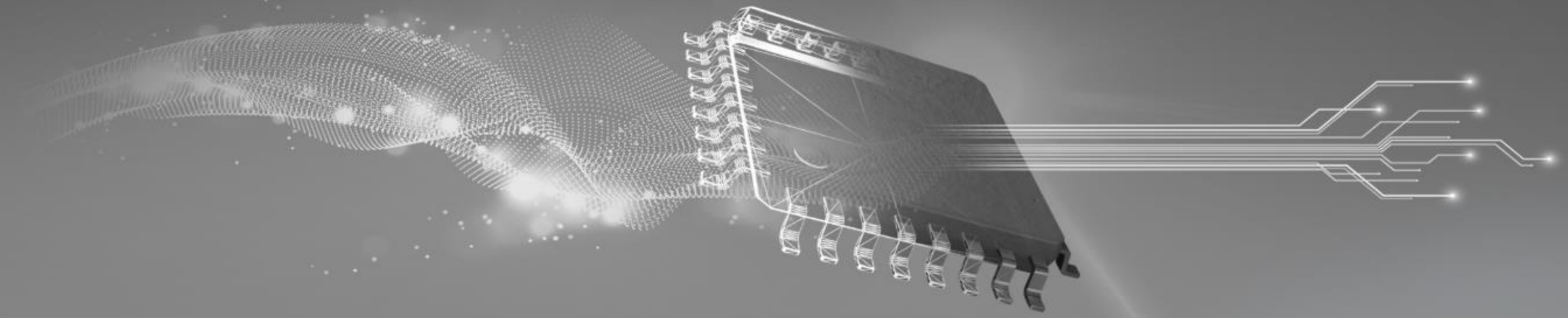
Designing in emerging applications: Ultrasonic sensing and capacitive touch

Presenters:

Leo Estevez – MSP430 Applications

Dennis Lehman – MSP430 Applications

TI TECH DAYS



Ultrasonic Liquid Level Sensing

Presenter: Leo Estevez – MSP430 Applications

Agenda

TI’s Solution

Test fixtures

Transducers

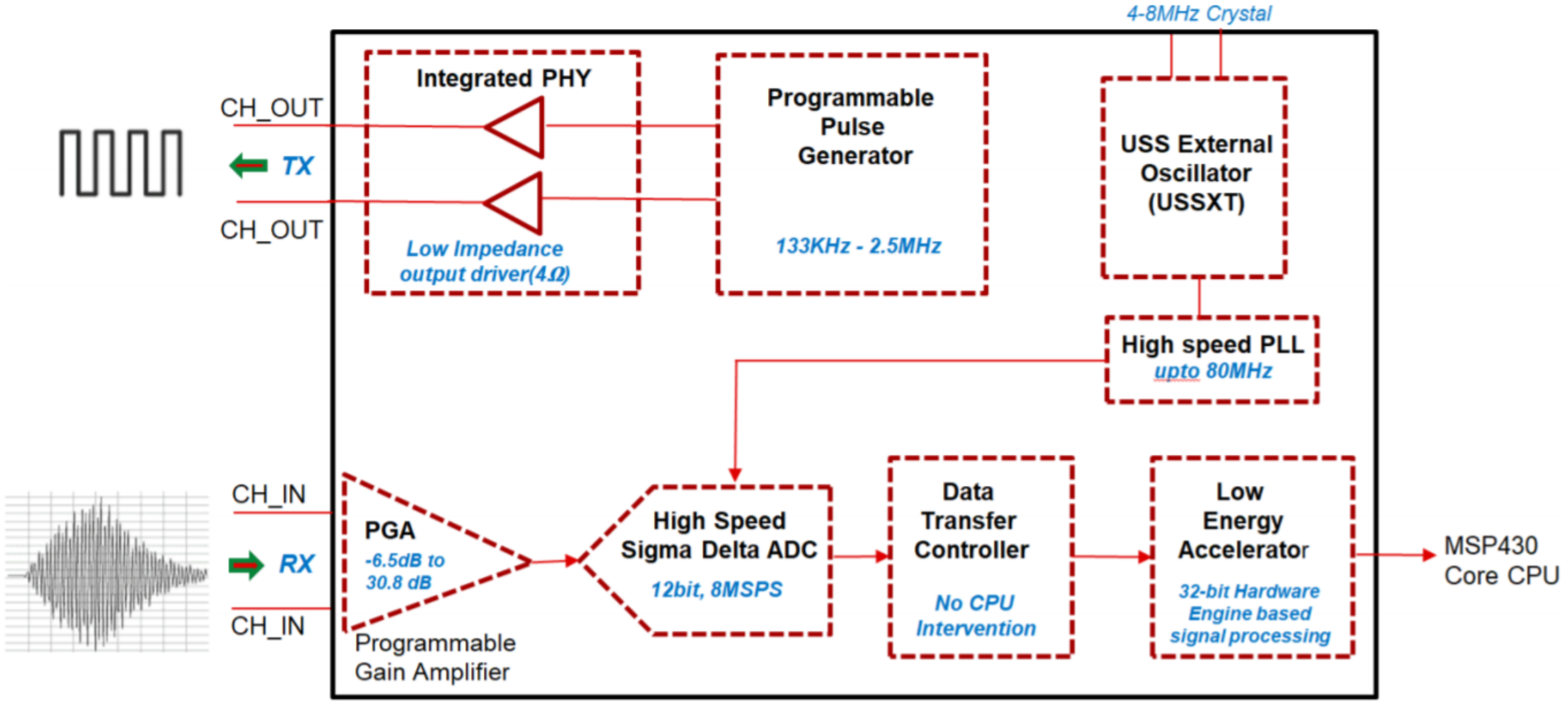
Adverse operating conditions

Additional applications and demo

Technology/Cost comparisons

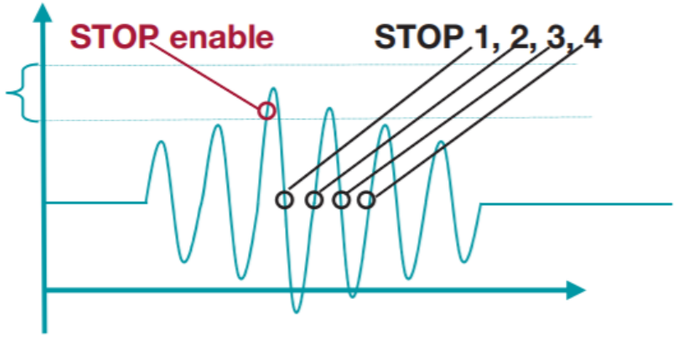
- In liquid sensors are prone to corrosion/mechanical failure and can’t work with arbitrary containers. (drink dispensers, coffee machines, etc.)
- The additional cost of a transducer can be 50 cents(in high volumes).
  - The transducer can often be fit directly into the chassis of the tank or machine and doesn’t require modification to the container itself.
- Ultrasonic level sensing enables resolutions**(~20 microns)** which could enable feedback for flow control while dispensing fluid from a container(or to a container).
- Average current consumption is **<20uA** per measurement per second.

TI's ultrasonic sensing solution (MSP43FR604x)



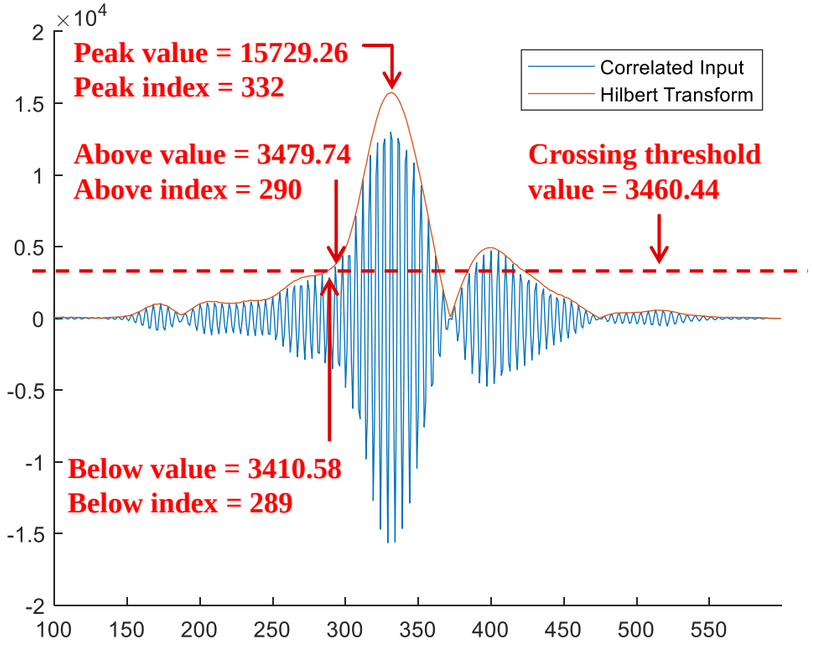
ADC based correlation vs. TDC zero crossing

TDC Zero-Crossing (Amplitude Dependent)



1. Stop timer when threshold exceeded.
2. Find subsequent zero crossings.

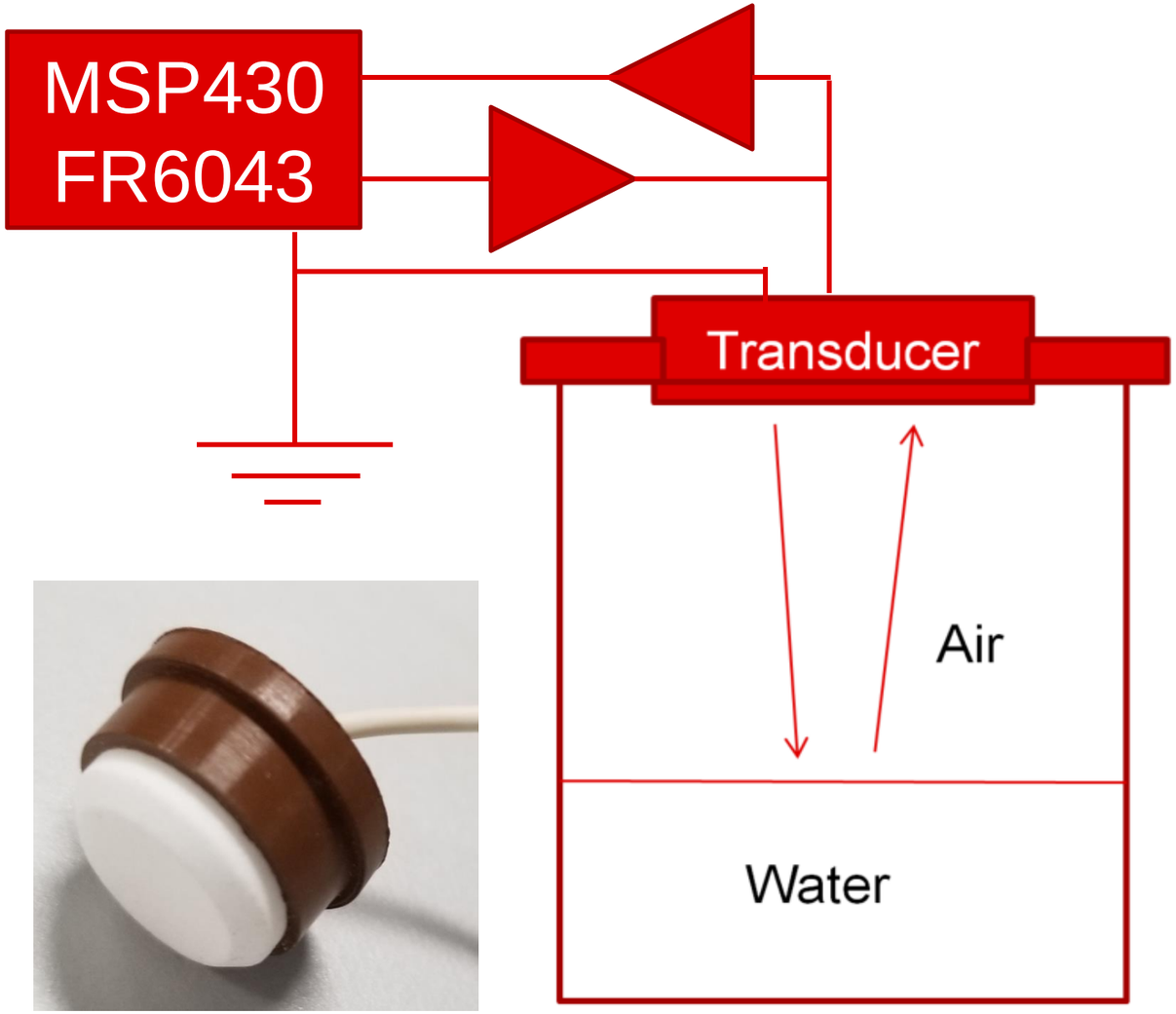
ADC Based Correlation (Amplitude Independent)

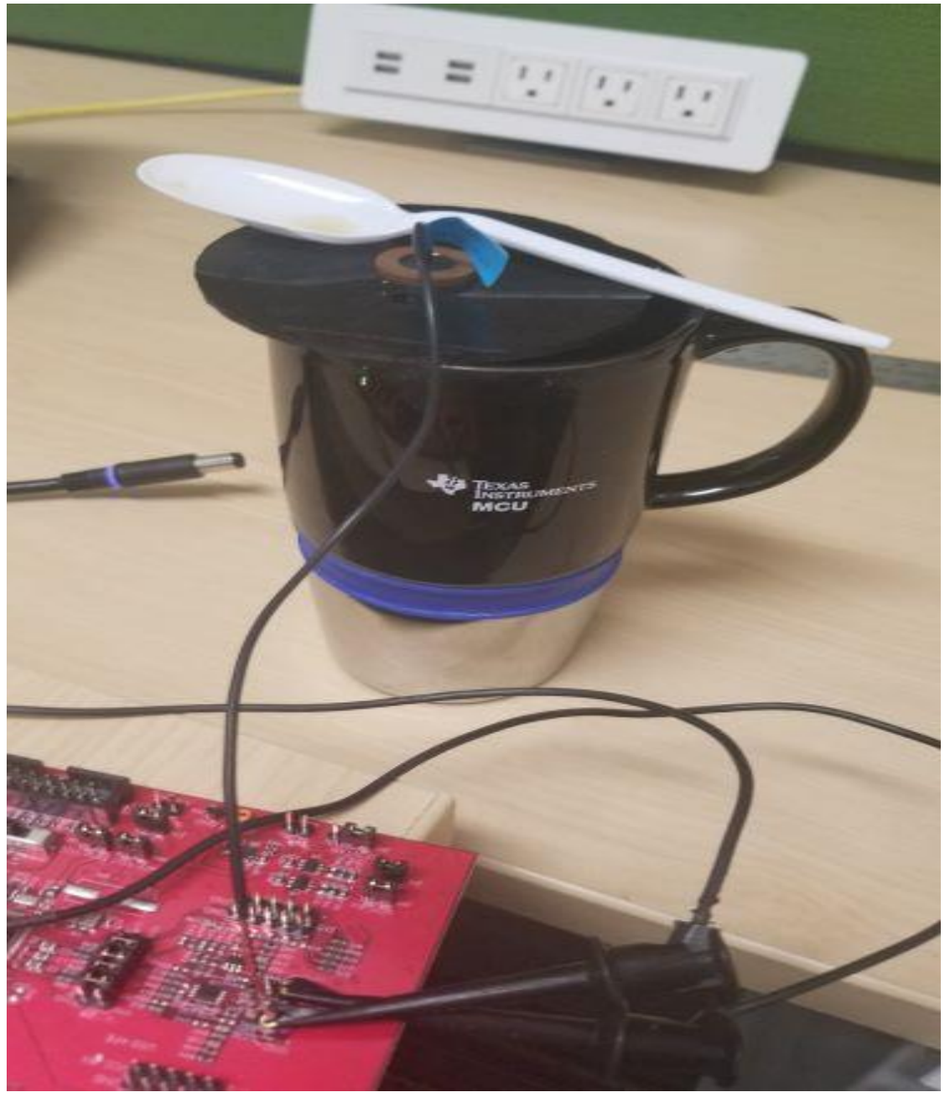


1. Perform full correlation of input with binary transmit pattern
2. Compute Hilbert transform
3. Find envelope peak value and index
4. Calculate threshold using the peak value
5. Interpolate to find threshold crossing.

