TECH DAYS
Texas Instruments

車用超音波距離感測器趨勢與應用指南
Design guide for TI Ultra Sonic Sensor

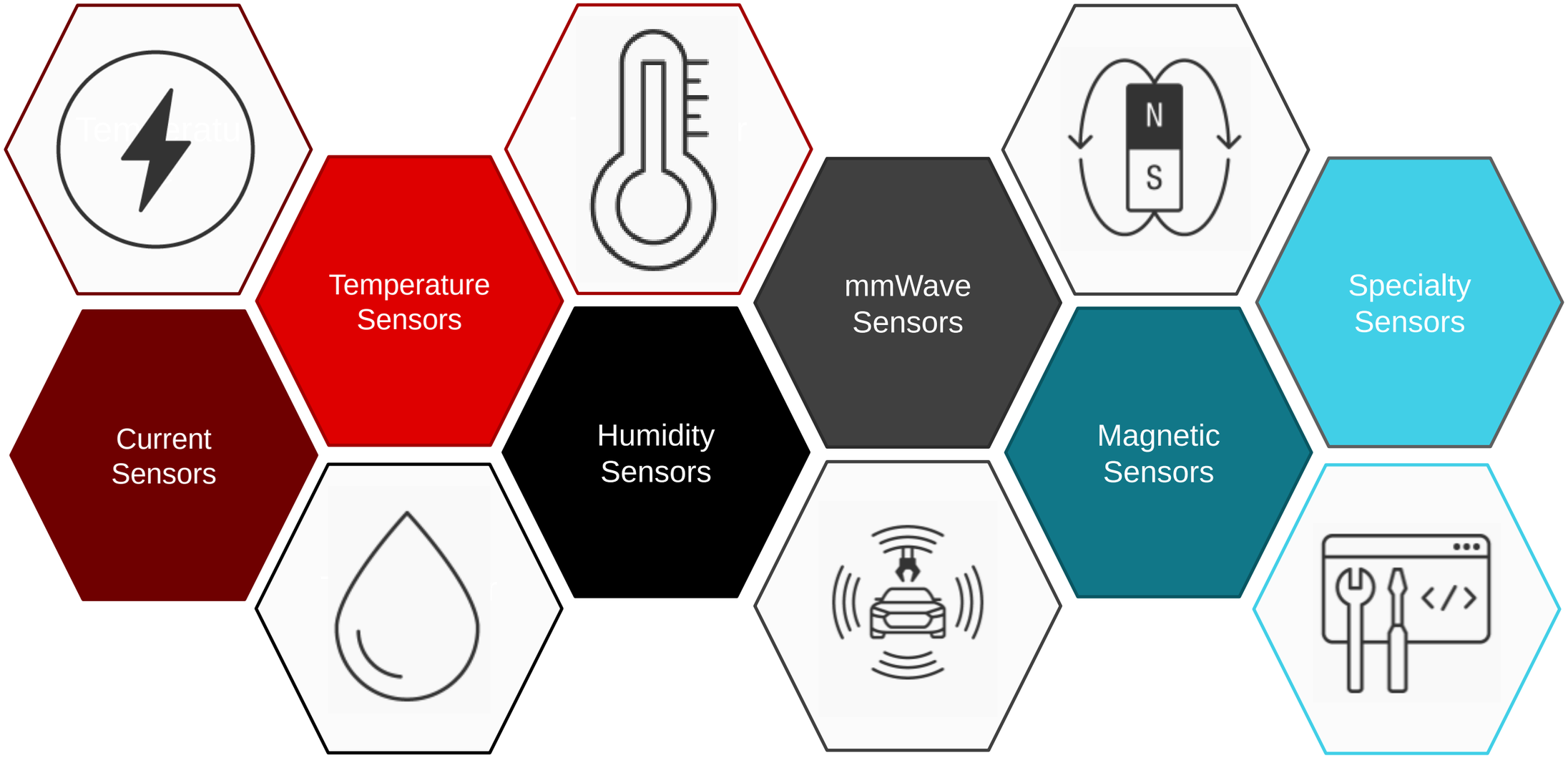
April, 25, 2019

Agenda

- Ultrasonic Sensing Technology Fundamentals
- TI Ultrasonic Sensing Portfolio
  - PGA460-Q1
  - TDC1000-Q1
- Ultrasonic Automotive Systems
  - Park Assist
  - Kick-to-Open
  - Level Detection
  - Powertrain Fluid Concentration
- TI Evaluation Tools and Support
- Q&A

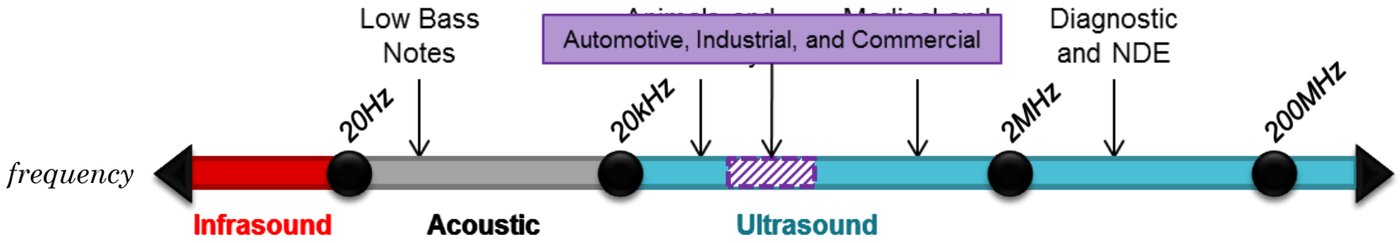
Sensors to build smarter systems

Sensors for today's design challenges and tomorrow's innovations

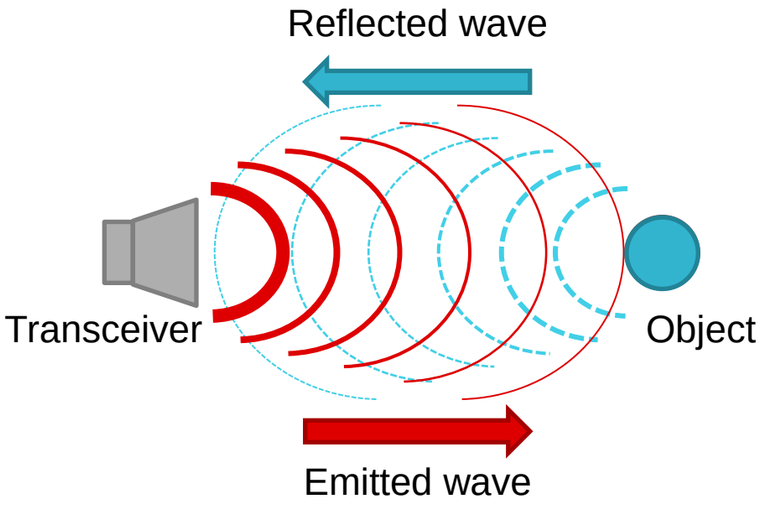


ULTRASONIC SENSING TECHNOLOGY FUNDAMENTALS

Principles of Ultrasound



- **What is ultrasound or ultrasonic?**
  - of or involving sound waves with a frequency above the upper limit of human hearing
- **What is the speed of sound?**
  - the distance travelled per unit time by a sound wave as it propagates through an elastic medium; in dry air at 20 °C (68 °F), the speed of sound is *343 m/s* (767 mph)
- **What is ultrasonic time-of-flight (TOF)**
  - a round-trip time estimation of an ultrasonic wave emitted from the sensor to the targeted object, and then reflected from the object back to the sensor
- **What is an ultrasonic sensor or transducer (XDCR)?**
  - divided into three categories: transmitters, receivers, and transceivers
  - transmitters convert electrical signals into ultrasound, receivers convert ultrasound into electrical signals, and transceivers can both transmit and receive ultrasound



Ultrasonic Module Properties

Transducer Types

Two types of transducers are available: *closed-top* and *open-top.* Type selection should be based on the ambient **ENVIRONMENT** conditions**.** Will the transducer be exposed to dust, rain, mud, dirt, snow, ice, etc.?

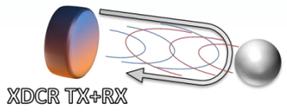
Closed-top	Open-top
• Piezoelectric membrane protected against water (hermetically sealed), heat, and humidity • Constructed to mitigate ESD strikes • **Suitable for outdoor or harsh environments**	• Piezoelectric membrane directly couples to air for increased receiver sensitivity • Small driving voltage to generate maximum SPL • Large off-the-shelf selection for purchase • Low-cost
• Requires large driving voltage enabled by transformer • Limited off-the-shelf selection for purchase • High-cost	• **Limited to indoor or protected environments**

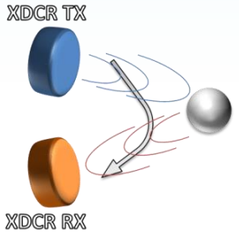
https://www.murata.com/

Topologies

Two transducer topologies are available: monostatic or bistatic. Topology selection should be based on the **short range** requirement**.** Will the system need to reliably detect less than 30cm or nearly 0cm?

Monostatic	Bistatic
• Single transducer element can be transmit echo, and then listen for returning echoes. • No need to consider spacing and angular compensation as with separate elements. • Low-cost and small solution size.	• Dedicated transmitter can generate more SPL. • Dedicated receiver element is more sensitive and receptive of returning ultrasound. • No blind-zone allows for near 0cm detection. • Can be used for trip / intercept applications.
• Excitation's ringing-decay creates an initial blind-zone, limiting minimum detectable range. • Limited to roundtrip TOF applications.	• TOF roundtrip calculation must factor in angle of incoming echo at receiver. • High-cost and larger solution size.