6

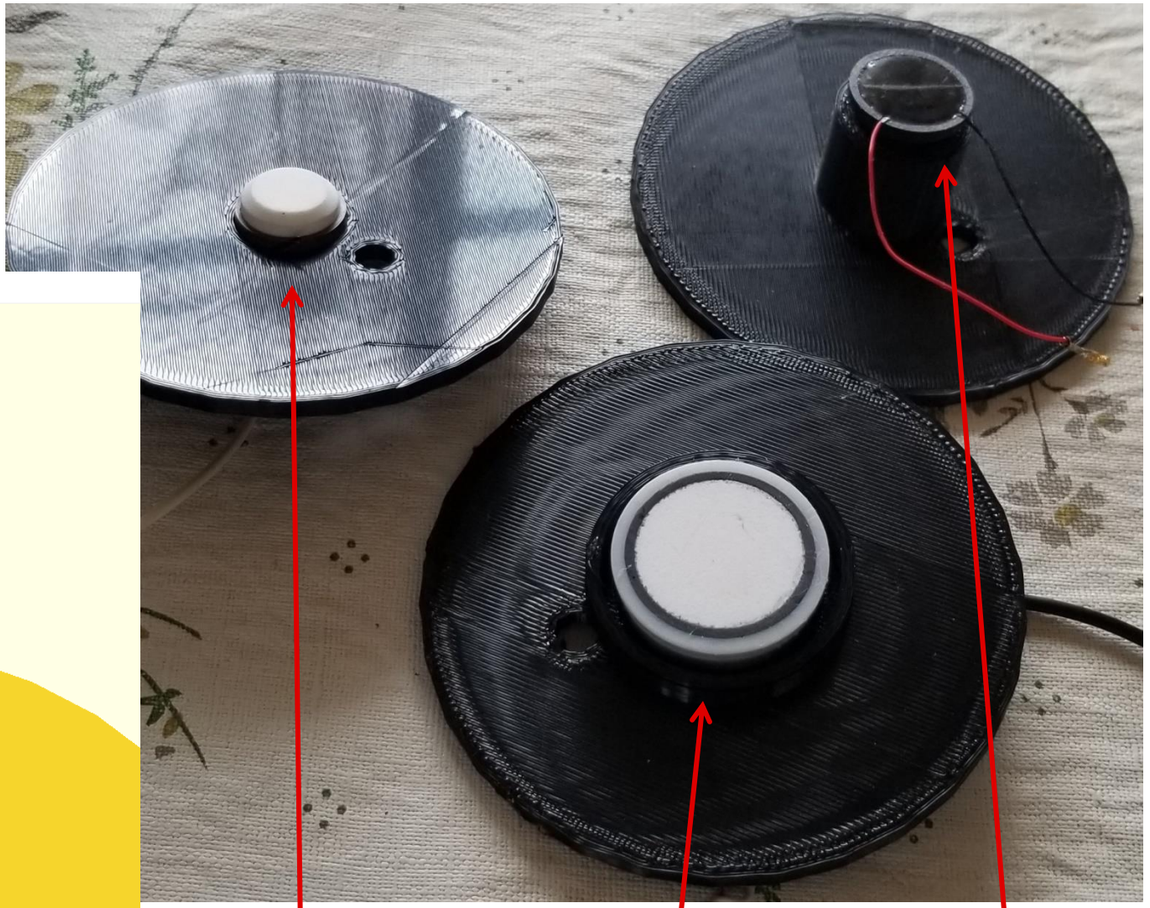
Ultrasonic configuration





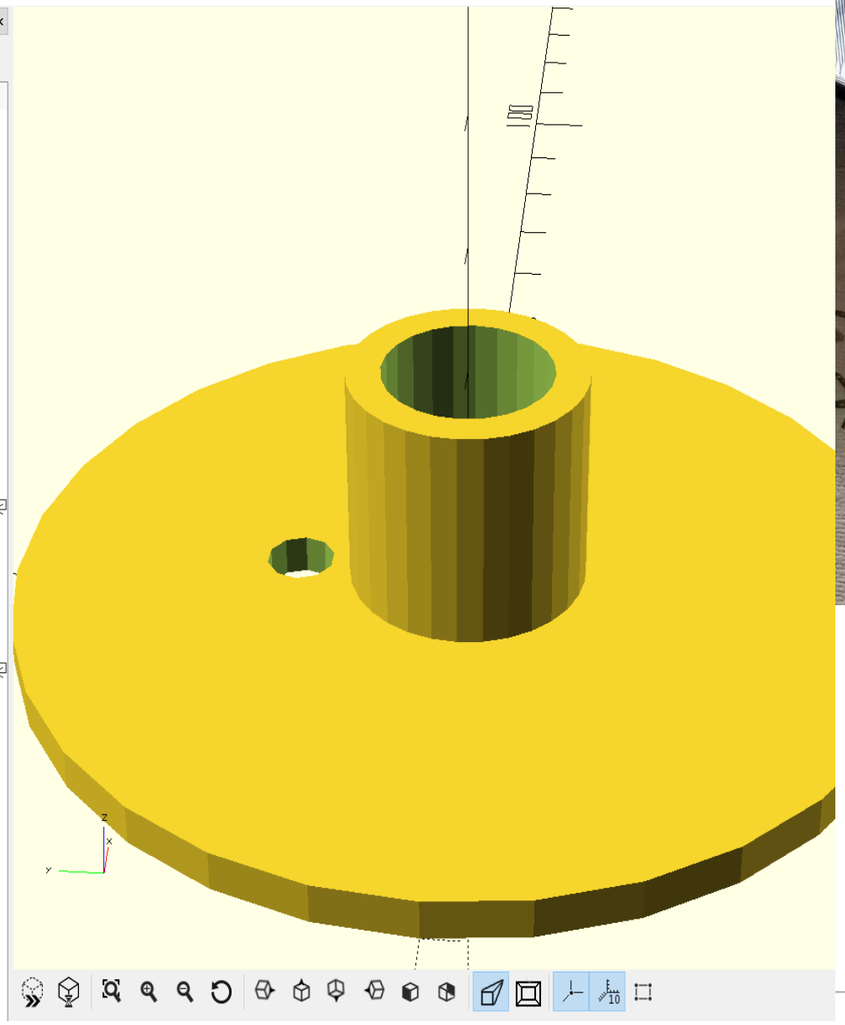
http://www.ti.com/lit/an/slaa951a/slaa951a.pdf

OpenSCAD test fixtures



200kHz 175kHz 500kHz

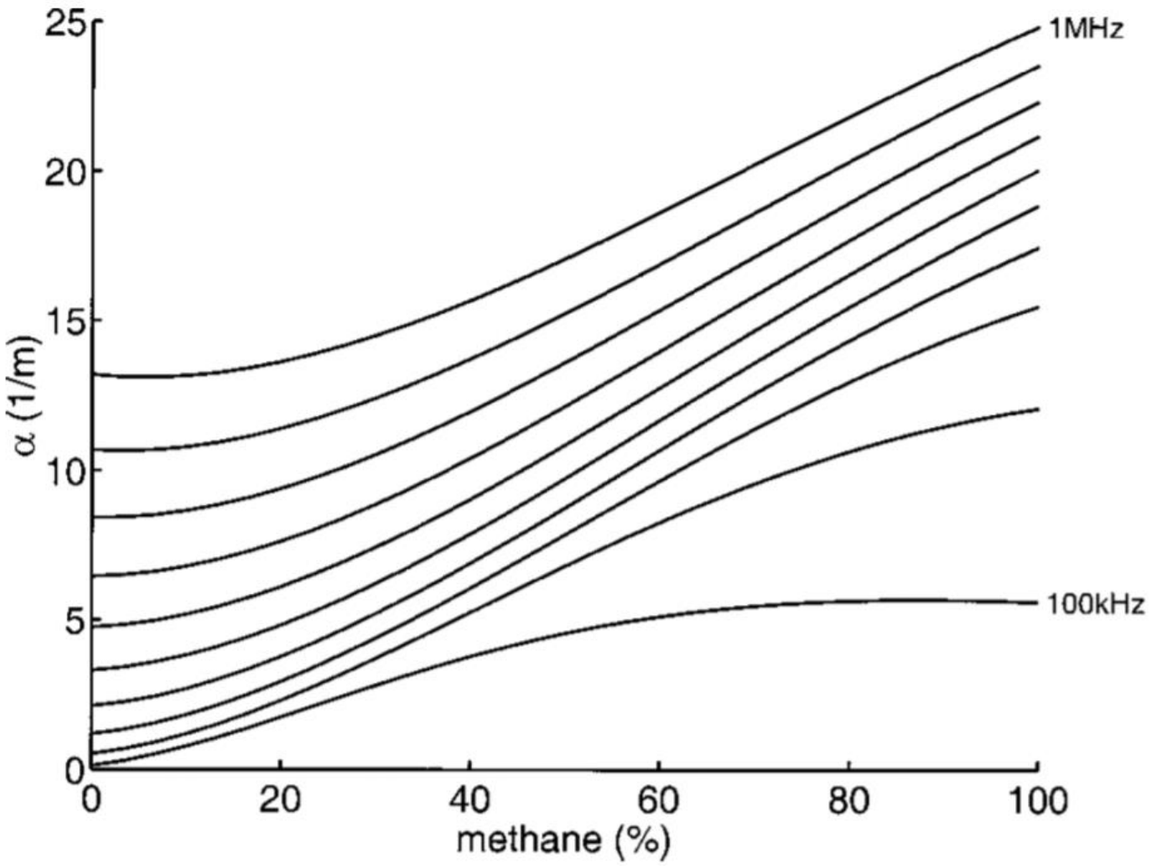
```
File Edit Design View Help
Editor
TRANSDUCER_RADIUS=7.5;
HOLE_RADIUS=3;
LID_RADIUS=40;
LID_LENGTH=3;
CYLINDER_LENGTH=20;


difference(){
    union(){
        translate ([0, 0, 0])
        rotate([0, 0, 0])
        cylinder (h = LID_LENGTH, r = LID_RADIUS);

        translate ([0, 0, 0])
        rotate([0, 0, 0])
        cylinder (h = CYLINDER_LENGTH, r =
    TRANSDUCER_RADIUS+3);
    }
    union(){
        translate ([0, 0, 0])
        rotate([0, 0, 0])
        cylinder (h = CYLINDER_LENGTH, r =
    TRANSDUCER_RADIUS);

        translate ([0, 15, 0])
        rotate([0, 0, 0])
        cylinder (h = LID_LENGTH, r = HOLE_RADIUS);
        }
    }
```



http://www.openscad.org/

Tradeoffs in transducers

Frequency	3.3V Excitation Range	8 Pulse Standard Deviation	Minimum Distance
175kHz	> 100 cm	100-500 ns	3.5 cm
200kHz	20 cm	50-400 ns	1.5 cm
500kHz	15 cm	10-300 ns	1 cm

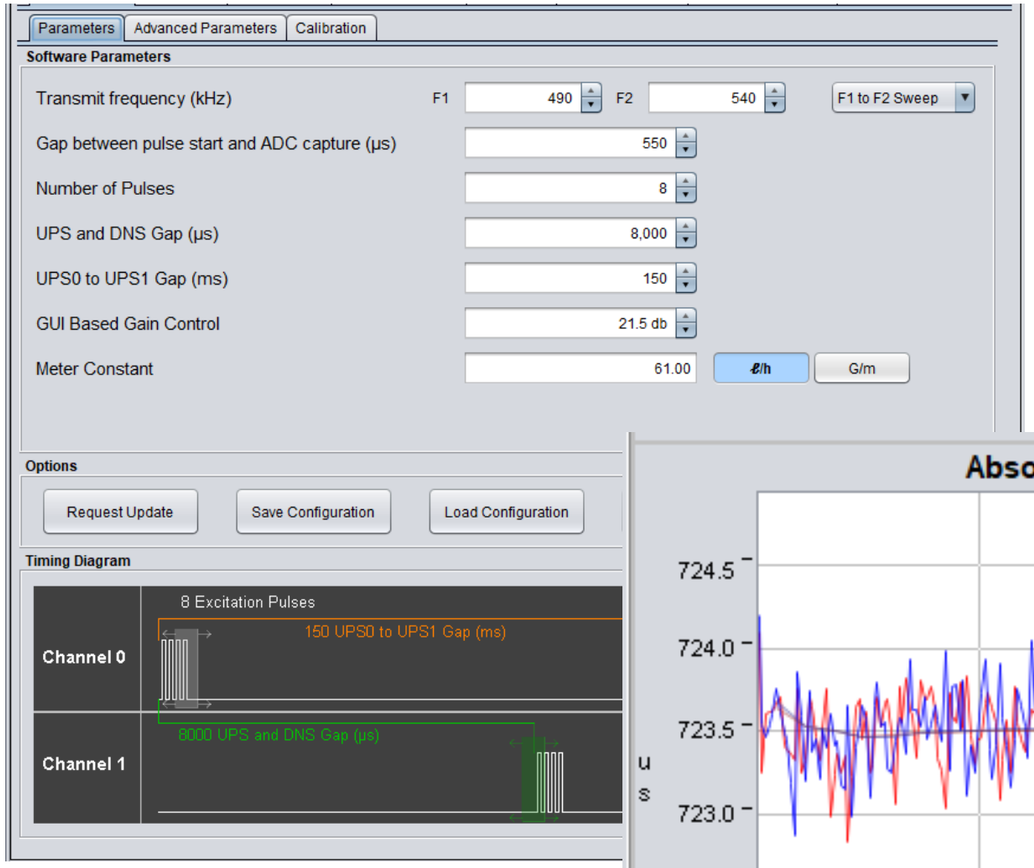


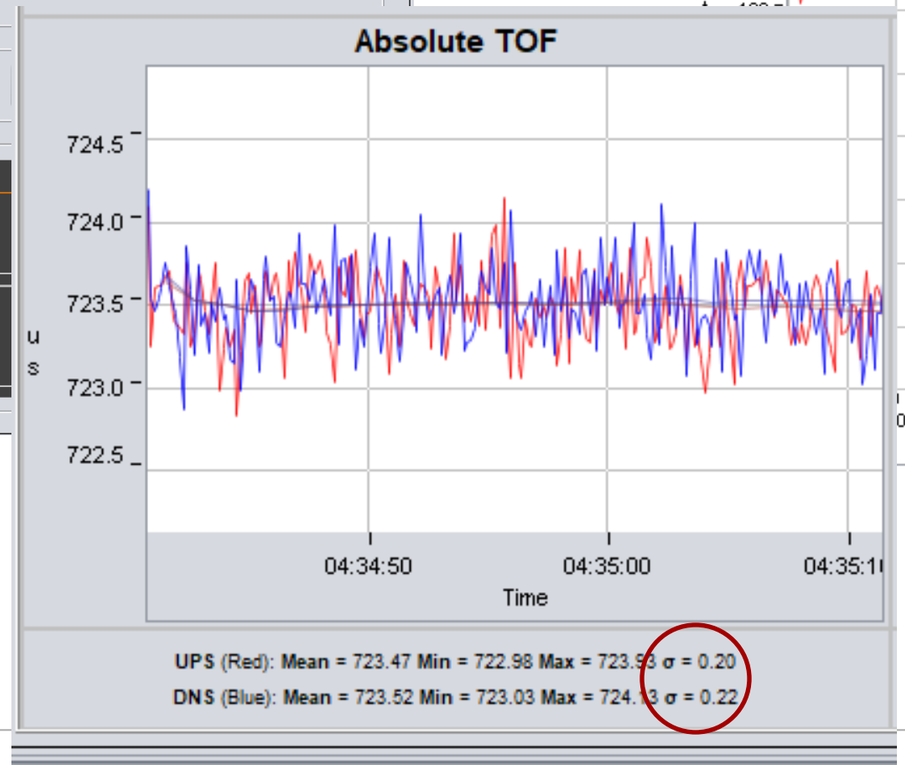
The standard deviation in measurements Increases with distance.