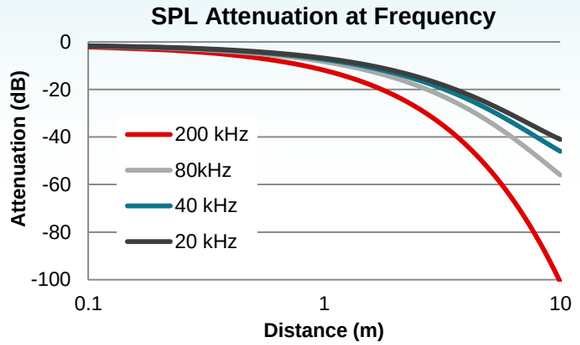




Frequencies

The resonant frequency of air coupled transducers ranges from 30 to 480kHz. Frequency selection should be based on the **resolution** and **long range** requirement.
↑ Frequency :: ↑ Resolution :: ↑ Directivity :: ↑ Attenuation :: ↓ Distance

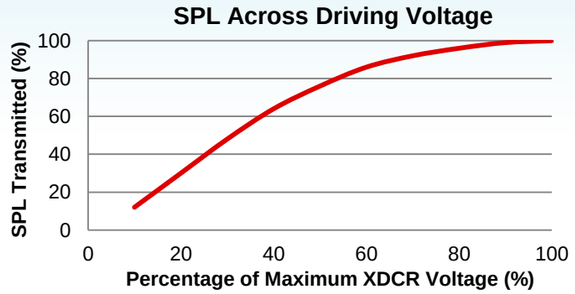
Low (30-80kHz)	High (180-480kHz)
• Maximize long range performance. • Large off-the-shelf selection for purchase.	• Maximize resolution (approximately 1mm). • Short blind-zone in monostatic topology. • Transmission concentrated into forward facing direction (no side lobes).
• Long blind-zone in monostatic topology. • Low resolution (approximately 1cm). • Ultrasonic aggressors likely to be the same frequency.	• Short maximum detectable range. • Limited off-the-shelf selection for purchase .



Driver Strength

Two types of driver-modes are available: *transformer* and *direct*. Driver selection should be based on the transducer's **maximum drive voltage**. What drive voltage will produce sufficient or maximum SPL?

Transformer	Direct
• Able to maximize drive requirements for closed-top transducers (beyond 100Vpp). • Equivalent circuit enables de/tuning for short range. • Fixed and tunable coil types available. • Center-tap push-pull or single-ended available.	• Able to maximize drive requirement for open-top transducers (beyond 6Vpp). • Able to drive closed-top transducer for short range applications. • Half-bridge or full-bridge drive topology available. • Low-cost and small footprint.
• Additional calibration required at mass production • High-cost and large footprint	• Short range tuning limited to damping resistor due to lacking inductive element

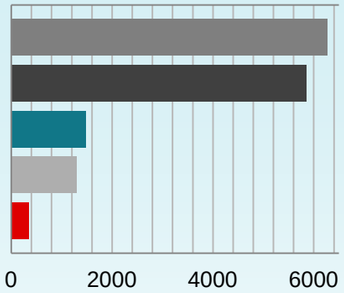


Target and Environmental Properties

Transmission Medium

- Ultrasound waves can travel through a wide variety of media (gases, liquids, solids) to detect objects with mismatched acoustic impedances.
- Ultrasound attenuation in air increases as a function of frequency and humidity. Therefore, **air coupled ultrasound is typically limited to frequencies below 500kHz** due to excessive path loss/absorption in air.
- Liquid and solid applications can utilize transducers into the low MHz range for high-accuracy applications.

Speed of Sound through Different Media (m/s)



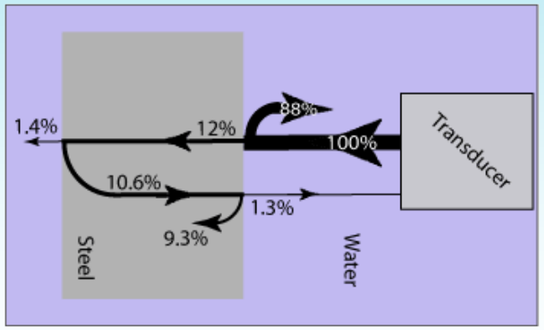
Aluminum (20°C)	6260
Iron (20°C)	5850
Water (20°C)	1481
Petroleum (34°C)	1290
Air (20°C)	343

Acoustic Impedance

Acoustic impedance (Z) is a measure of the opposition that a system presents to the acoustic flow resulting of an acoustic pressure applied to the system. This difference in Z is commonly referred to as the **impedance mismatch**. The greater the impedance mismatch, the greater the percentage of energy that will be reflected at the interface or boundary between one medium and another.

Material	Density (kgm^{-3})	Acoustic Velocity (ms^{-1})	Acoustic Impedance ($kgm^{-2}s^{-1}x10^6$)
Air	1.3	330	0.000429
Water	1000	1450	1.45
Muscle	1075	1590	1.70
Al.	2700	6320	17.1
Iron	7700	5900	45.43
Steel	7800	5900	46.02
Gold	19320	3240	62.6

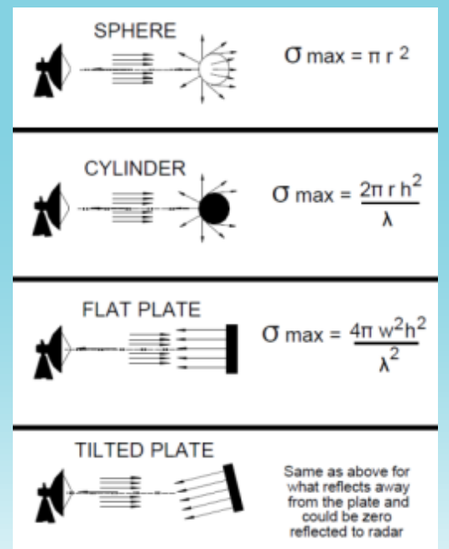
$$Relfection\ Coefficient = R = \left(\frac{Z_2 - Z_1}{Z_2 + Z_1}\right)^2$$

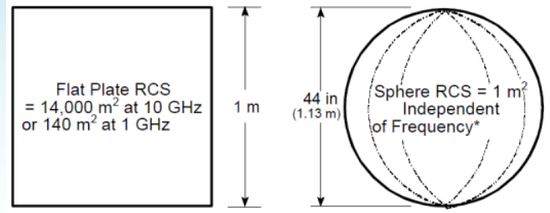


https://www.nde-ed.org/EducationResources/CommunityCollege/Ultrasonics/Physics/reflectiontransmission.htm

Radar Cross Section

Radar cross section (RCS) is the measure of a target's ability to reflect radar signals in the direction of the radar receiver. The conceptual definition of RCS includes the fact that not all of the radiated energy falls on the target.
A target's RCS (σ) can be visualized as the product of three factors:
σ = **Projected cross section** x
Reflectivity x **Directivity**





http://www.rfcafe.com/references/electrical/ew-radar-handbook/radar-cross-section.htm

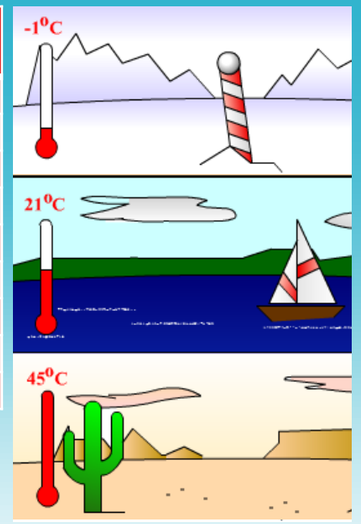
Ambient Conditions

- Temperature is the primary condition that affects the speed of sound. Molecules at higher temperatures have more energy, thus they can vibrate faster. Since the molecules vibrate faster, sound waves can travel more quickly.

$$v_{sound}\ (m/s) = 331m/s + [0.6m/s/\,℃ * Temperature(℃)]$$

- As humidity increases, so does the speed of sound. Dry air absorbs far more acoustical energy than does moist air. This is because moist air is less dense than dry air.

T (°C)	v_{sound} (m/s)
-40	307
-20	319
0	331
20	343
40	355
60	367
80	379
100	391
120	403



https://www.nde-ed.org/EducationResources/HighSchool/Sound/tempandspeed.htm

Competing Sensor Technologies

Sensor Type	Ultrasonic	Passive Infrared	mmWave	Optical TOF
Effective Distance	**0.1 to 10 m**	0.1 to 5 m	**0 to 100+ m**	0 to 10 m
Resolution	**5 to 10 mm**	5 cm	<5 cm	**1 mm**
Typical Frequency	40 kHz – 4 MHz	38 kHz	24-94 GHz	10-100 MHz
Current	**7-12 mA**	**< 5 mA**	>1000 mA	16-18 mA
Sensor Type	Mono- or Bi-static piezoelectric or electrostatic transducer	Infrared Emitting Diode (IRED) and Position Sensitive Detector (PSD)	Frequency-Modulated Continuous-Wave Radar (FMCW Radar)	Range Imaging Time-of-Flight Camera (Scannerless LIDAR)
Cost ($ for IC)	**Low ~$1.65**	**Low ~$0.40**	High (24.00)	Mid (3.00-4.00)
Cost ($ for solution)	**Low ($2-3)**	**Low ($0.60-2)**	High (24.00)	Mid (3.00-4.00)
Comments	• Limited performance against absorbent material • Robust in environmental stress	• Limited performance in high temperature environments and corner regions • Insensitive to slow motion	• Presence of electrical towers/electromagnetic hotspots can cause interference	• Limited performance with ambient light or reflective/glossy materials

TI ULTRASONIC SENSING PORTFOLIO

TI Ultrasonic Sensing Solutions

Proximity

Highly integrated automotive park assist solution for wide detection range

Flow

Accurate flow measurement with Ultra-Low power consumption

Level

Analog front end for fluid level and concentration measurement

Imaging

Multi-channel Ultrasonic analog front end for medical imaging

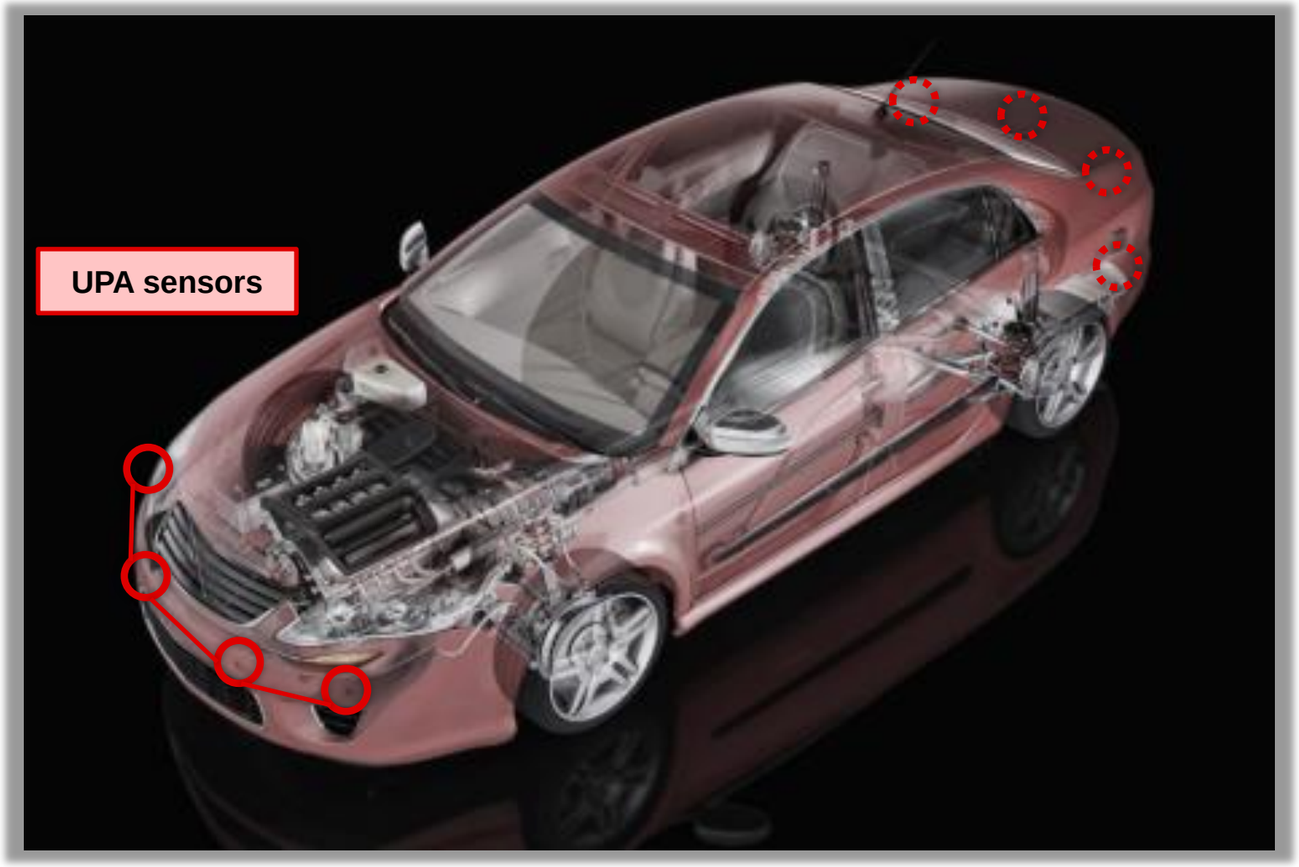
TI Ultrasonic Park Assist Journey

TI began development of ASICs in 2007 entering the Ultrasonic Park Assist market

2012
TI's first generation PGA450-Q1 ultrasonic park assist IC goes into production vehicles

2017
TI released it's 2nd generation IC – **PGA460-Q1** delivering exceptional performance and lowering system cost

2018-19
TI is accelerating its development on next generation UPA ICs which will result in a family products to address advanced park assist functions in next generation entry level to fully autonomous vehicles



PGA460-Q1

Ultrasonic Signal Processor and Transducer Driver

In Production

Features

- Distance: 20cm – 5m (automotive ISO pole);
  5cm – 11m (non-auto)
- Transducer Frequency: 30kHz – 80kHz , 180kHz - 480kHz
- Wide Dynamic Analog Gain : 32dB to 90dB
- Wide Transformer current drive : 30mA -500mA
- Integrated Accurate Temperature Sensor (<± 5°C error)
- Interface: 1-Wire UART or Time Command Interface (TCI)
- Operating Temperature: -40 to 105 °C, AEC Q-100 Qualified
- Package: 16-pin TSSOP

Applications

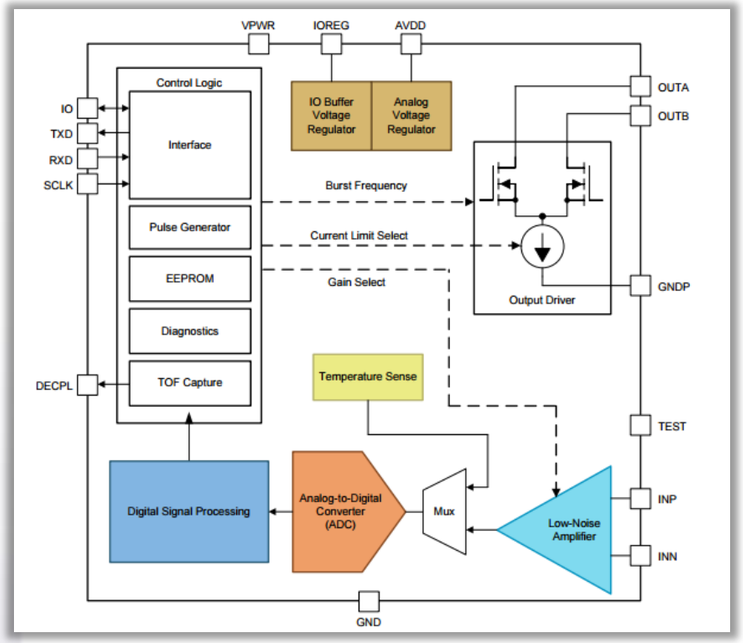
- Automotive Park Assist
- Automotive Blind Spot Detection
- Automotive Door Opening/List-Gate Sensing
- Automotive Intrusion Detection Alarm

Tools & Resources

- PGA460 Datasheet
- PGA460 EVM Training Video Series
- PGA460 Schematic and Layout examples
- BOOSTXL-PGA460 : EVM
- TIDA-01597 : Reference Design for Park Assist
- TIDA-01424 : Reference Design for Kick-to-Open

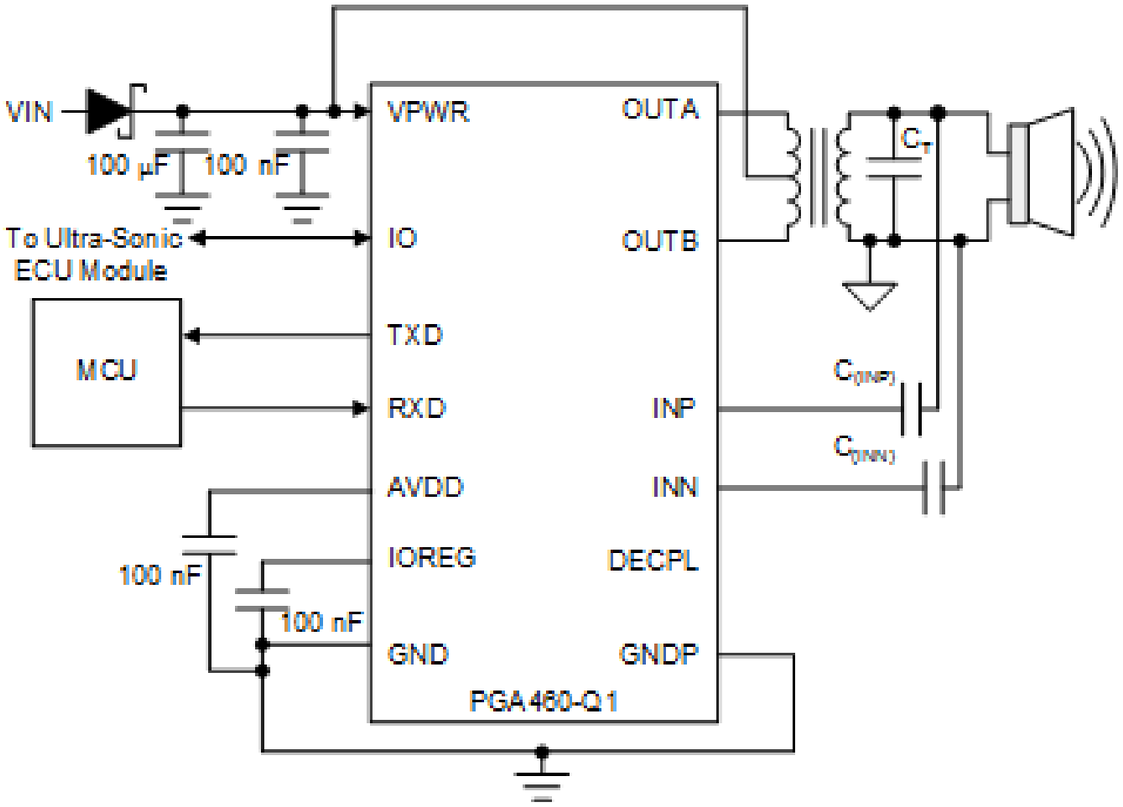
Benefits

- Can meet Automotive Park Assist OEM and Tier 1 requirements of 20cm – 5m+ detection
- Integrated System Diagnostic
  - Transducer Frequency / Voltage / Decay period
  - Noise Measurement
  - Echo Data Dump Function
- Flexible transducer frequency range allows for the device to drive and receive with a wide range of transducers
- Cost competitiveness