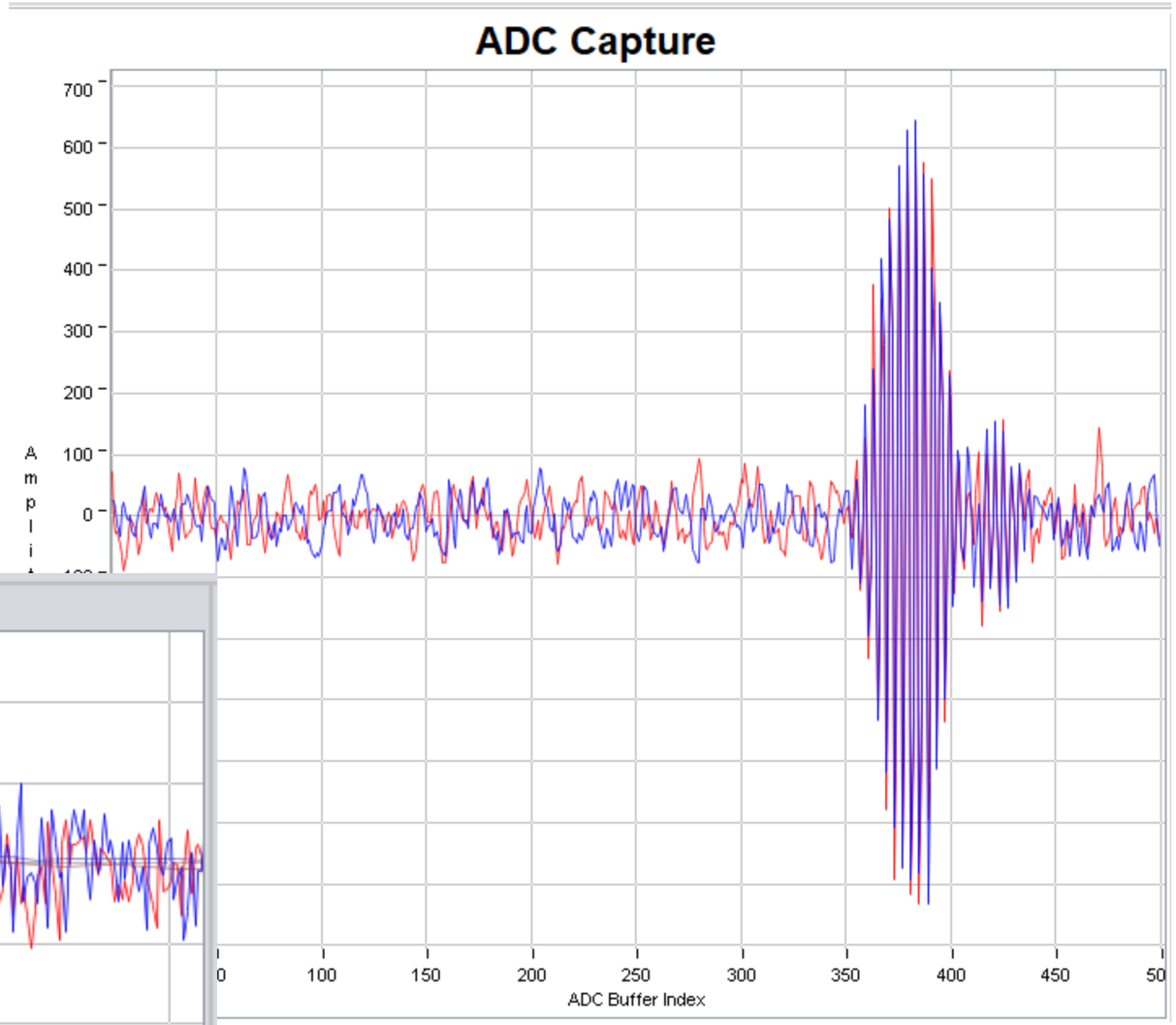
Increasing excitation voltage and/or a collimating waveguide can extend range.

The attenuation of the ultrasonic wave Increases with frequency and can vary based on the gas mixture.

500kHz @12cm

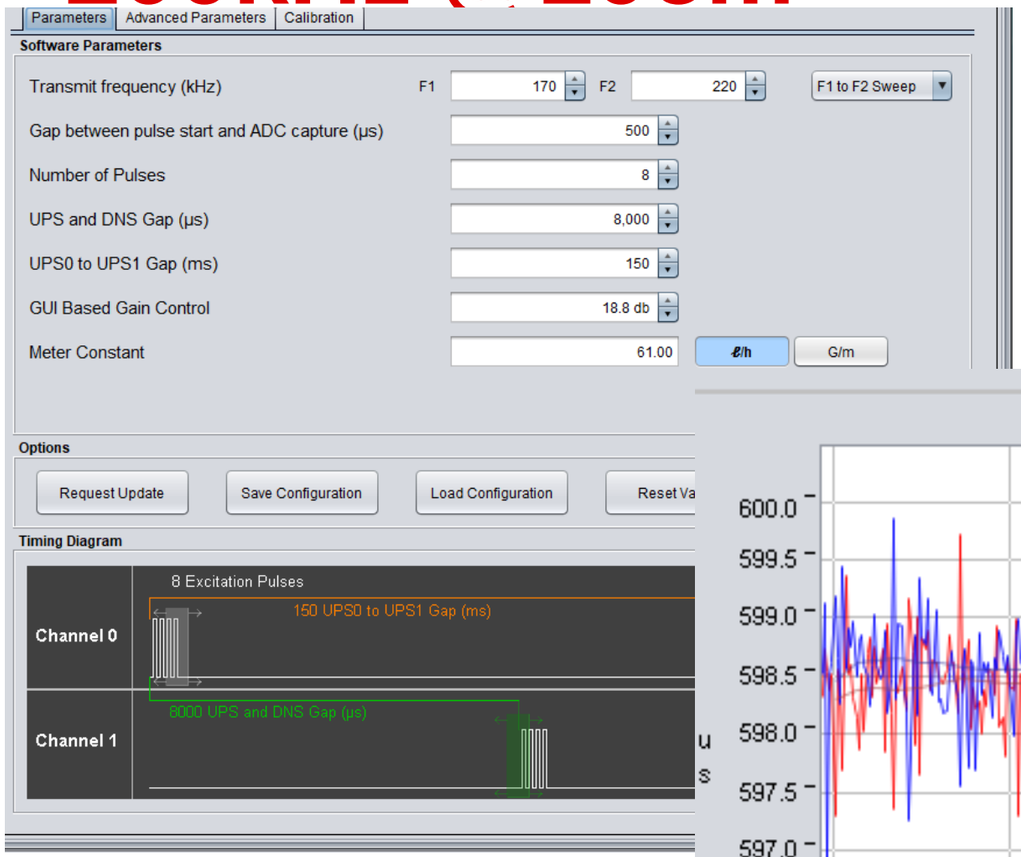


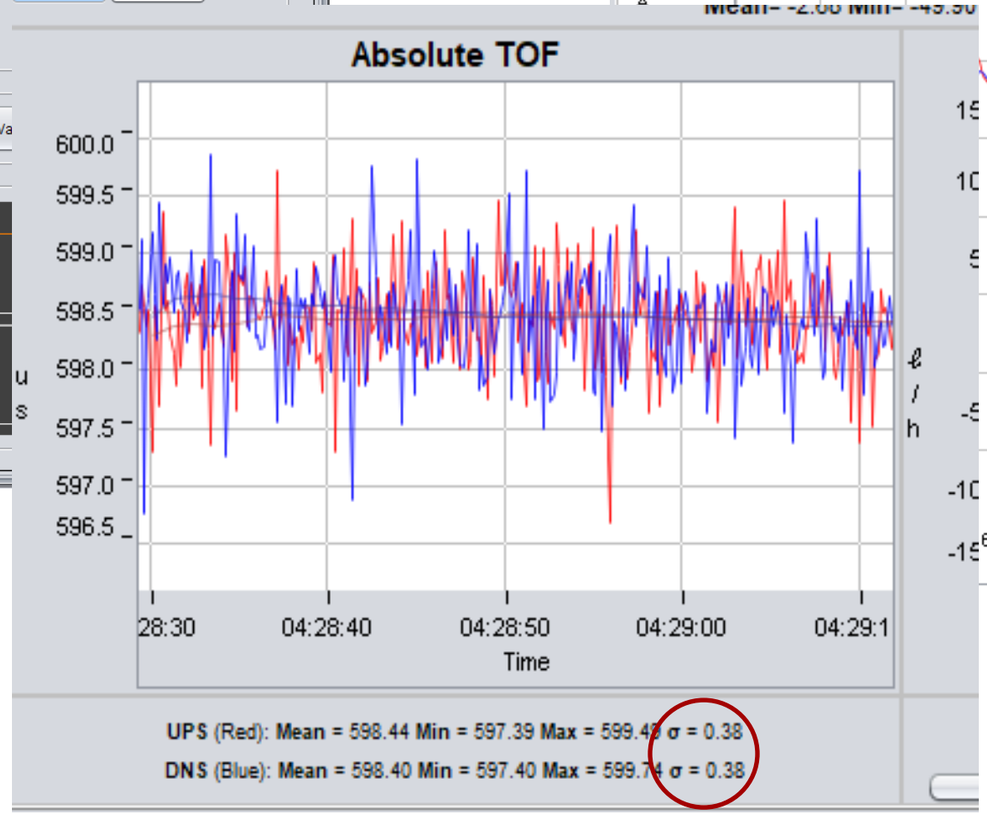


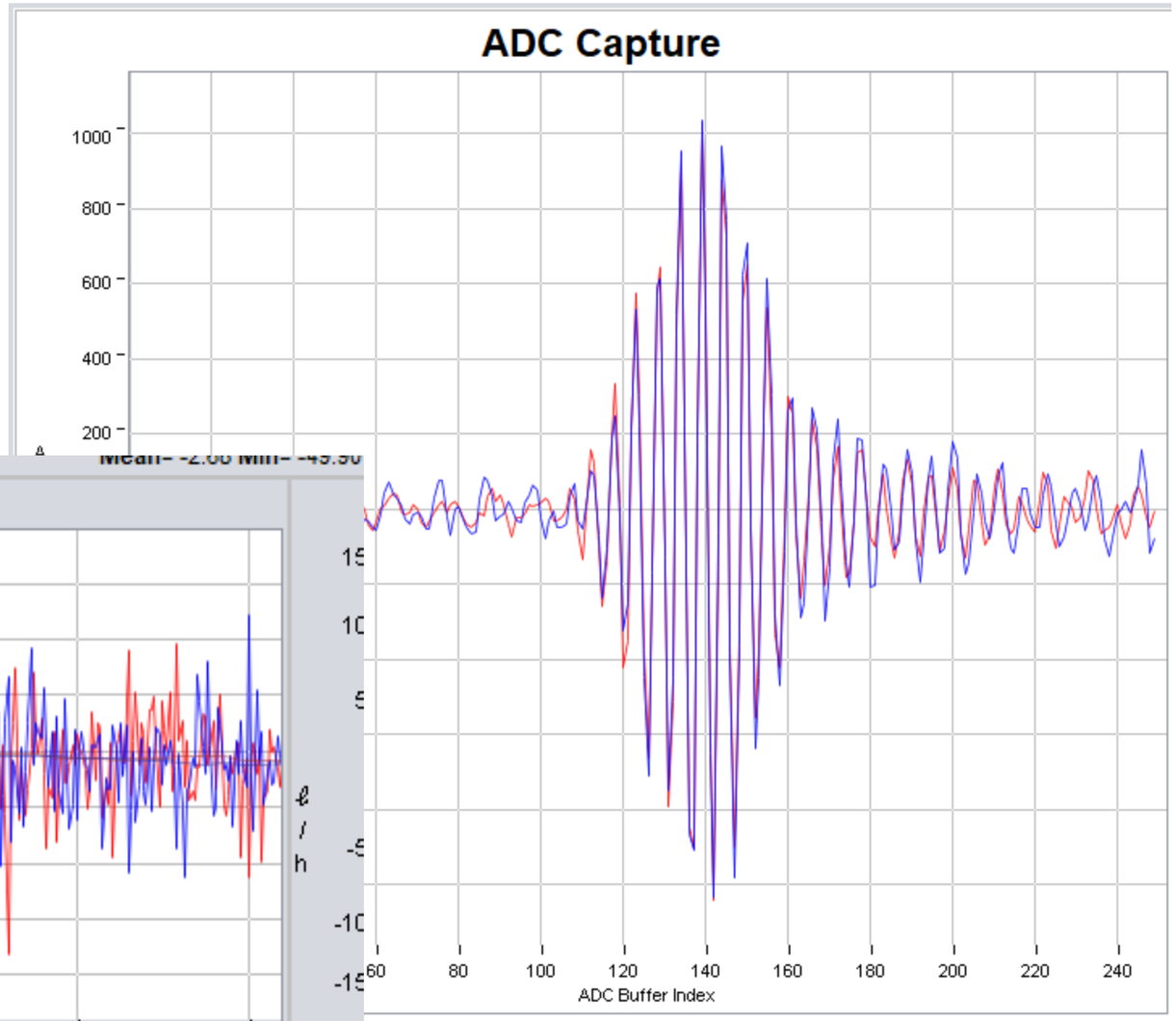


0.2us * 343m/s = 68.6um
(34.3um one way)