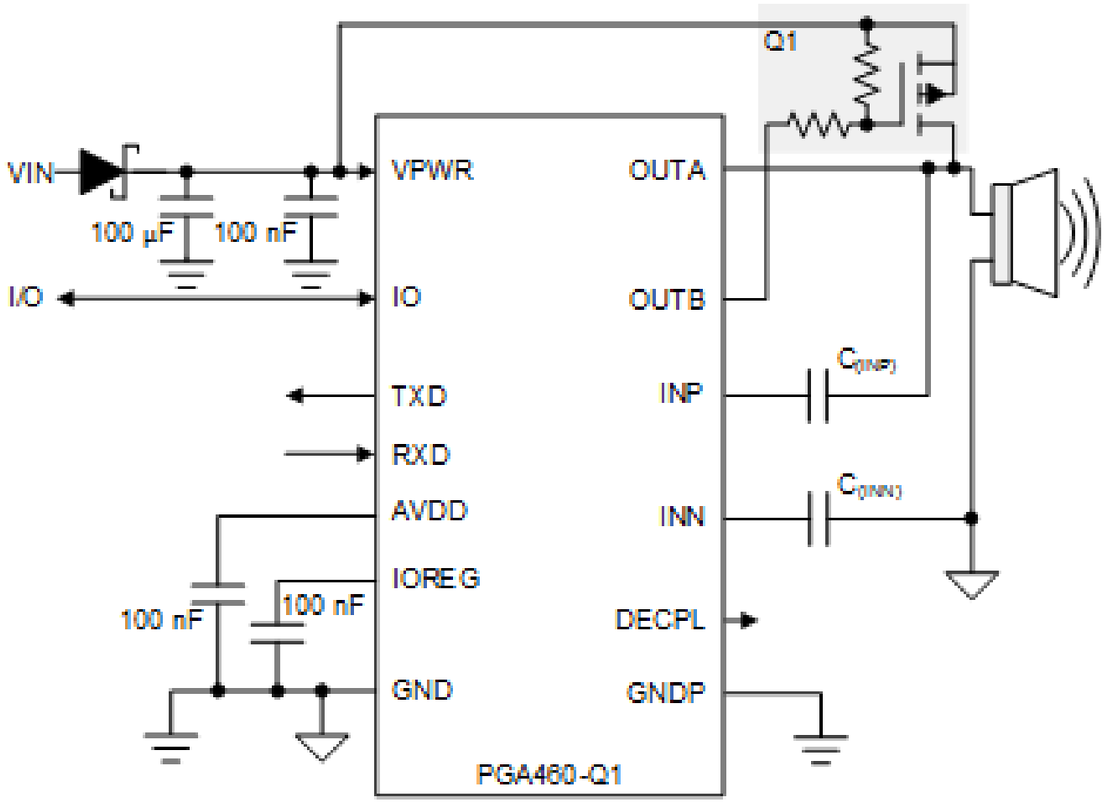


ULTRASONIC AUTOMOTIVE SYSTEMS

PGA460-Q1 Ultrasonic Module Solution



TRANSFORMER



DIRECT-DRIVE

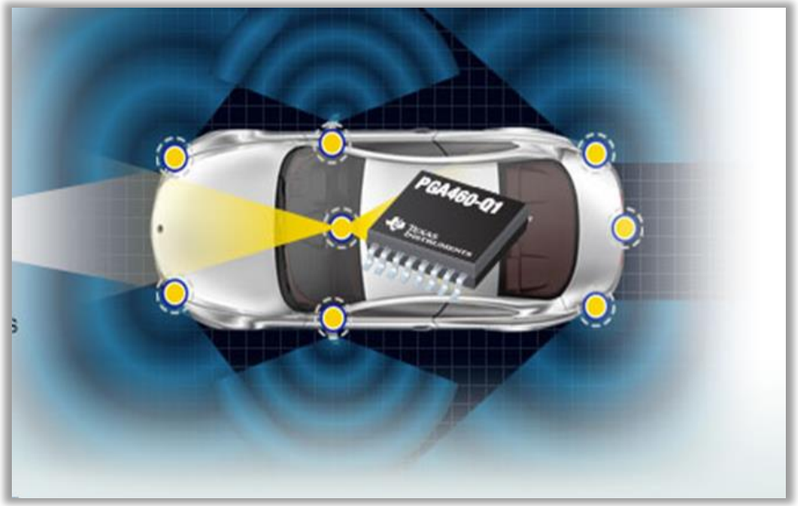
Ultrasonic Parking Assist

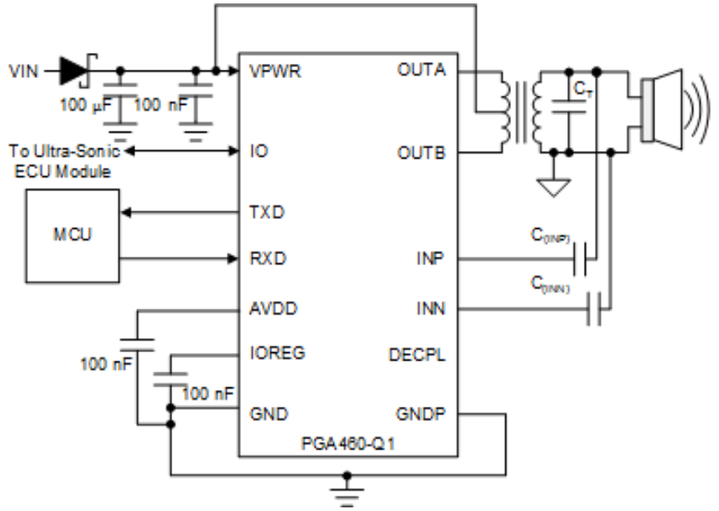
EE Requirements

- Cost-competitive, fully integrated SoC
- Object detection from 20cm to 5m
- TCI or LIN communication from module to local ECU (STAR) or directly to the BCM (BUS)

TI Value Proposition

- A combination of strong AFE performance, Time Varying Gain (TVG) and digital gain features allow for consistent object detection from 20cm – 5m
- Sensor Diagnostics (Decay Frequency and Time, Excitation Voltage), Supply, and Transceiver Diagnostics
- Cost competitive solution





Want to learn more? Check out these links:

- PGA460-Q1 Datasheet
- PGA460-Q1 EVM Training Video Series
- PGA460-Q1 Schematic and Layout examples
- BOOSTXL-PGA460 : EVM
- TIDA-01597 : Automotive Ultrasonic Sensing Module Reference Design for Park Assist

TIDA-01597

Automotive Ultrasonic Sensing Module Reference Design for Park Assist

Features

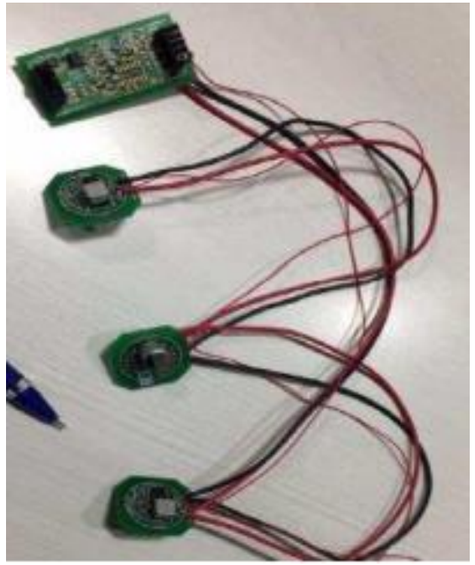
- Combines up to eight PGA460-Q1 devices to detect objects from 20 cm to 5.0 m
- Provides system diagnostic information
- Circuitry for level OWU/USART and TCI interface option included
- 22-mm diameter solution size

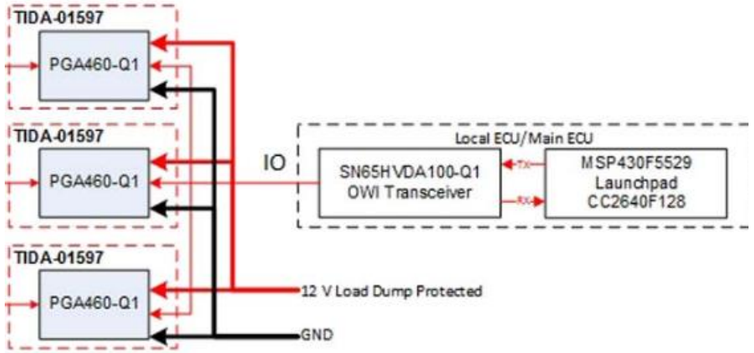
Benefits

- TIDA provides hardware architecture for park assist
- Ranging capabilities
  - Reliably detects far (5m) and close (20cm)
- PGA460 can be put in ultra-low quiescent current low-power mode to reduce power when not in use and be woken up by commands on communication interfaces

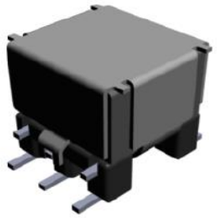
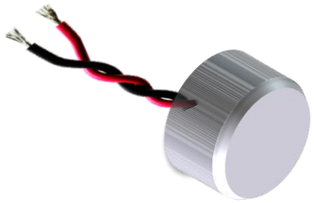
Tools & Resources

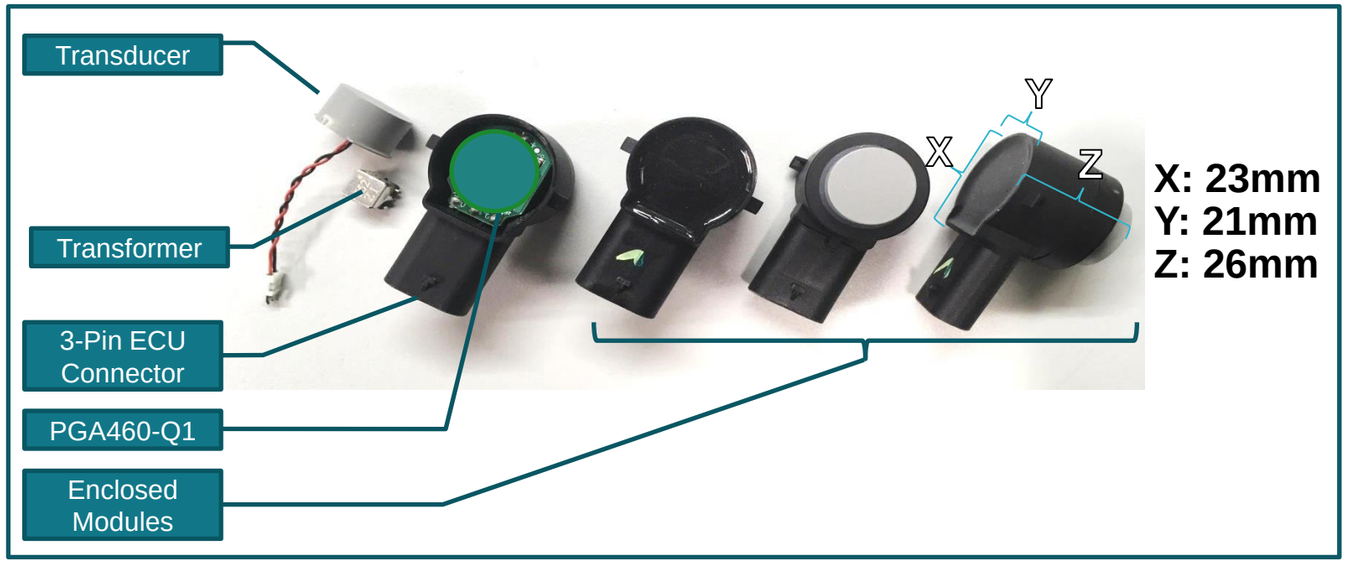
- TIDA-01597 Design Guide
- TIDA-01597 Design Files
- Automotive Ultrasonic Sensing for Park Assist User Guide
- Ultrasonic Park Assist Reference Design Solution Page





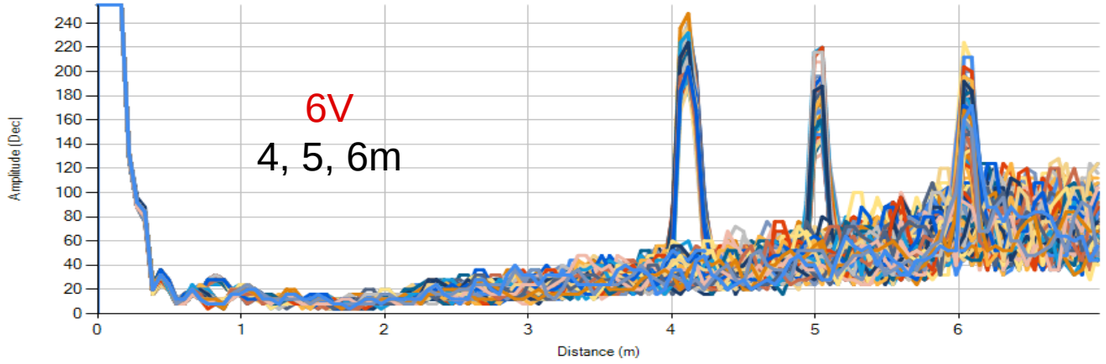
PGA460-Q1 Ultrasonic Module in Production

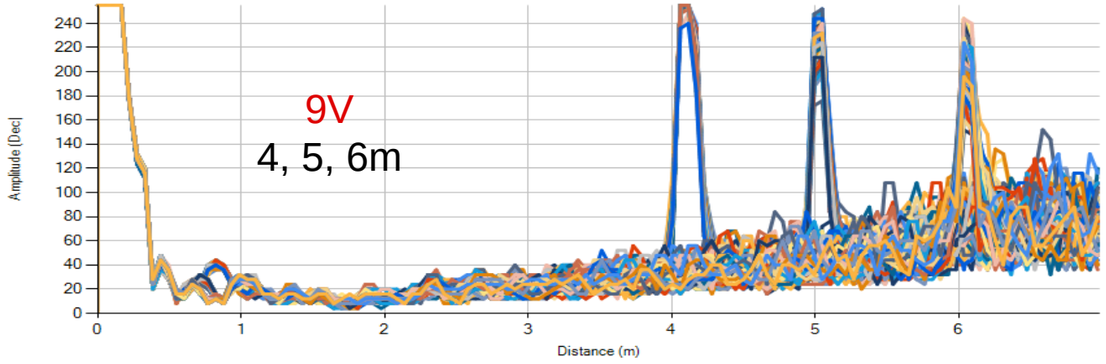
 Integrated Driver and Signal Conditioner	 Transformer	 Transducer

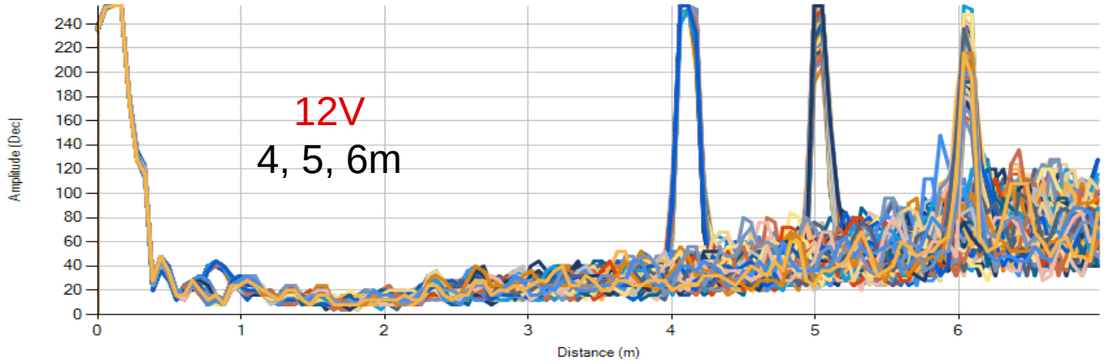


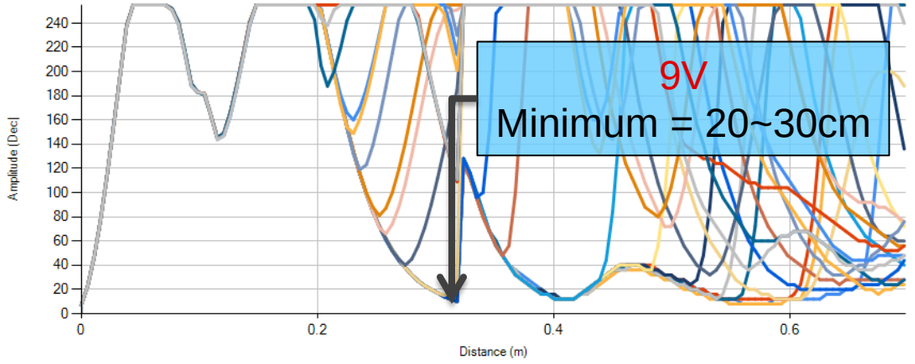
PGA460-Q1 Automotive Park Assist Typical Performance

Long Range Burst Configuration

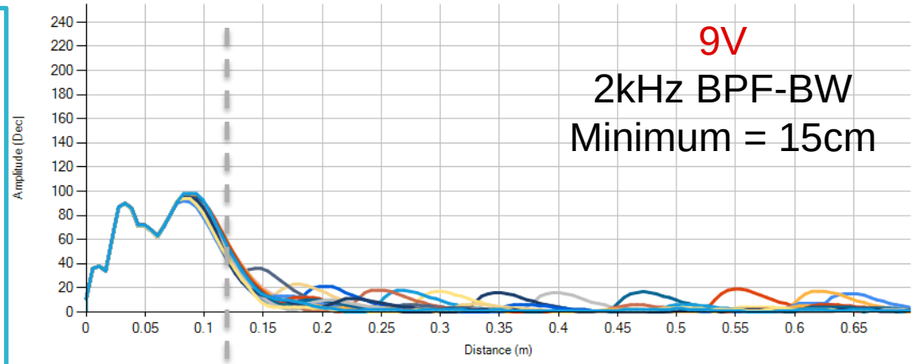


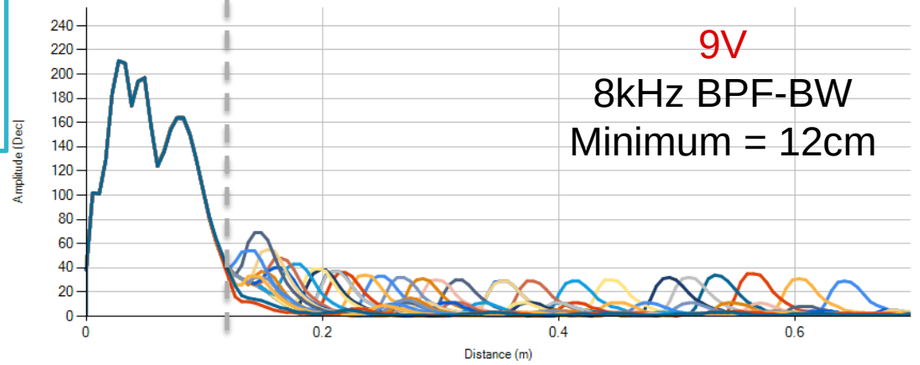






Single Burst Configuration





Kick-to-Open/Smart Trunk Opener

EE Requirements

- Ability to detect objects from 15cm – <1m
- Low system quiescent current
- Ability to operate off of a 12V car battery supply