200kHz @10cm

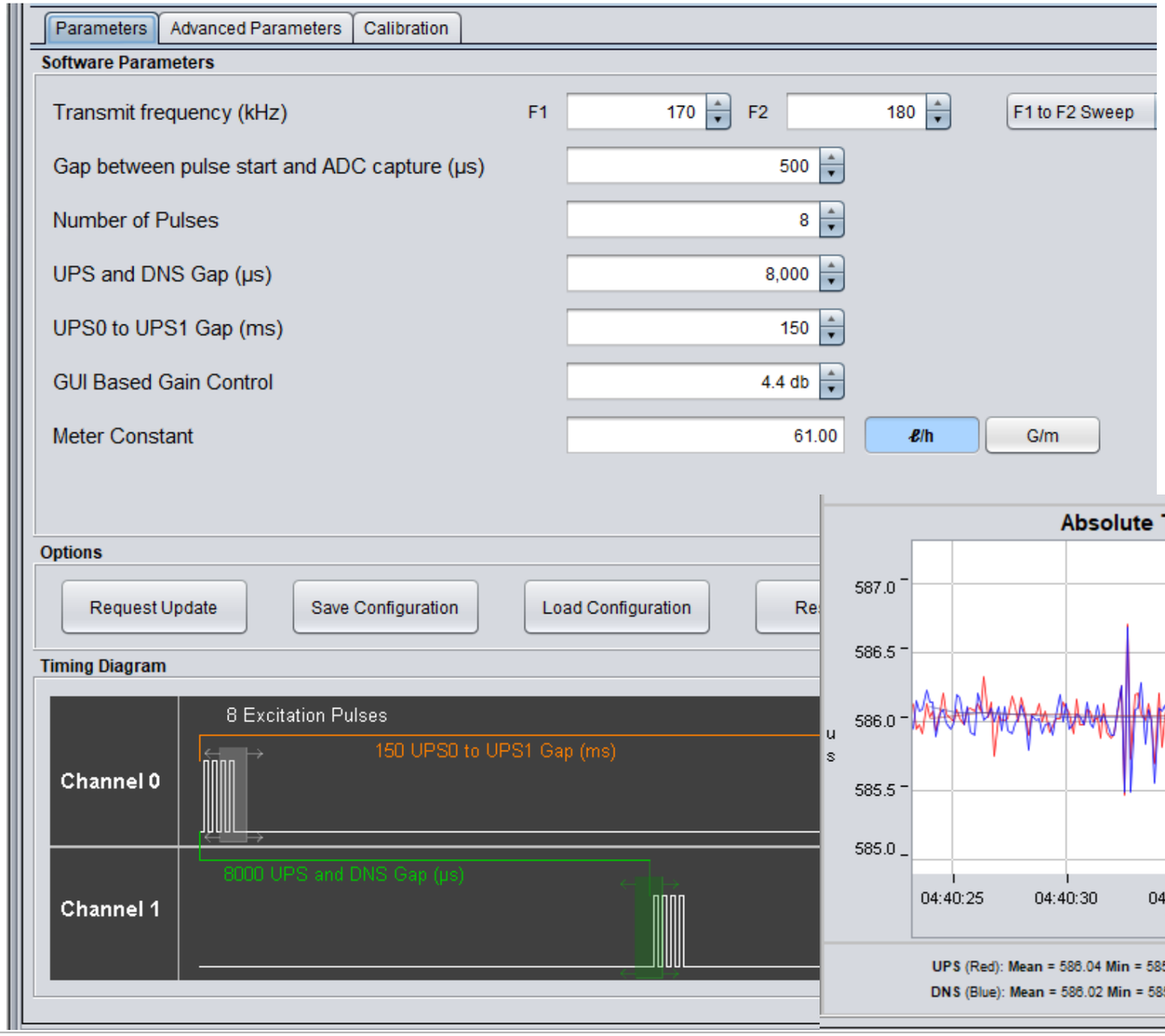


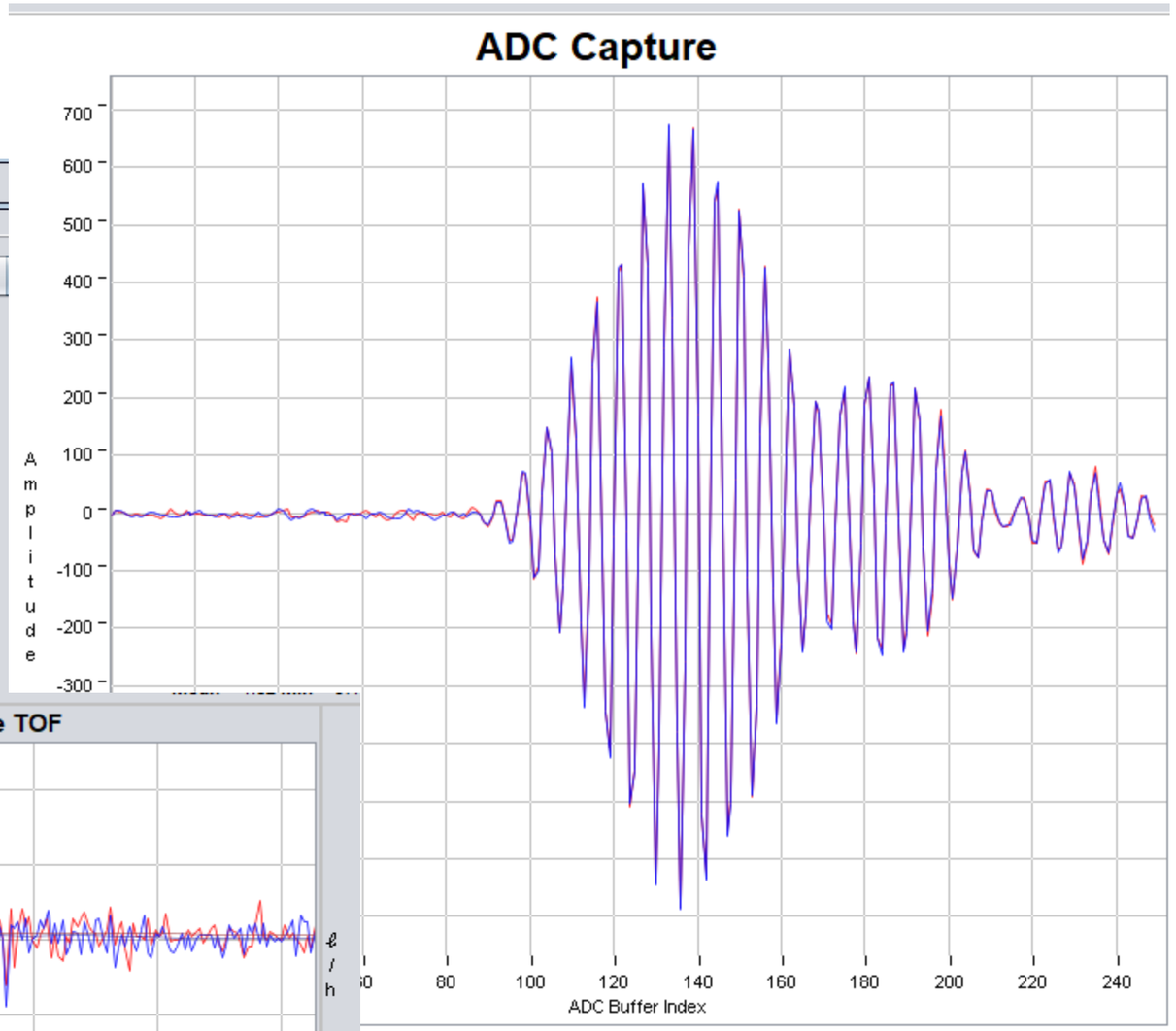




0.4us * 343m/s = 137.2um
(68.6um one way)

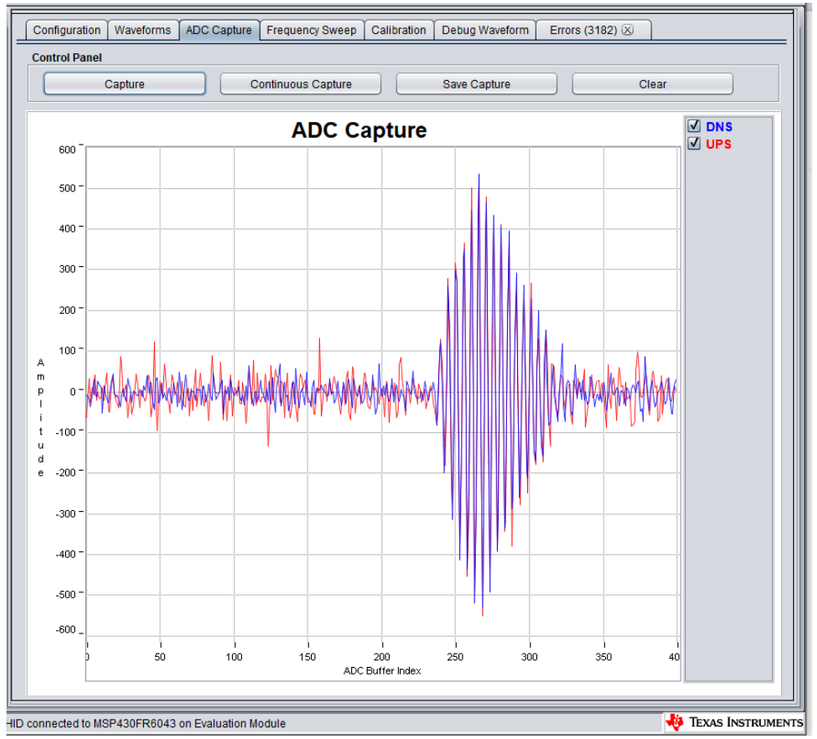
175kHz @10cm



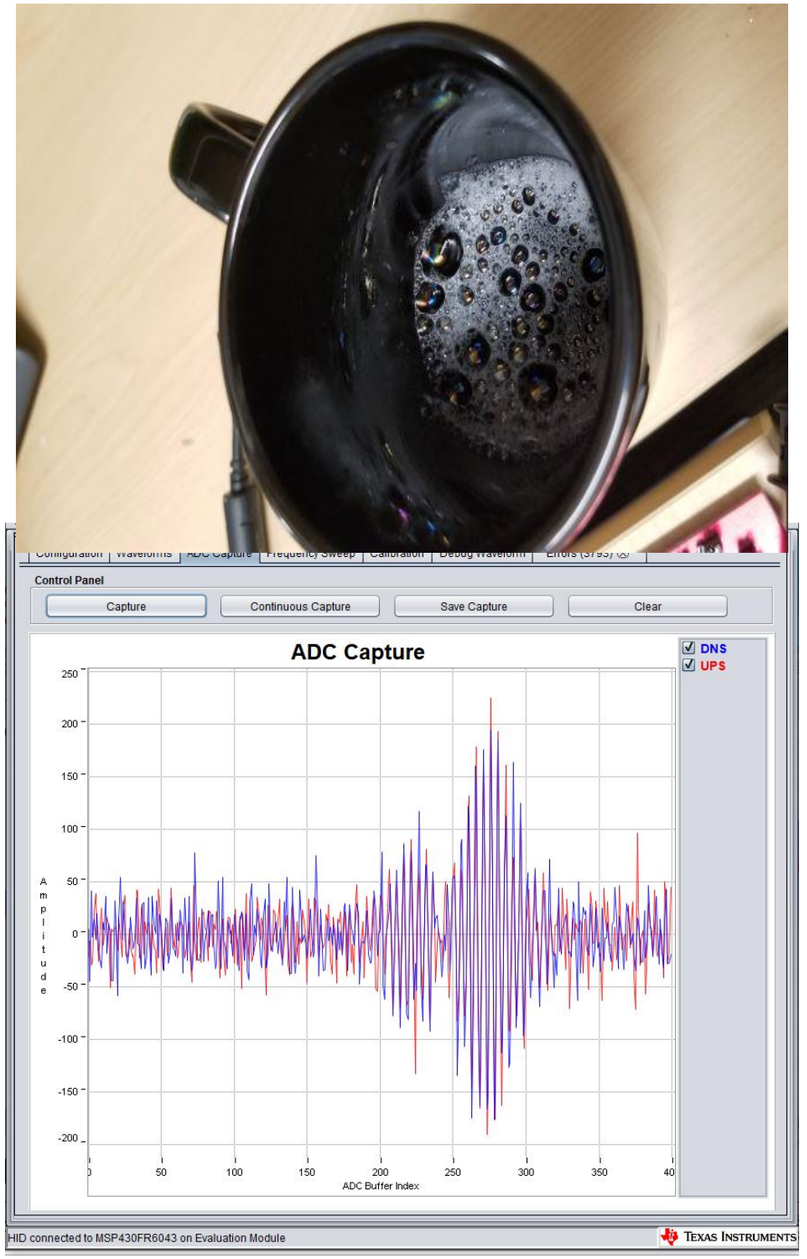


0.13us * 343m/s = 44.6 um
(22.3um one way)