TI Value Proposition

- Superior near-field object detection vs. competitors
- Smaller, easier to use, and more cost effective than discrete solutions
- Offers both transformer drive and direct drive options in one chip (PGA460-Q1)
- BU has more system knowledge and experience with kick-to-open applications than competitors, demonstrated through strong content on TI.com

Key collateral for winning:

- PGA460-Q1 Datasheet
- PGA460-Q1 EVM Training Video Series
- PGA460-Q1 Schematic and Layout examples
- BOOSTXL-PGA460 : EVM
- TIDA-1424 : Automotive Ultrasonic Kick-to-Open Reference Design

TIDA-01424
Automotive Ultrasonic Kick-to-Open Reference Design

Features

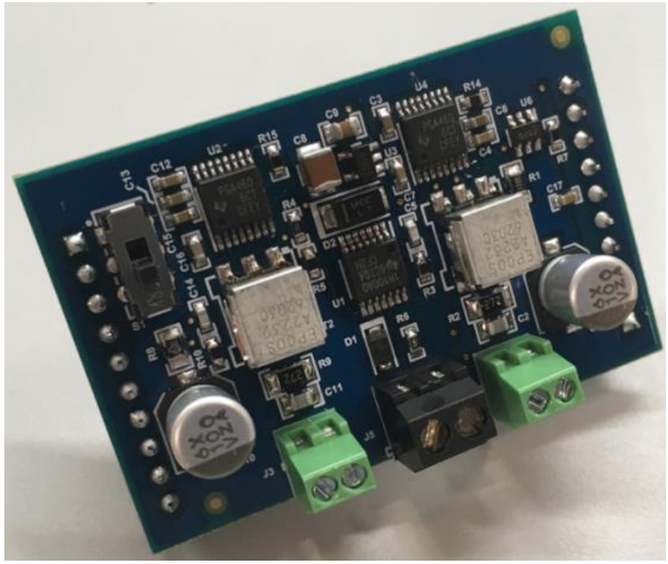
- Detects foot motion for hands-free trunk, lift-gate, or door operation
- Two ultrasonic sensor channels
  - Differential measurements: immune to EMI
- Operates from a 12V automotive battery
  - Survives reverse-battery & load-dump faults
- Detects kicks for distances up to 50cm
  - Sensitivity to identify small changes
- Design has been tested and includes schematics, layout and test results

Benefits

- Simple design id cost-effective for automotive body applications
  - Compact 2 layer board
- Can be used on variety of vehicles without adjustment
- Low current drain from battery while inactive
- Includes protection against common electrical power faults

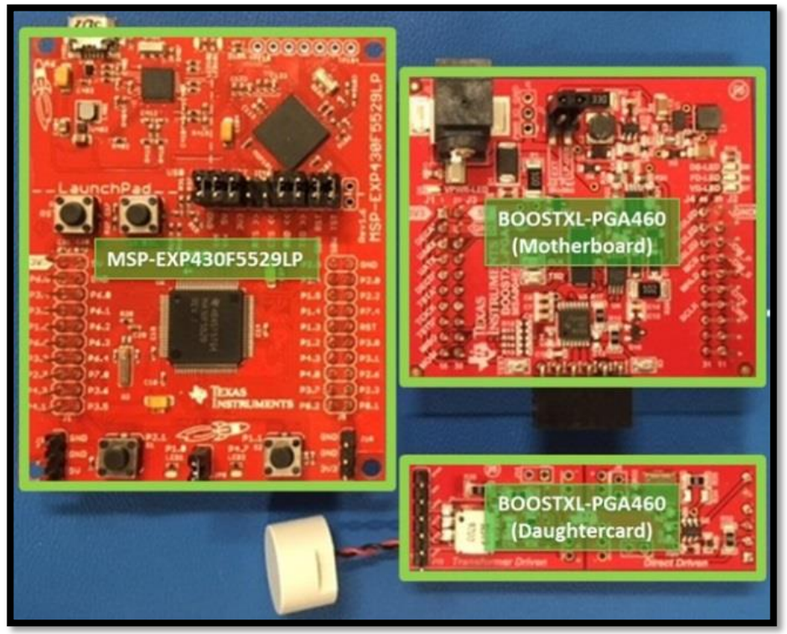
Tools & Resources

- TIDA-01424 Design Guide
- TIDA-01424 Design Files
- Automotive Ultrasonic Kick-to-Open User Guide

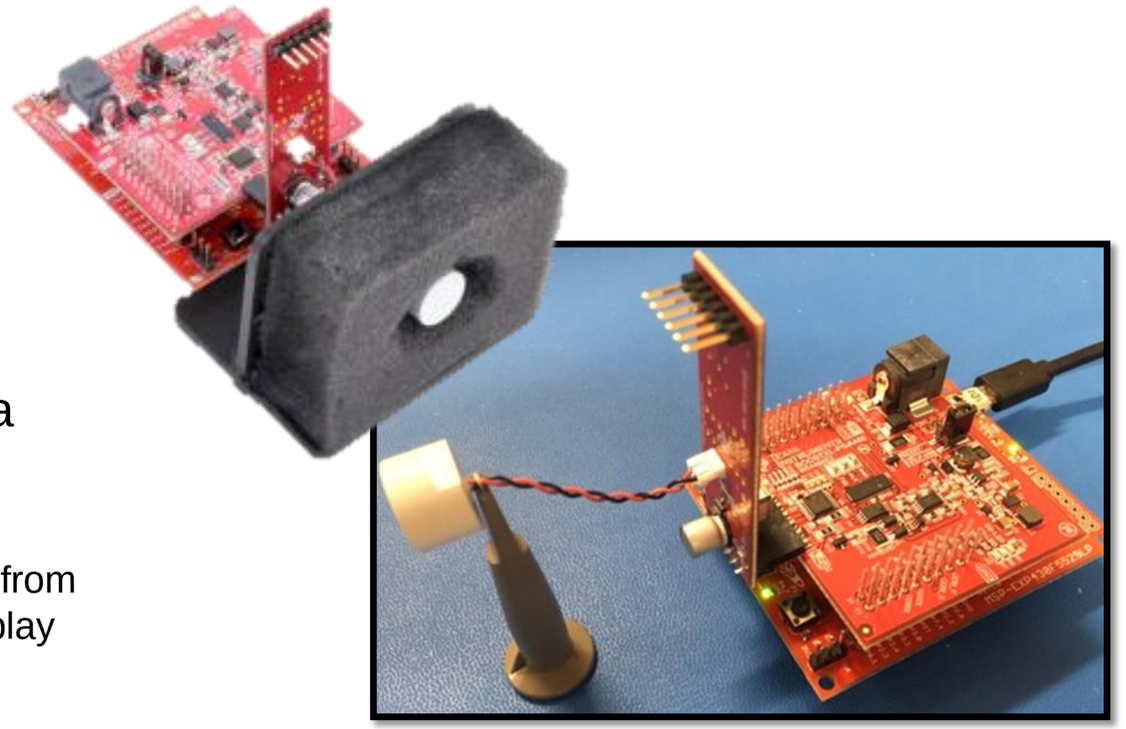


TI EVALUATION TOOLS AND SUPPORT

BOOSTXL-PGA460 EVM



- The **BOOSTXL-PGA460** is a fully assembled evaluation module (EVM) designed for the combined evaluation of the PGA460-Q1 ultrasonic-sensor signal conditioner IC, an ultrasonic transducer, and center-tap transformer or bridge driver.
  - Due to the two driver options, the user has the ability to evaluate any two pin, open or closed top ultrasonic transducer in the operating frequency range of 30 to 80 kHz, or 180 to 480 kHz.



- The accompanying ***MSP430F5529 LaunchPad™ Development Kit*** is used as the USB-to-PC GUI communication bridge, and example implementation of a master MCU to communicate with the PGA460-Q1 via USART or IO interfaces.
  - The MSP-EXP430F5529LP is controlled by commands received from the BOOSTXL-PGA460 GUI, and returns data to the GUI for display and further analysis

BOOSTXL-PGA460 GUI

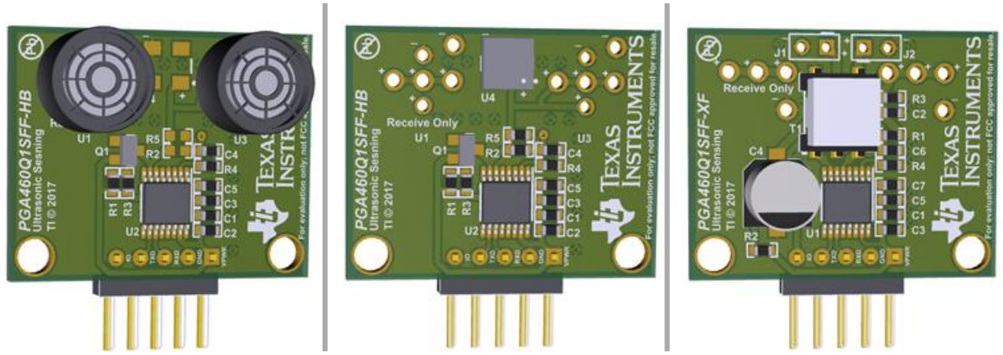
Graphical User Interface for the BOOSTXL-PGA460 EVM enables customers to:

1. Optimize the driver, AFE, and DSP settings for any specific transducer and use-case
2. Configure threshold timing and levels for accurate echo detection and calculation of target distance, width, and amplitude
3. Configure time-varying gain settings for minimal ringing-decay saturation, and maximum scaling of SNR for long distance targets
4. Configure and monitor system diagnostics
5. Alternatively communicate to and evaluate the PGA460-Q1 using TCI or OWU
6. Read and write register values on a bit level
7. One-Wire UART Bus Bumper Graphical Demo

End-Equipment Size Reference Designs

PGA460Q1SFF reference designs are examples of the single-sided small form factor (SFF) size PGA460 solutions, available as three variants:

- a transformer driven twisted-pair closed-top transducer
- a half-bridge driven surface mount open-top transducer
- a full-bridge driven radial lead bi-static transducer pair

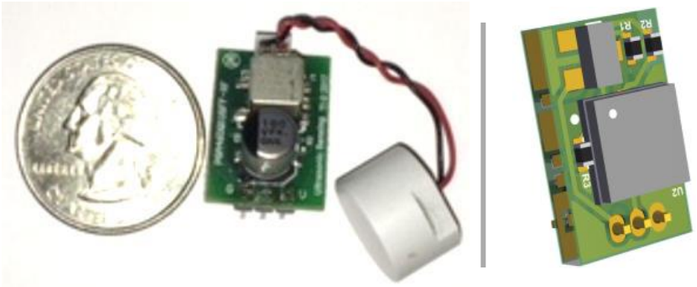


- Evaluation options include:
  - access to UART TXD and RXD pins, and IO pin for TCI or OWU
  - mono-static or bi-static transducer configurability
  - Mounting holes for bracket installation

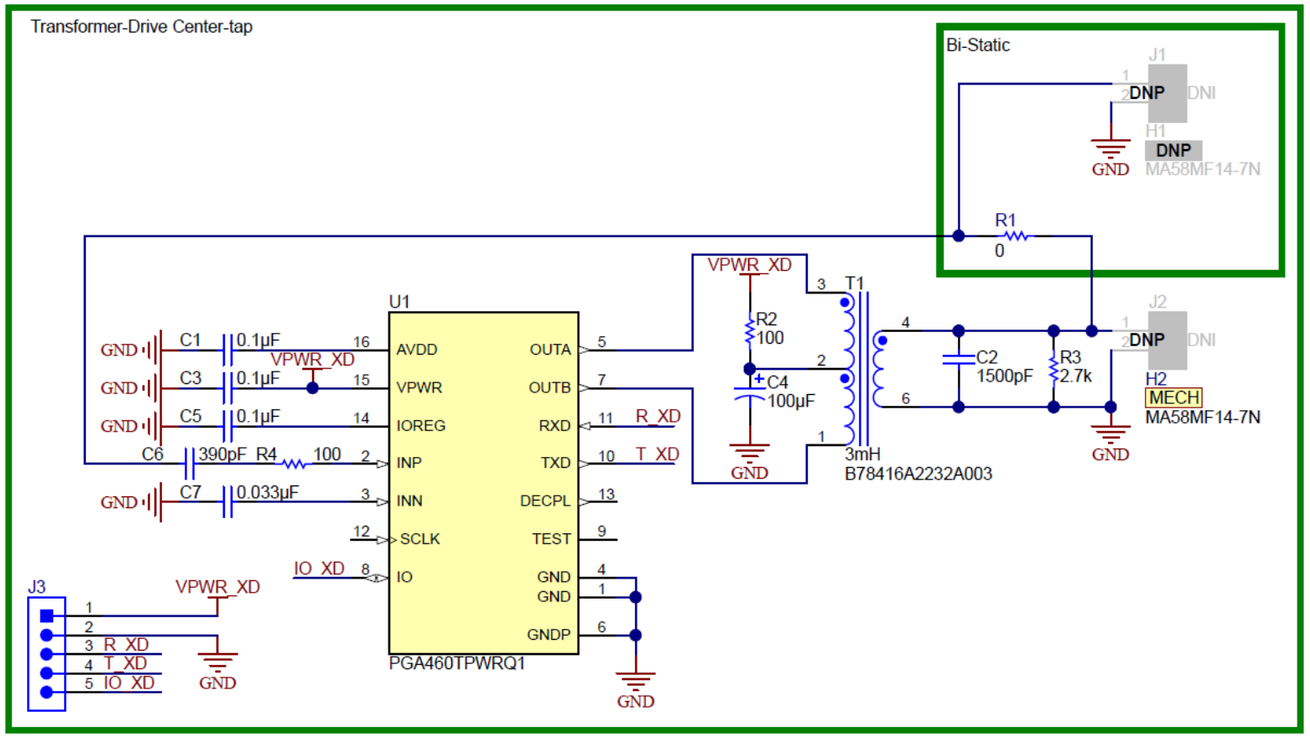
PGA460Q1USFF reference designs are examples of ultra small form factor (USFF) size PGA460 solutions, available as two variants:

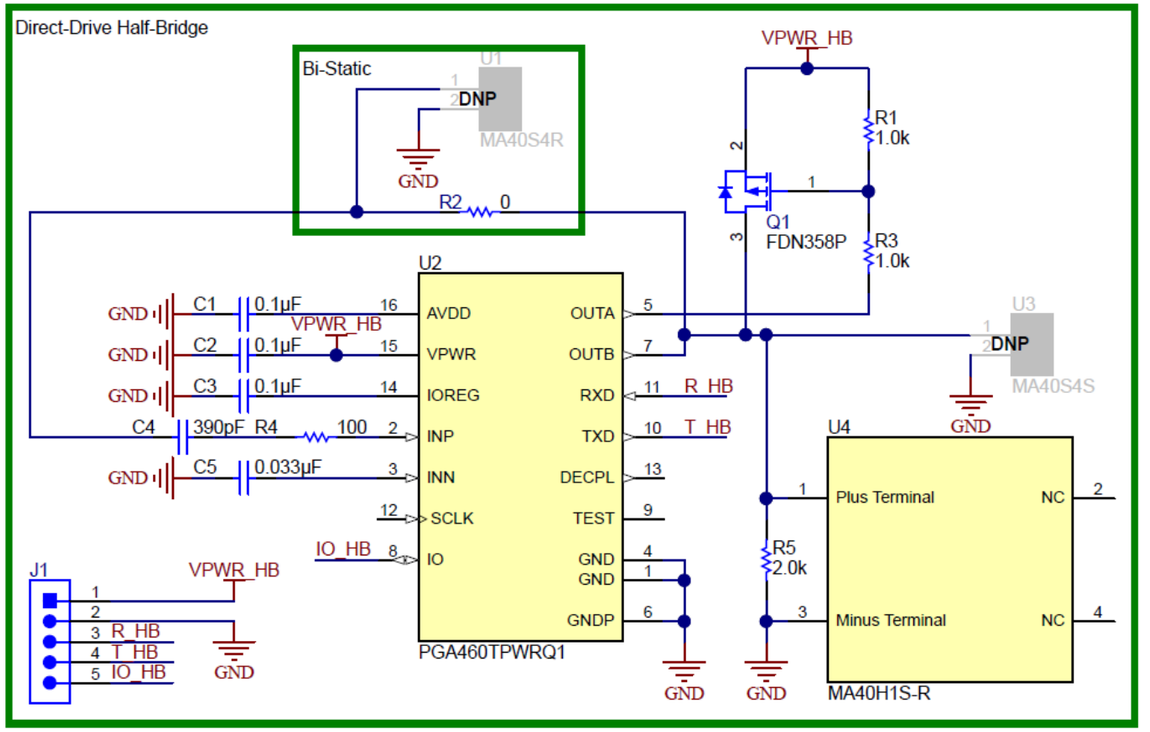
- a transformer driven twisted-pair closed-top transducer
- a half-bridge driven surface mount open-top transducer

- To minimize the connector pinout, only power, ground, and IO are routed



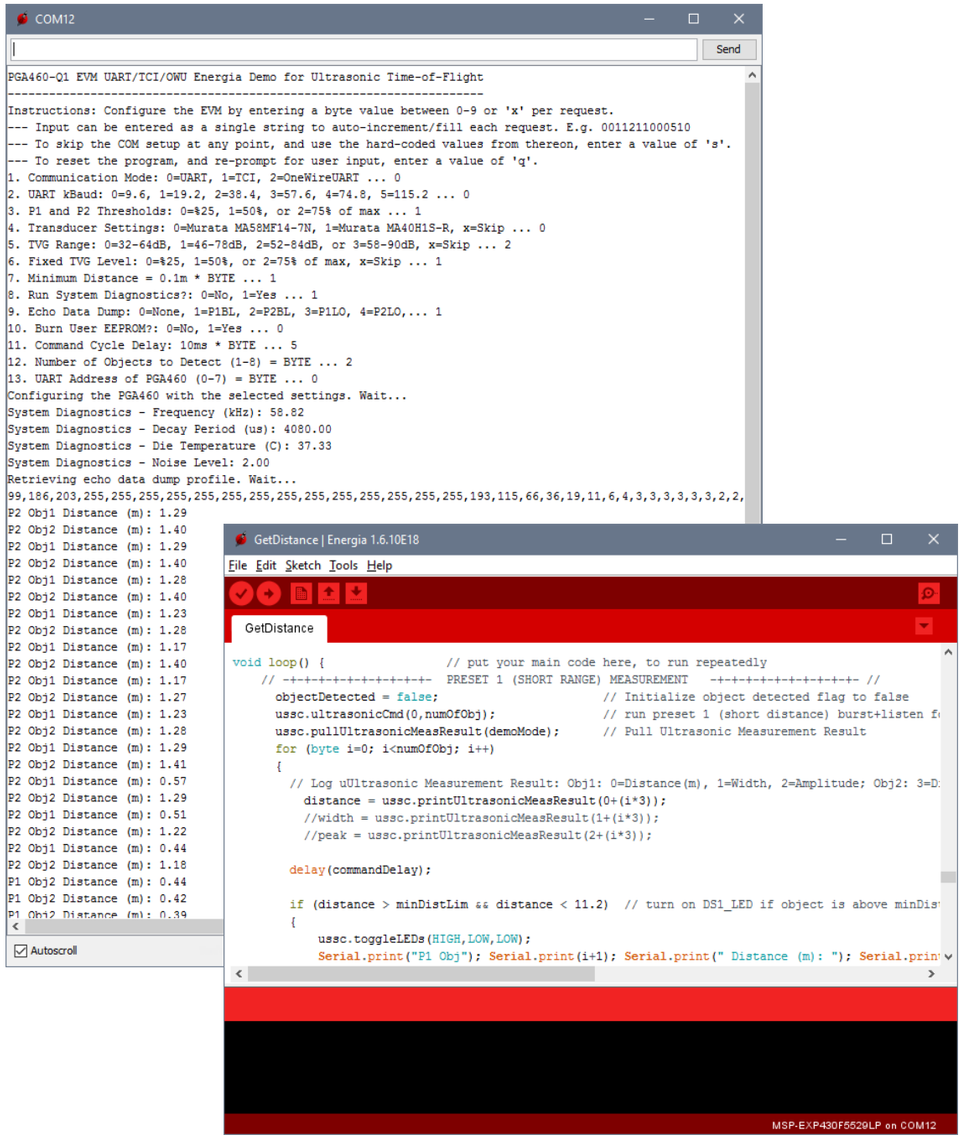
Small Form Factor Reference Design Schematics