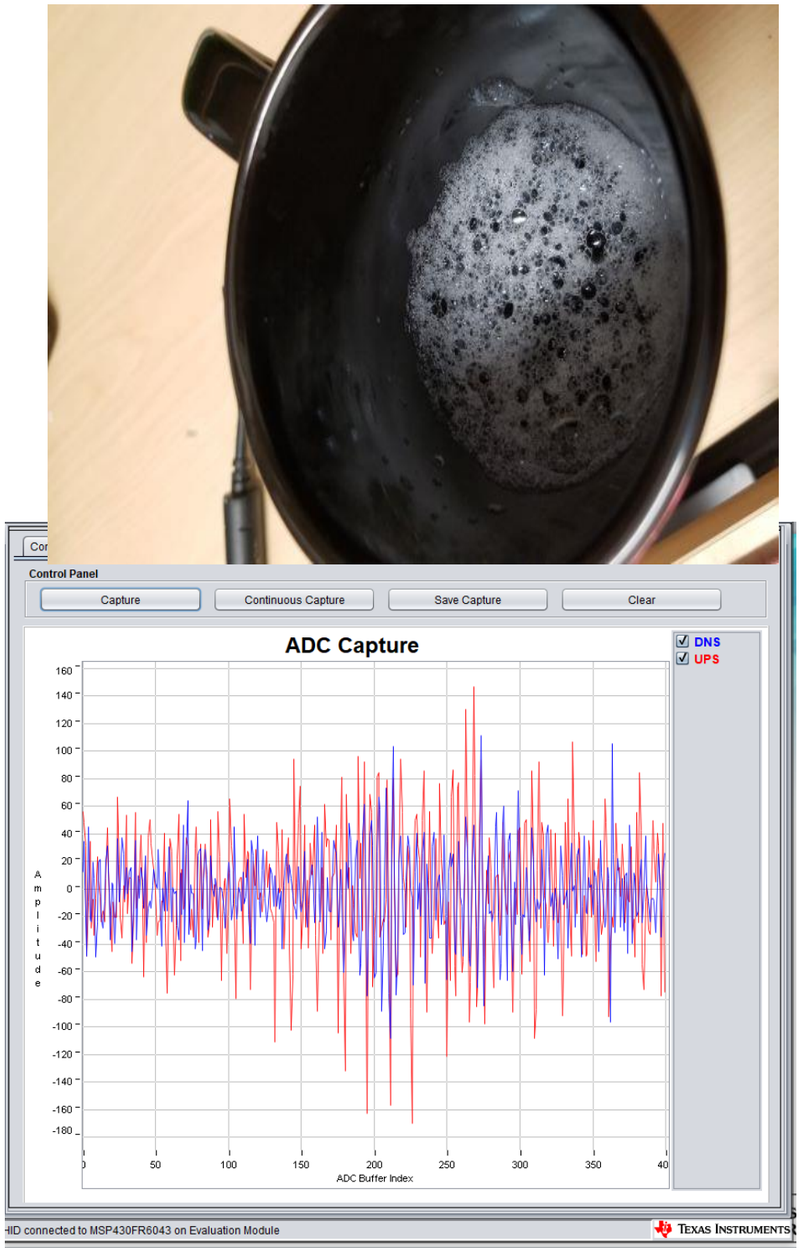
200kHz foam experiments



No Foam

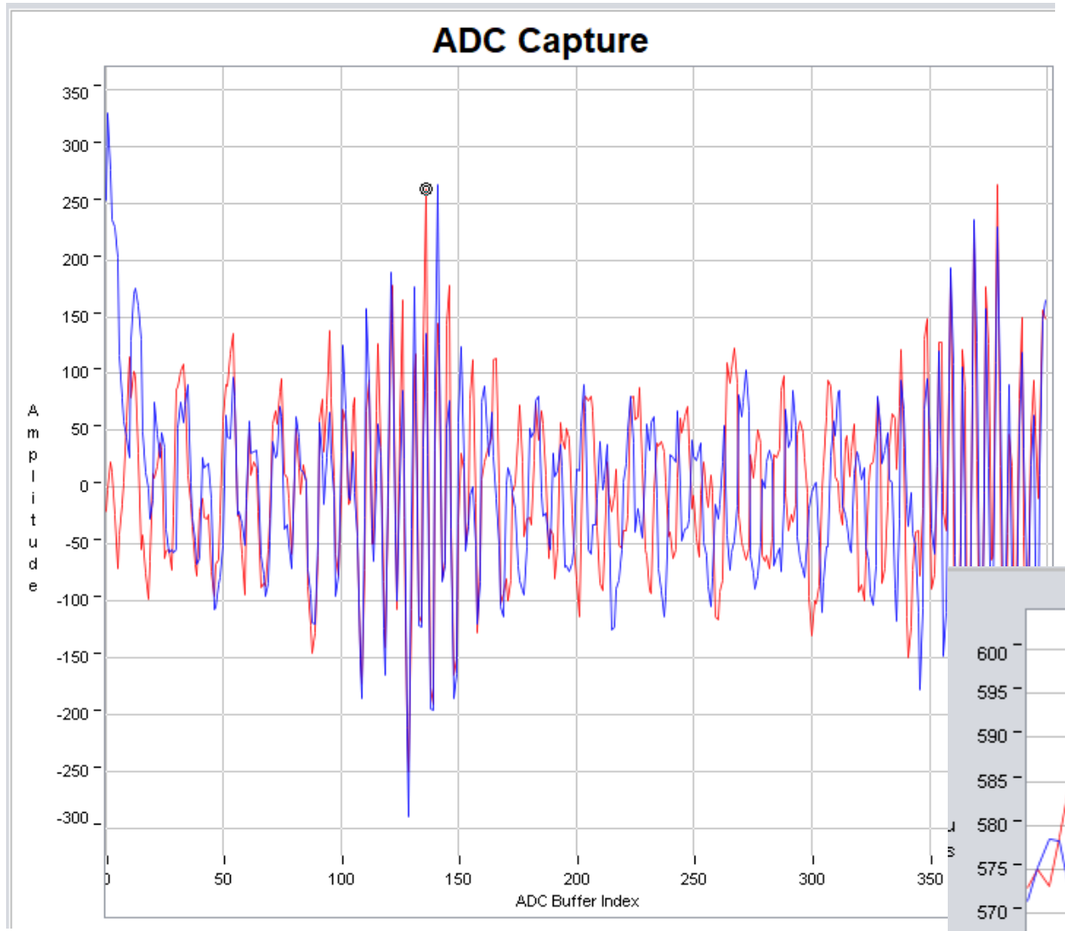


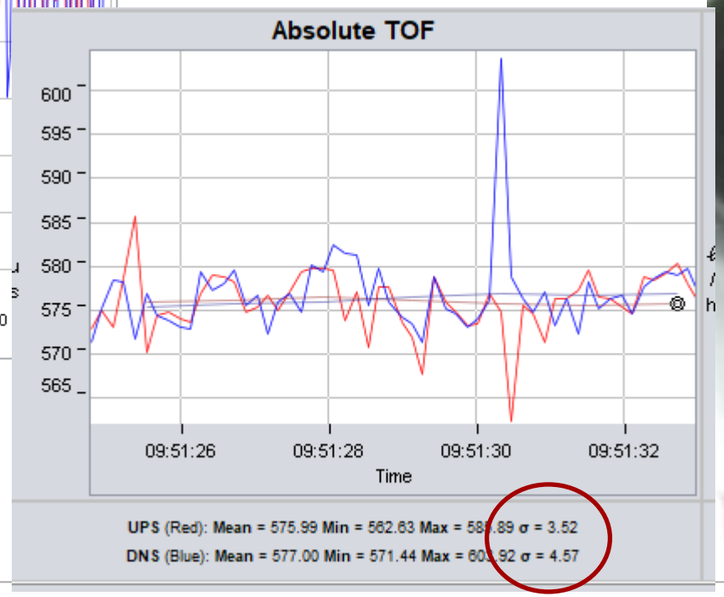
Some Foam



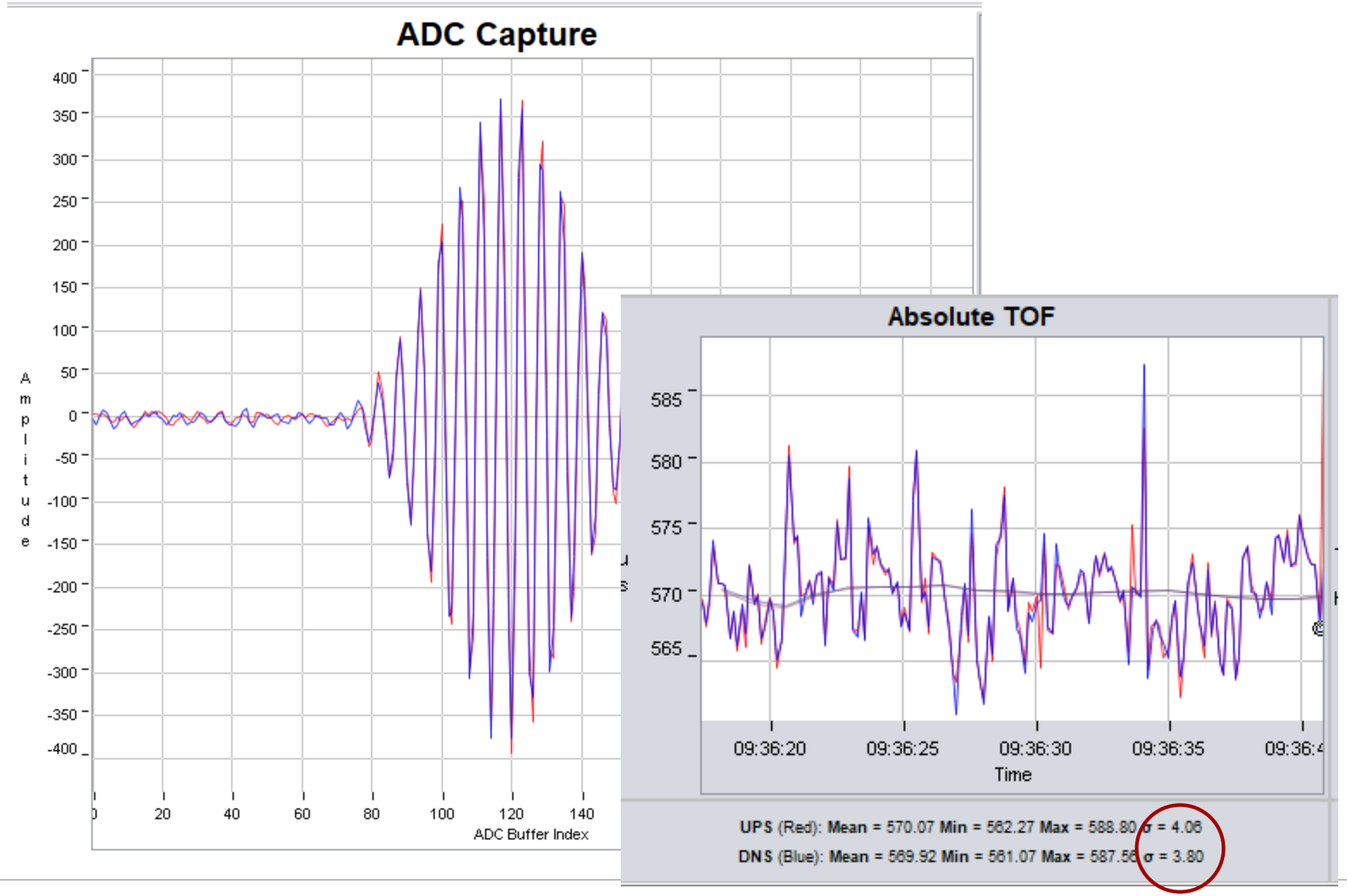
More Foam

200kHz condensation effects



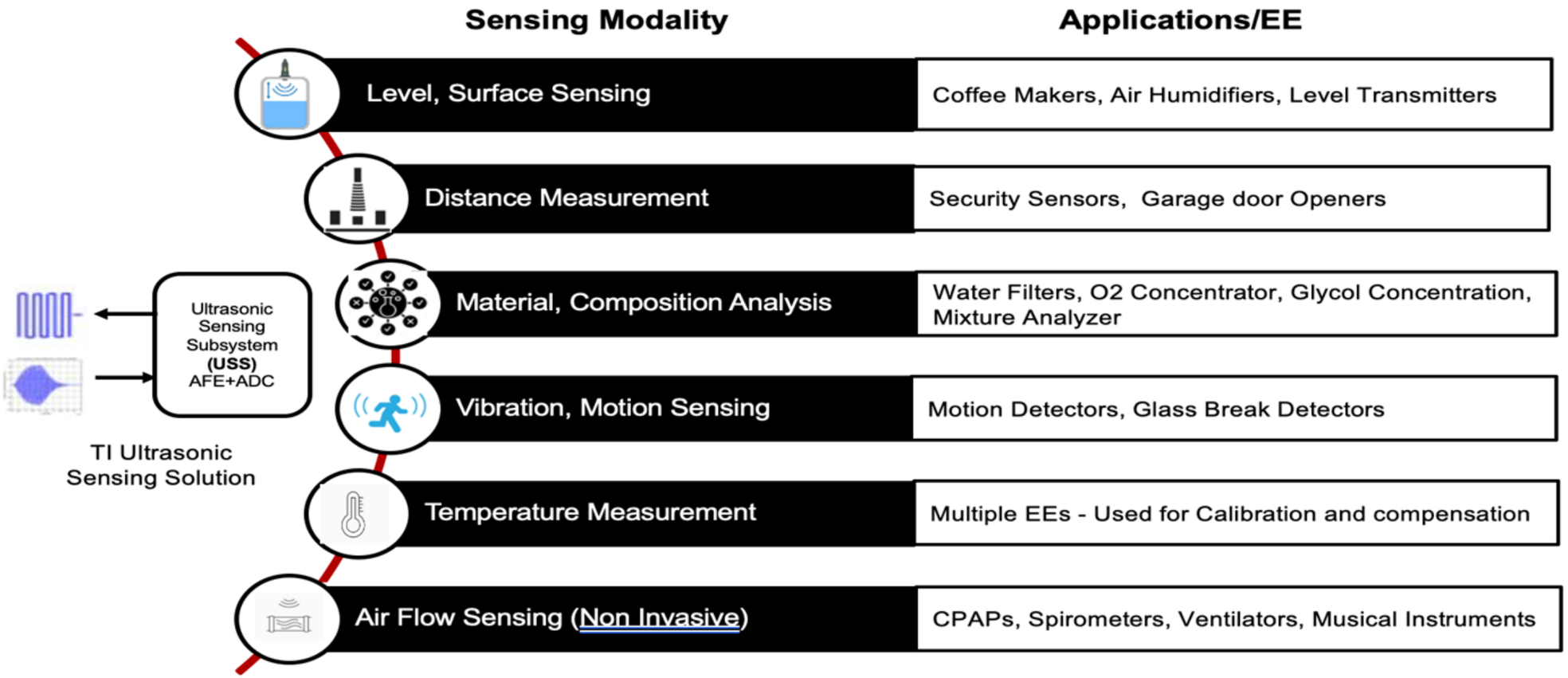


175kHz condensation effects



4us * 343m/s = 1.37mm
(0.68 mm one way)

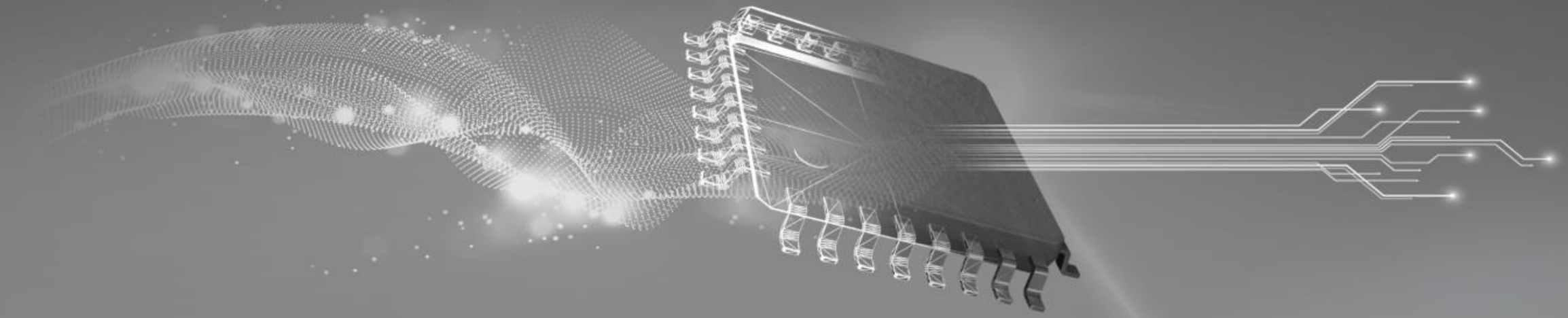
Additional applications/demo



www.ti.com/tool/evm430-fr6043

(Technical Documents)

TI TECH DAYS



Automated tools make capacitive sensor design quick and easy

Presenter: Dennis Lehman – MSP430 Applications

Agenda

CapTIvate™ Technology

Automating Sensor Designs

CapTIvate Design Center

OpenSCAD Demo

MSP430™ capacitive touch sensing microcontrollers

CapTIvate™ MCUs: Easiest to use capacitive touch solutions

MSP430™ capacitive touch sensing MCUs feature CapTIvate™ technology offering the lowest power capacitive touch solutions. With support from 1 to 64 buttons, sliders, wheels and proximity with reliable performance in wet, dirty and greasy conditions as well as through metal, glass, plastic and other overlays, we have a capacitive touch solution for your MCU-based design.

Agenda

CapTIvate™ Technology

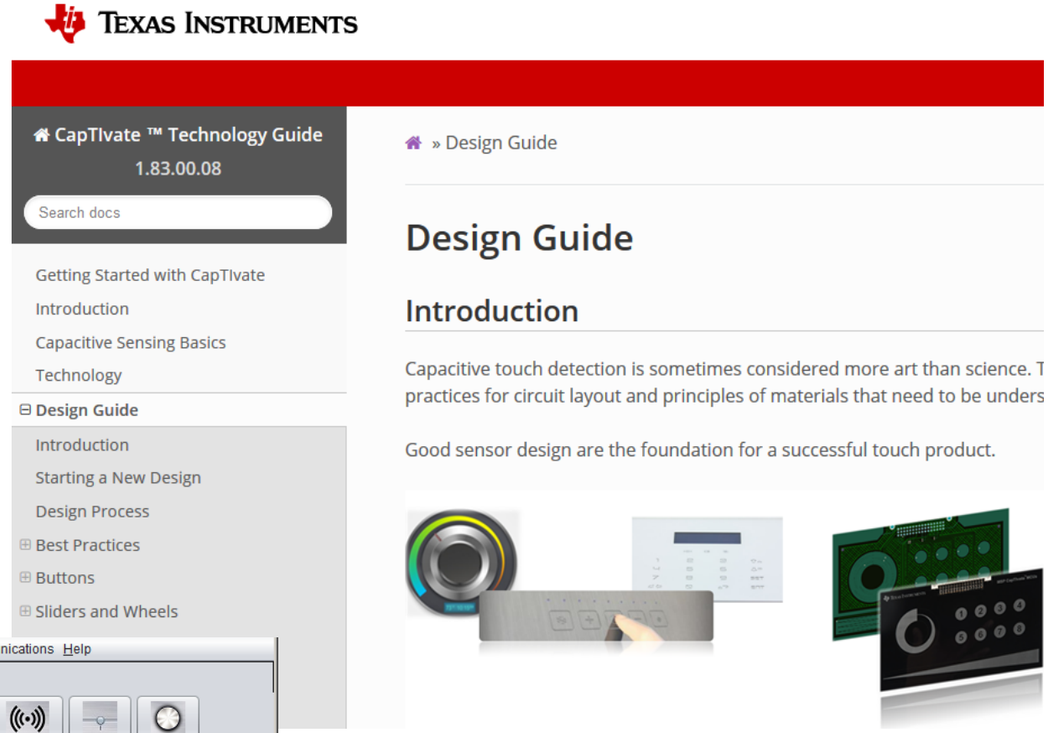
Automating Sensor Designs

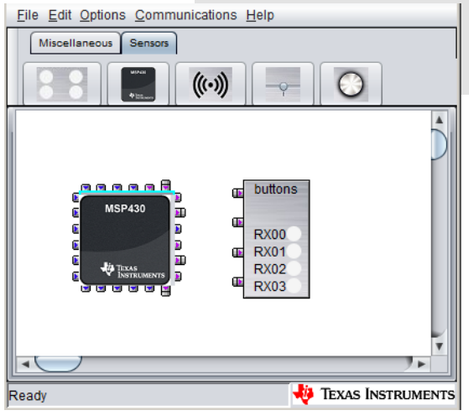
CapTIvate Design Center

OpenSCAD Demo

CapTIvate Technology Guide highlights

- https://ti.com/captivatetechguide
  - MSP430 CapTIvate MCU selection
  - CapTIvate Technology
  - Sensor design guidelines
  - CapTIvate Design Center GUI
  - Development Tools
  - Getting Started Workshop
  - Video
    - Tune capacitive sensors in 5mins or less





CapTIvate tools

EVALUATION BOARD

CAPTIVATE-FR2633 – Capacitive touch MSP430FR2633 MCU board

DEVELOPMENT KIT

CAPTIVATE-PHONE – Capacitive touch mutual capacitance sensor demonstration board with haptic feedback

EVALUATION BOARD

CAPTIVATE-BSWP – Capacitive touch self capacitance button, slider, wheel, and proximity sensor demonstration board

HARDWARE PROGRAMMING TOOL

CAPTIVATE-PGMR – MSP430 CapTIvate™ MCU programmer

EVALUATION BOARD

CAPT-FR2633-BNDL – CAPTIVATE-FR2633 + CAPTIVATE-BSWP + CAPTIVATE-PHONE + CAPTIVATE-PGMR bundle

Agenda

CapTIvate™ Technology

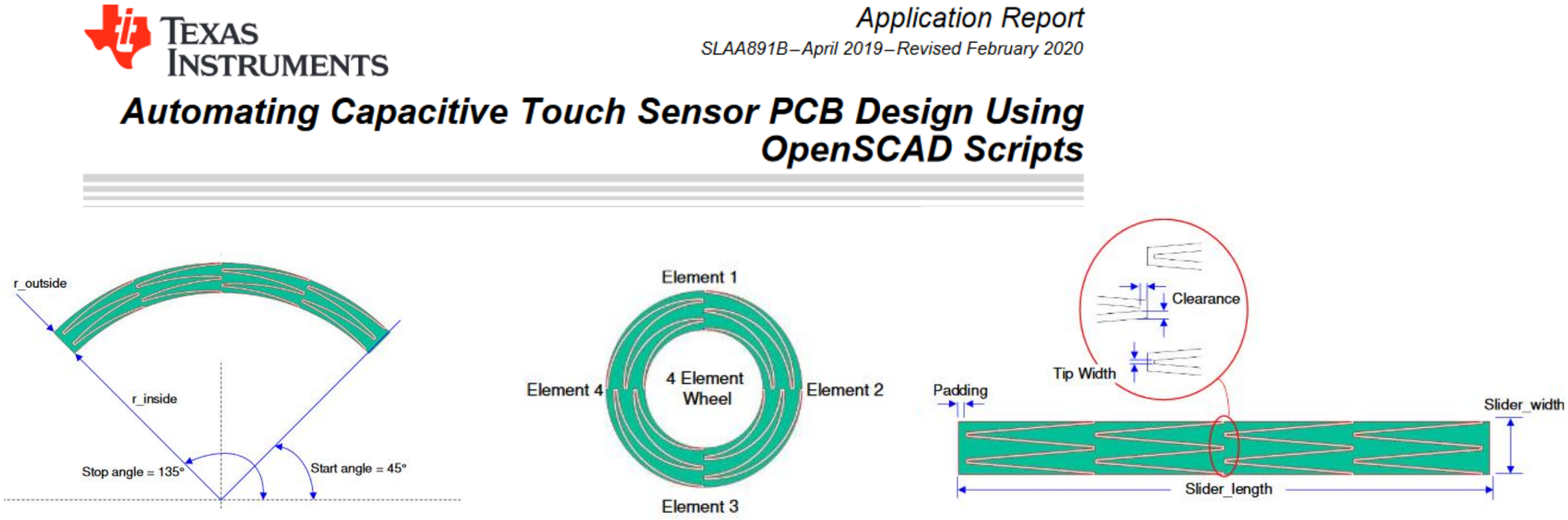
Automating Sensor Designs

CapTIvate Design Center

OpenSCAD Demo

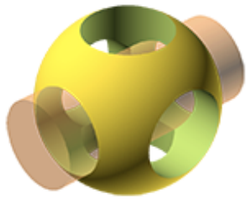
Automating PCB sensor design

- CapTIvate Tech Guide – Design Guide Chapter
- SLAA891- OpenSCAD auto-generates electrode patterns in seconds
- Scripts for sliders, curved sliders, wheels and touchpads provided by TI

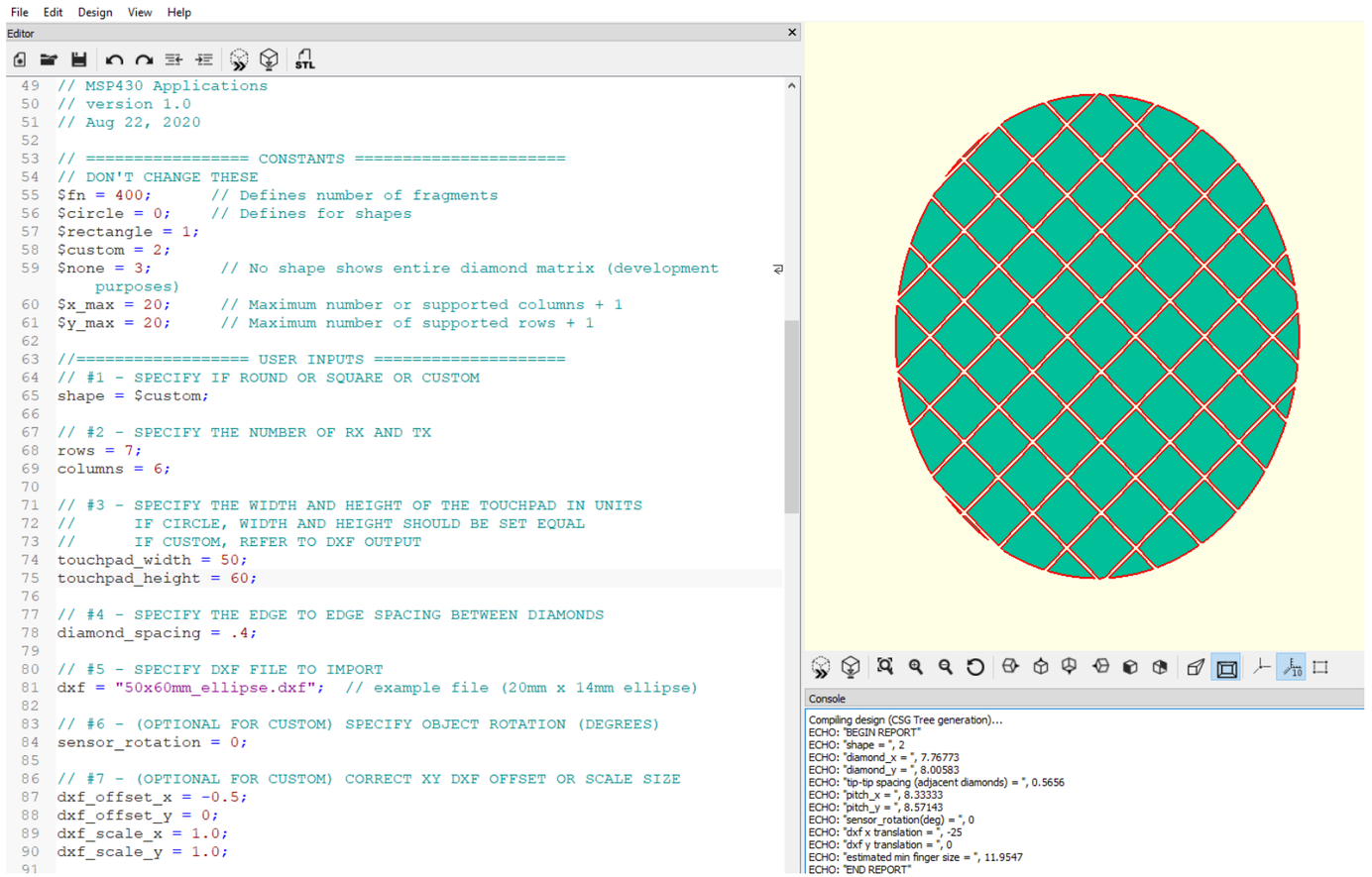


Automating PCB sensor design

- OpenSCAD
  - https://www.openscad.org
- Open Source (free)
- 2D/3D CAD
- Programming script controls sensor design



OpenSCAD
The Programmers Solid 3D CAD Modeller



Automating PCB sensor design

- Scripts can be customized by user
- Requires only a few parameters to define a sensor design

```
53  // USER DEFINED INPUTS:
54  //=====================================================================
55  // STEP #1
56  // USER DEFINED NUMBER OF ELEMENTS IN THE SLIDER (MIN IS 3, TYPICAL IS 4)
57  total_elements = 4;
58
59  // STEP #2
60  // USER DEFINED NUMBER OF FINGERS (TINES) (TYPICAL = 5)
61  tines = 5;
62
63  // STEP #3
64  // USER DEFINED LENGTH (mm IN THIS EXAMPLE)
65  slider_length = 150;
66
67  // STEP #4
68  // USER DEFINED WIDTH (mm IN THIS EXAMPLE)
69  slider_width = 15;
70
71  // STEP #5
72  // USER DEFINED LEFT AND RIGHT END PADDING SIZE (mm IN THIS EXAMPLE)
73  //(mm IN THIS EXAMPLE)
74  padding = 2;
75
76  // STEP #6
77  // USER DEFINED CLEARANCES AND TIP WIDTH (mm IN THIS EXAMPLE)
78  //(mm IN THIS EXAMPLE)
79  clearance = 0.5;
80  tip_width = 0.25;
```

OpenSCAD design process

- Live Demo at end of presentation

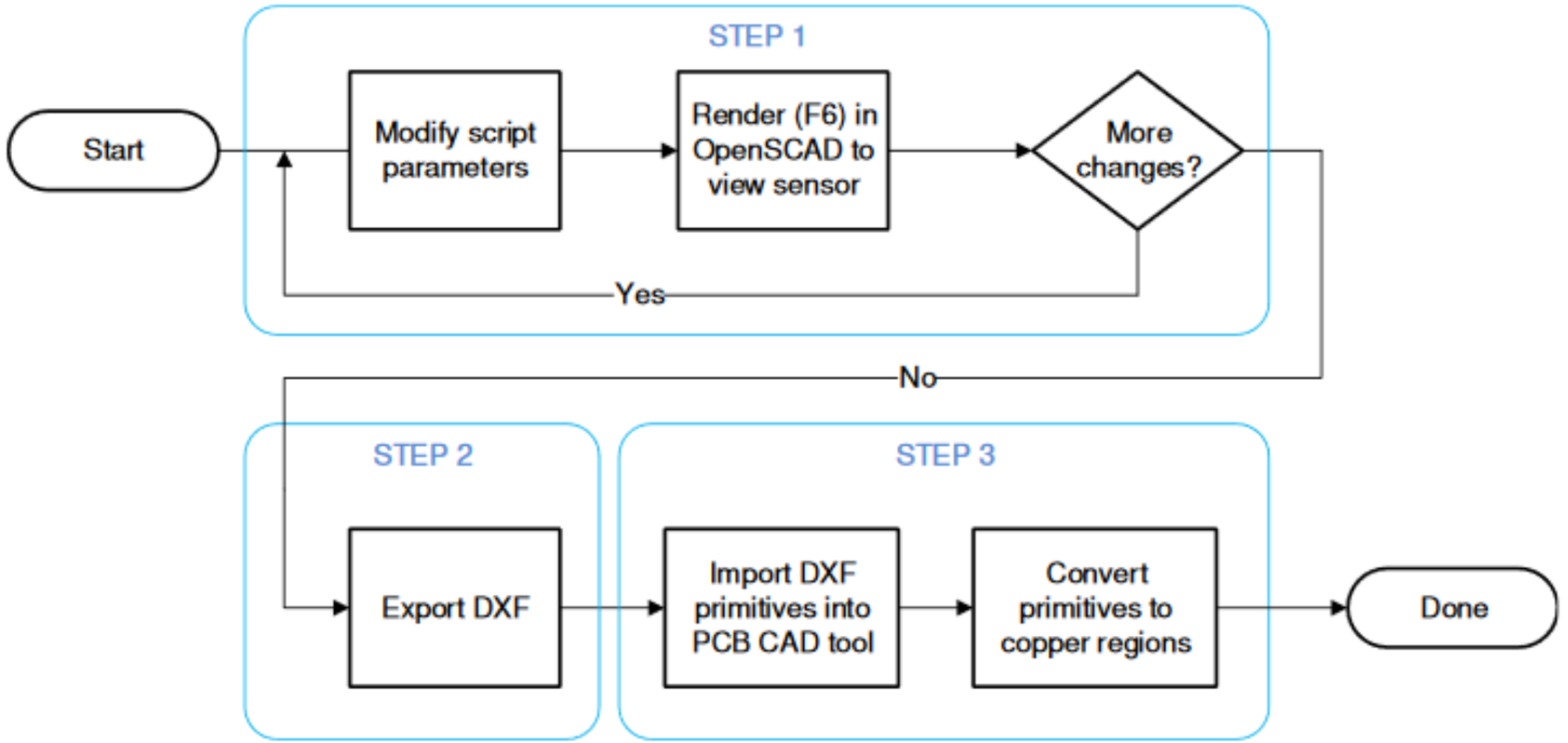


Figure 1. Workflow

Agenda

CapTIvate™ Technology

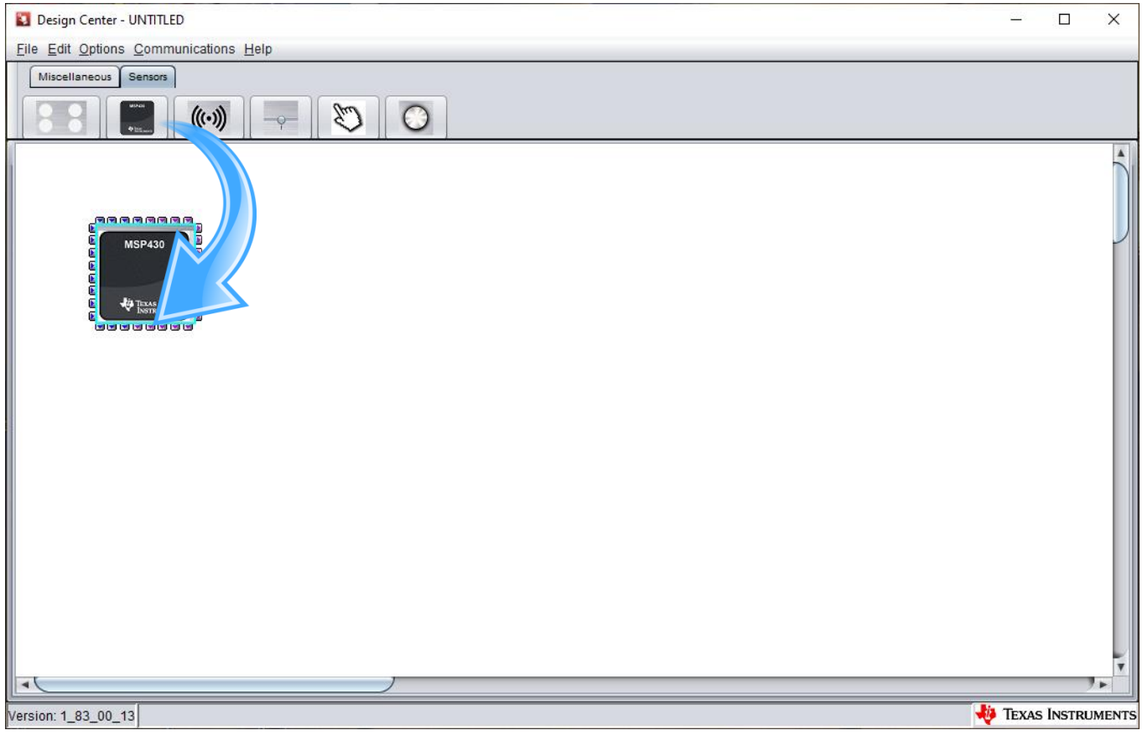
Automating Sensor Designs

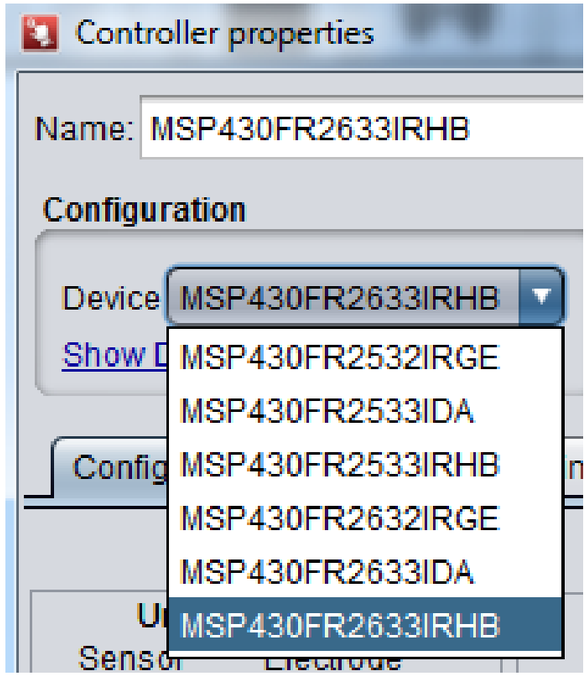
CapTIvate Design Center

OpenSCAD Demo

CapTIvate Design Center GUI

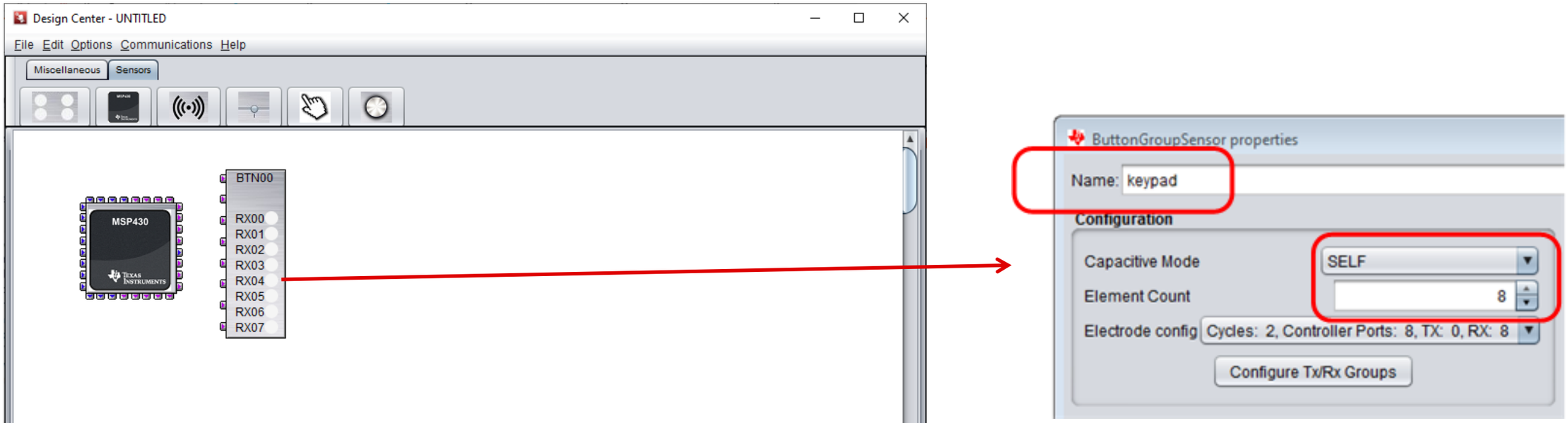
- Select MCU





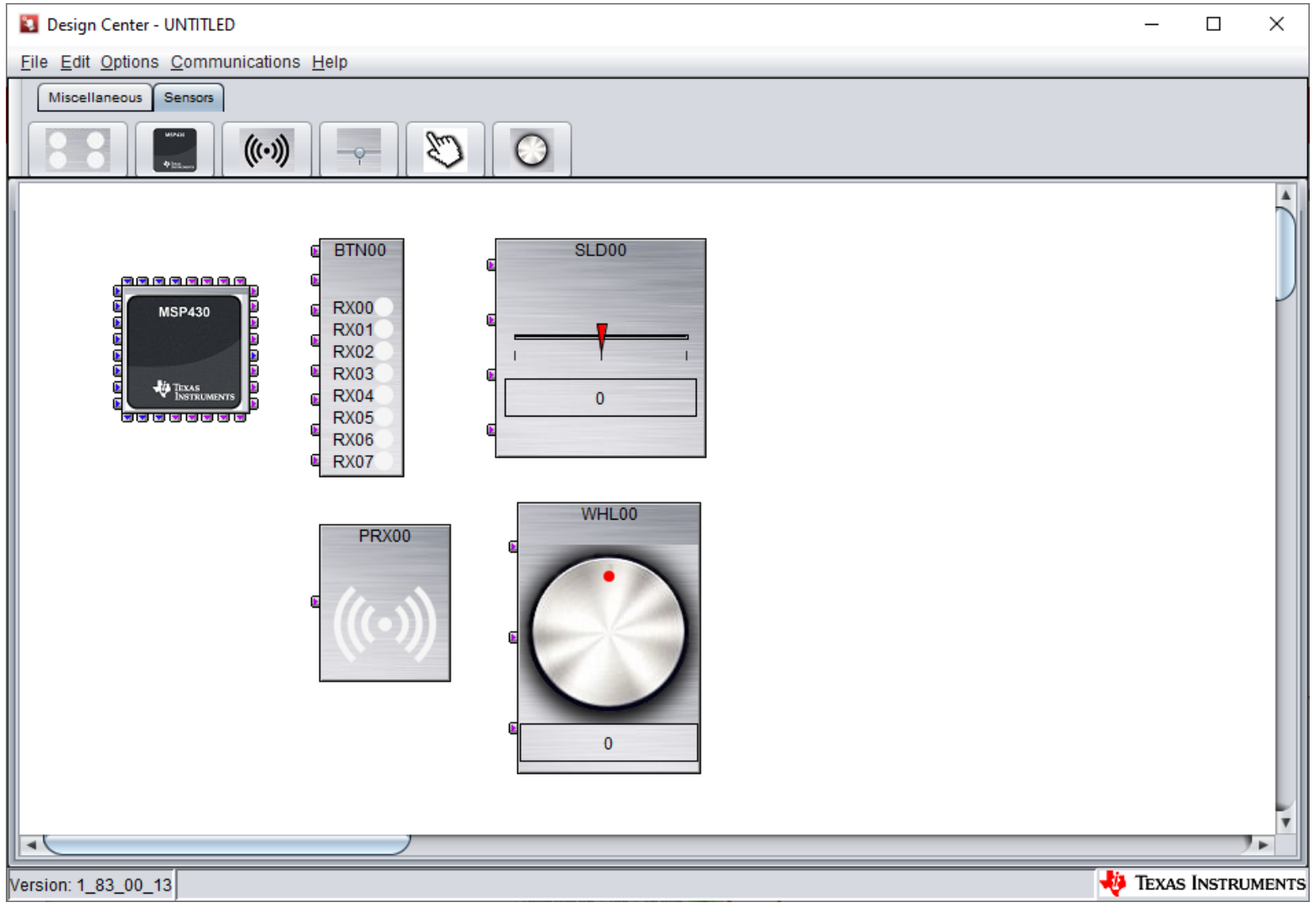
CapTIvate Design Center GUI

- Select and configure keypad sensor

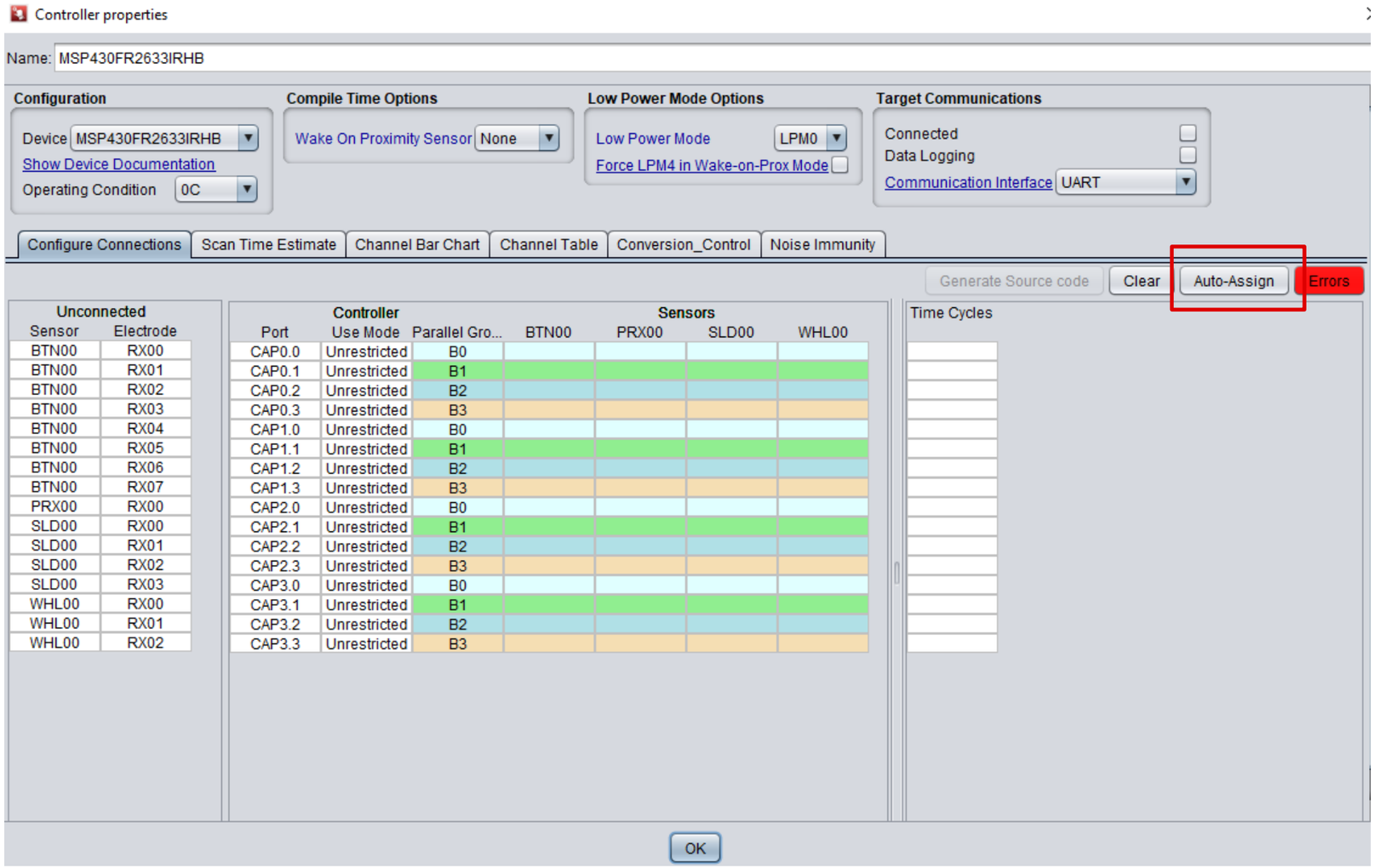


CapTIvate Design Center GUI

- Repeat for all sensors



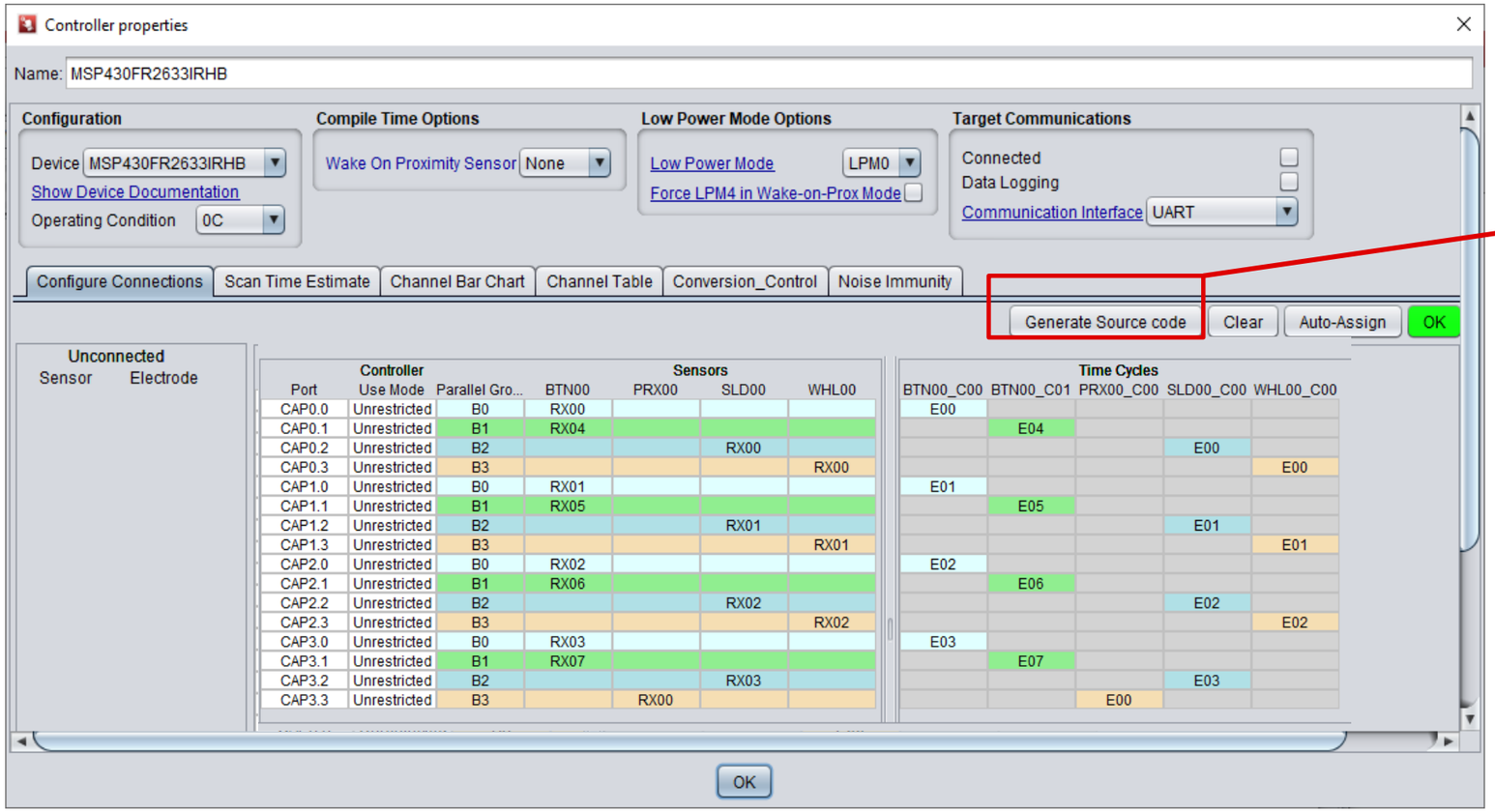
CapTIvate Design Center GUI

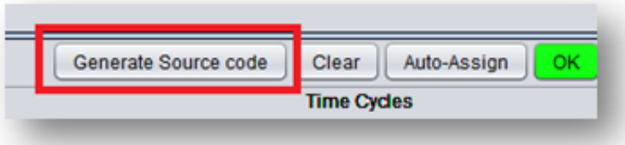


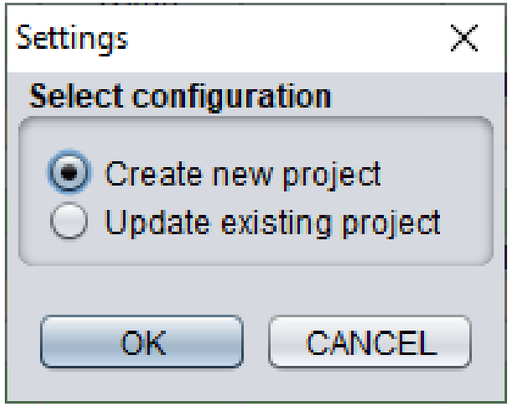
CapTIvate Design Center GUI

- Configuration MCU connections to sensors
- Generate MSP430 starter project firmware

Generates 100% of the code
to get started.
(no need to write code)







CapTIvate Design Center GUI

- Build and program MSP430

CAPT_Manager.c | CAPT_HAL.c | CAPT_HAL.h | main.c | I2CSla

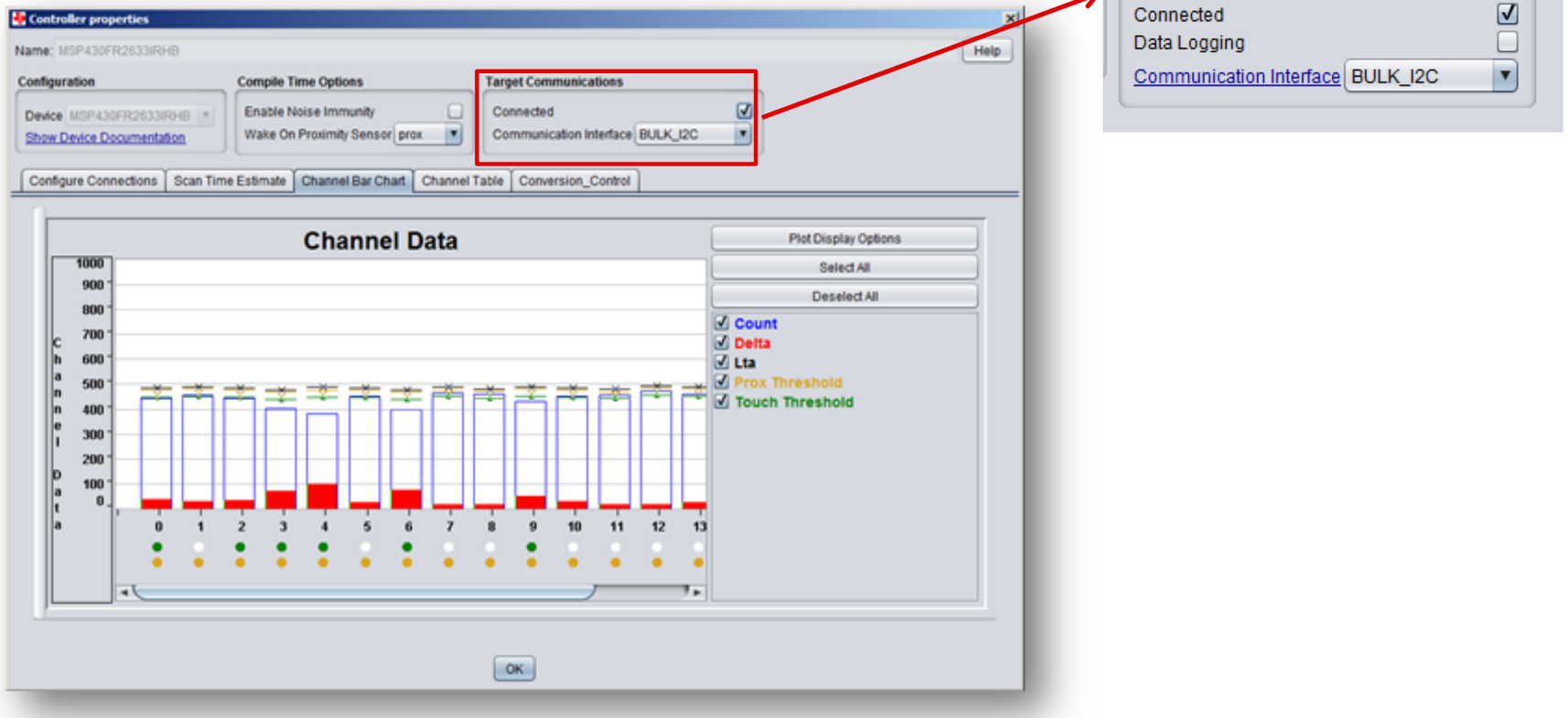
```
55 #include "driverlib.h"                    // MSPWare Driver Library
56 #include "captivate.h"                   // CapTIvate Touch Software
57 #include "CAPT_App.h"                    // CapTIvate Application Co
58 #include "CAPT_BSP.h"                    // CapTIvate EVM Board Supp
59
60 //*****************************************************************
61 // Function Implementations
62 //*****************************************************************
63
64 void main(void)
65 {
66     //
67     // Initialize the MCU
68     // BSP_configureMCU() sets up the device IO and clocking
69     // The global interrupt enable is set to allow peripherals
70     // to wake the MCU.
71     //
72     WDTCTL = WDTPW | WDTHOLD;
73     BSP_configureMCU();
74     __bis_SR_register(GIE);
75
76     //
77     // Start the CapTIvate application
78     //
79     CAPT_appStart();
80
81     //
82     // Background Loop
83     //
84     while(1)
```

Code Composer Studio

IAR SYSTEMS

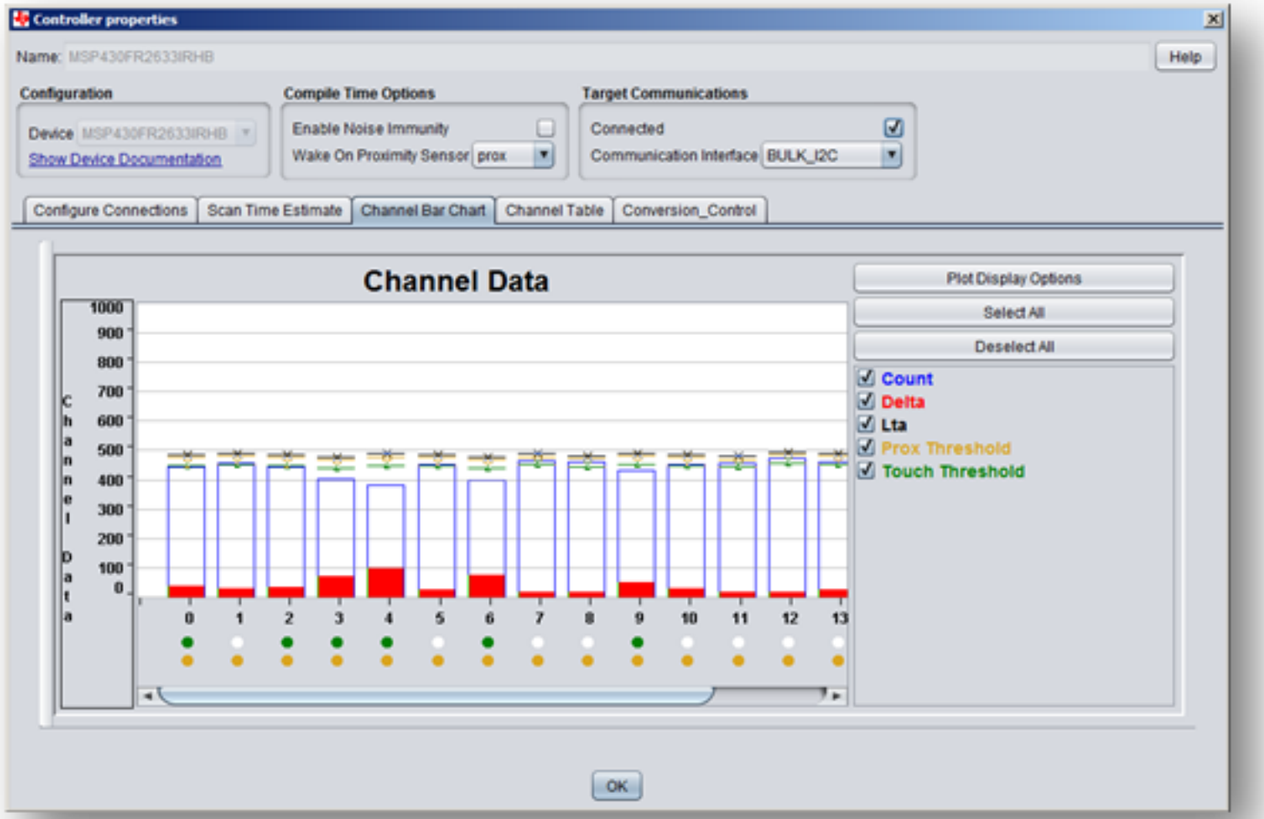
CapTIvate Design Center GUI

- Enable communications
- View sensor data



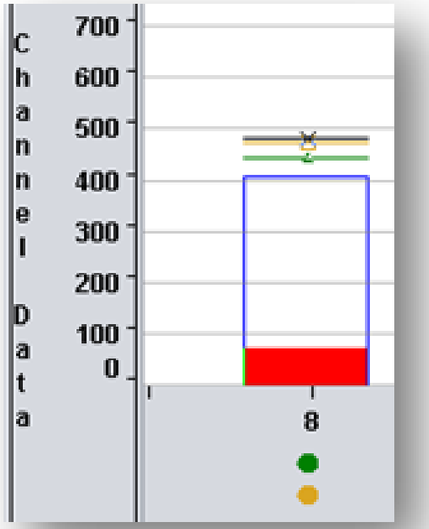
CapTIvate Design Center GUI

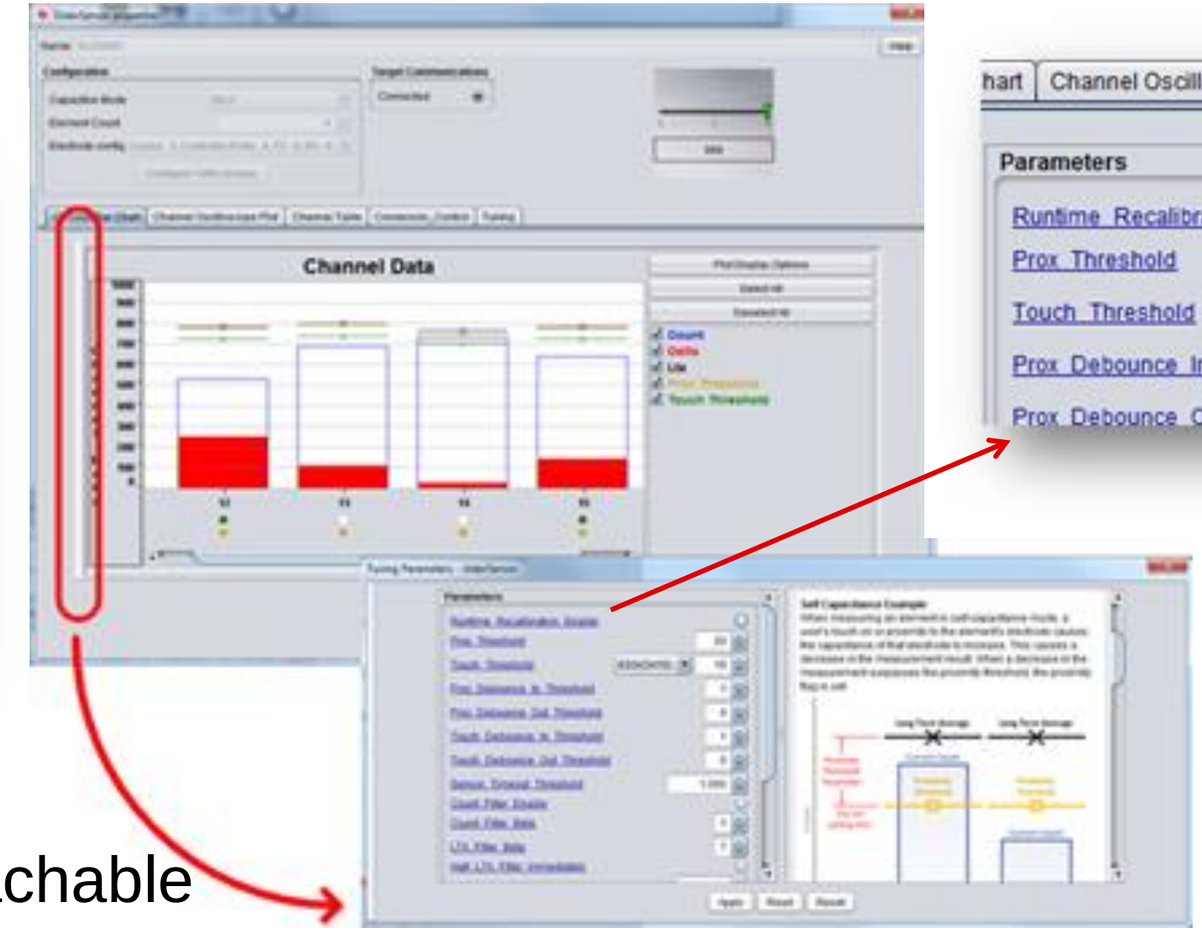
- View sensor output

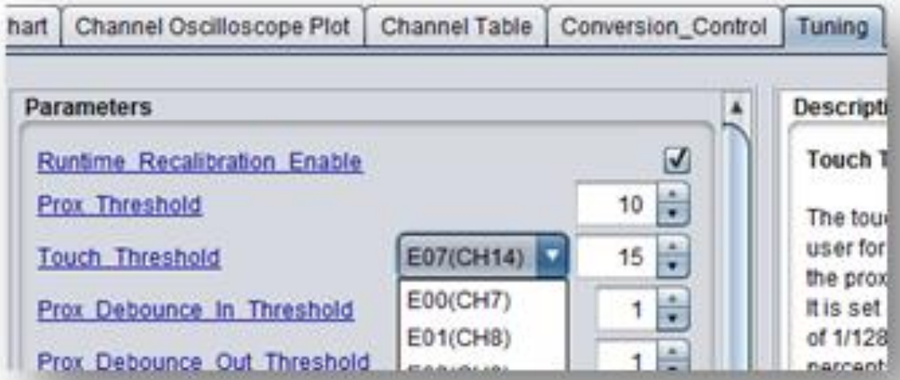


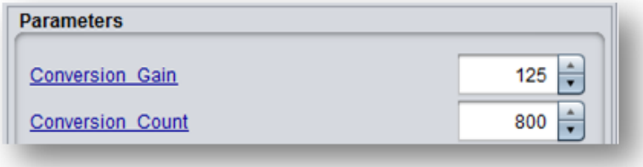
CapTIvate Design Center GUI

- Tune sensor's sensitivity and thresholds





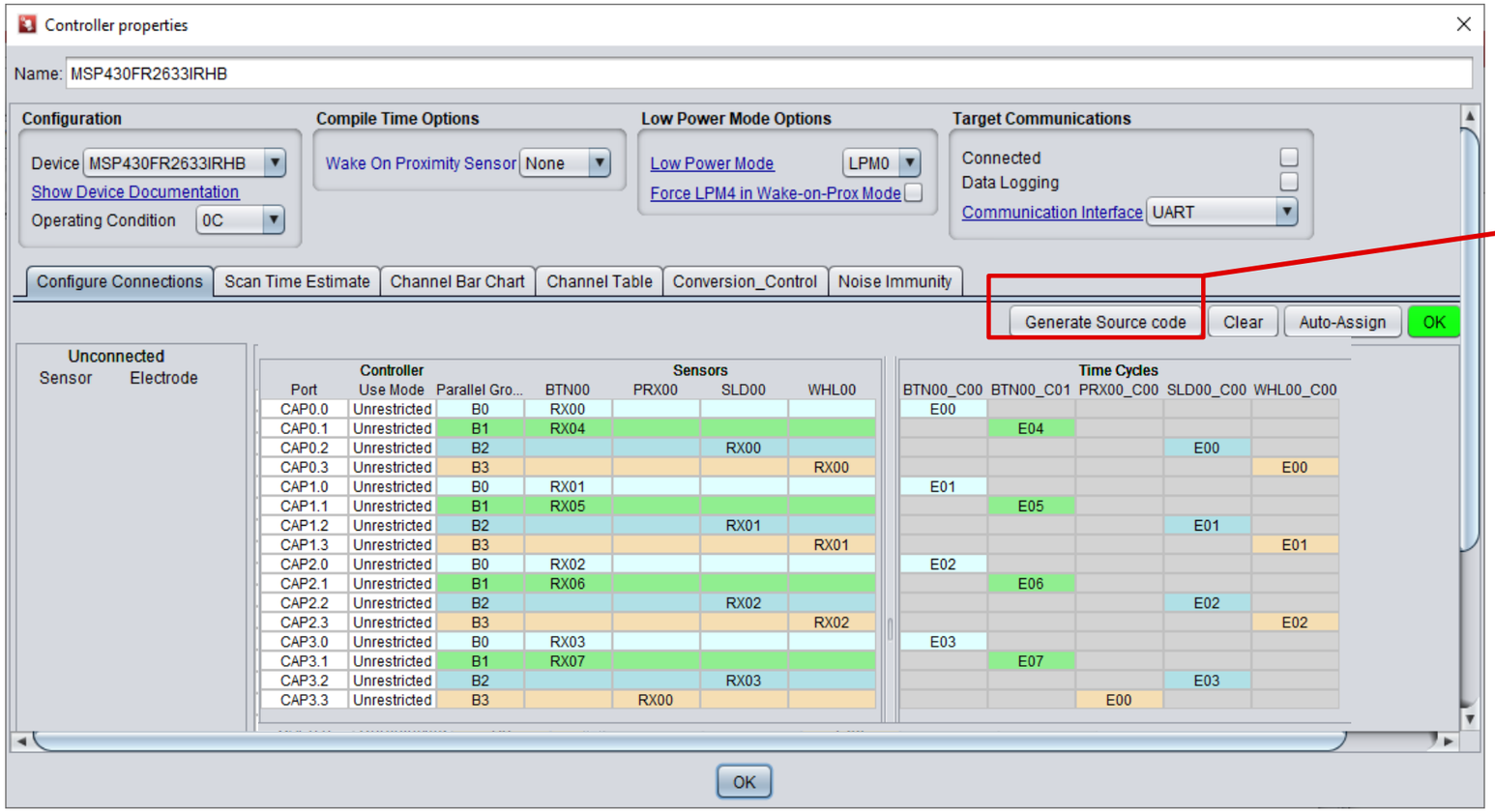


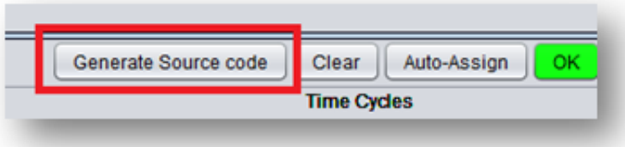


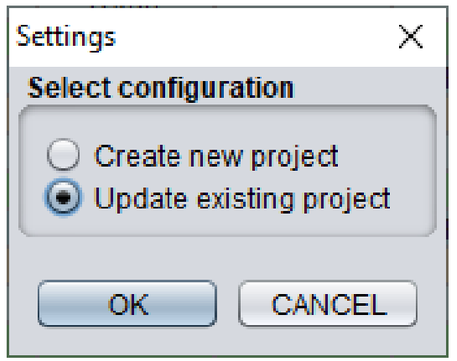
Detachable

CapTIvate Design Center GUI

- Generate final code







Agenda

CapTIvate™ Technology

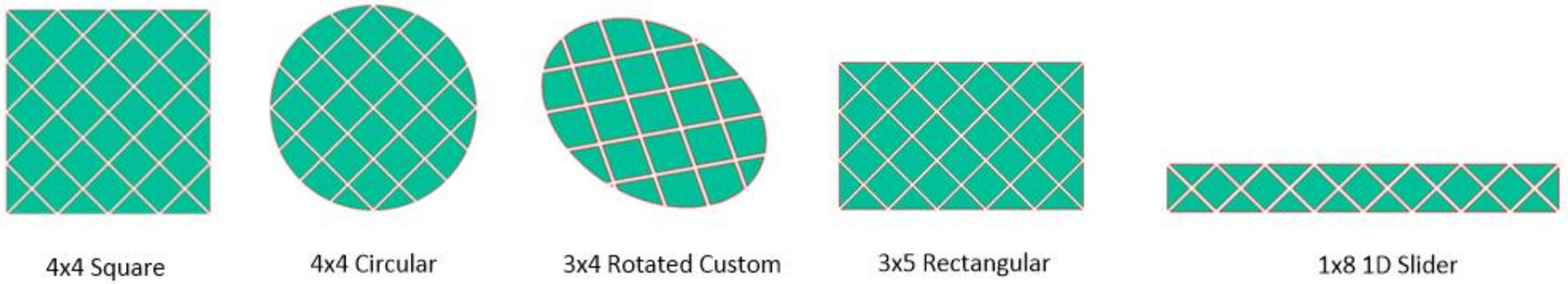
Automating Sensor Designs

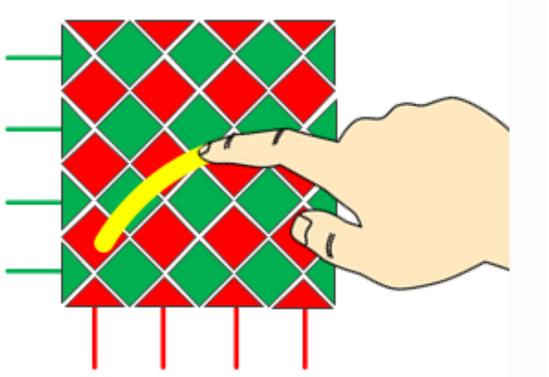
CapTIvate Design Center

OpenSCAD Demo

Design Touchpad using OpenSCAD

- Touchpad is a 2D sensor
- Remote Controls, headphones, earbuds
- Use OpenSCAD to generate diamond patterns





- OpenSCAD Demos

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