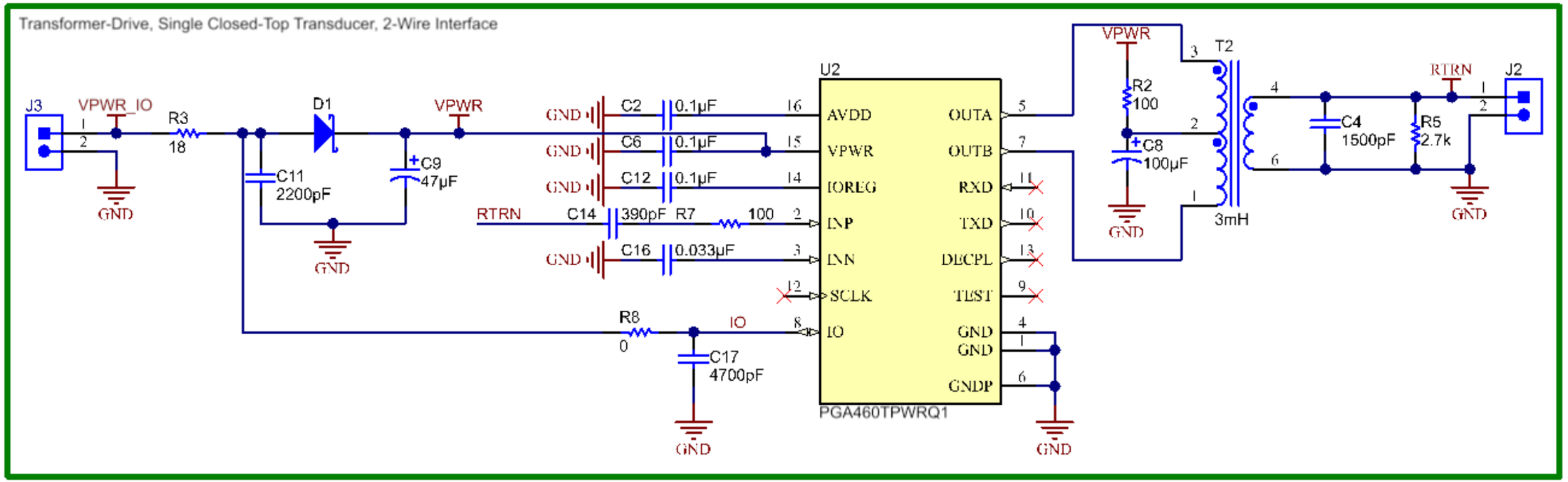


Example Demo Software for PGA460 Systems

- Master controller example software includes support for all available PGA460 communication modes:
  - Asynchronous UART
  - Time Command Interface
  - One-Wire UART (LIN-like)
  - Synchronous UART (SPI-compatible)
- Examples are created for the Energia ecosystems of TI LaunchPad MCUs to enable re-use of the PGA460 EVM's MSP-EXP430F5529LP, and demonstrate how to:
  - Configure the device settings/registers
  - Use the ultrasonic measurements results or echo data dump to monitor ultrasonic activity
  - Use the system diagnostic features
  - Evaluate a bus topology of up to eight devices for the UART and OWU communication modes
  - Use a transceiver and receiver-only module pair for object triangulation and tracking



2-Wire Ultrasonic Sensor Module for PGA460-Q1



where the add-on components from the original small form factor solution required enable the two-wire interface are as follows:

- R3 = Serial current-limiting supply resistor (alternative = inductor for EMC)
- D1 = Reverse polarity protection diode
- C9 = Reservoir capacitor for VPWR
- C11 = blocking supply capacitor (optional)
- R8 = Serial resistance for IO line (optional; placeholder for additional resistance or inductance)
- C17 = Capacitor for IO line (optional)

Relevant Tools & Resources for PGA460-Q1
Get started with TI's ultrasonic sensing technology

App Notes

- PGA460 Full-Bridge Driver Solutions for Ultrasonic Transducers
- PGA460 Software Development Guide (Rev. A)
- PGA460 Frequently Asked Questions (FAQ) and EVM Troubleshooting Guide
- PGA460 Ultrasonic Module Hardware and Software Optimization

E2E/Blog Posts

- Use Ultrasonic sensing for graceful robots
- Where are ultrasonic sensors used? – Part 1
- Where are ultrasonic sensors used? – Part 2
- How ultrasonic technology improves convenience and performance in home automation
- Everything You Need to Know for Ultrasonic ToF (Air-Coupled)

Videos

- Ultrasonic Sensing with the PGA460-Q1
- Ultrasonic Sensing Training Series
- PGA460 ultrasonic sensing: EVM hardware, transducer, and driver selection

TI Designs/EVMs

- PGA460-Q1 Ultrasonic Sensor Signal Conditioning EVM With Transducers
- Ultrasonic Distance Sensor with IO-Link Reference Design

TDC1000-Q1

Ultrasonic Analog-Front-End for Level, Concentration, and Flow Applications

In Production

Features

- Operating current: 1.8 uA (2 SPS)
- Programmable Features:
  - 2Ch : TX1/TX2 Excitation: 31.25 kHz to 4 MHz, up to 31 pulses
  - Low-noise and programmable gain amplifiers
  - Programmable threshold comparator for echo qualification
- Other Key Specs:
  - Measurement range: up to 8ms
  - RTD-to-RTD matching accuracy 0.05°C
- Available in AEC-Q100
- Package: 9.7 x 4.4 mm, TSSOP

Applications

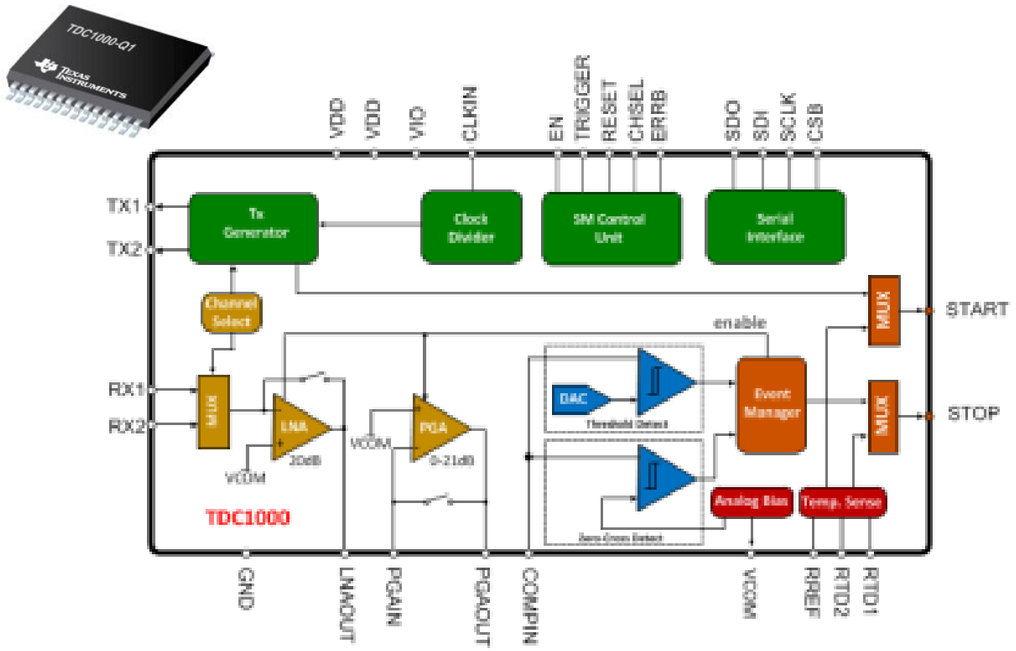
- Fluid level
- Fluid identification / concentration
- Flow metering: water, gas, heat
- Distance / proximity

Tools & Resources

- TIDA-00322 : Automotive Ultrasonic Fluid Level/Quality Ref Design
- TIDM-ULTRASONIC-FLOW-TDC : Ultrasonic Water Flow Meter Design
- TDC1000-C2000EVM : Ultrasonic for Level and Concentration EVM
- TDC1000-GASEVM : Ultrasonic Sensign Gas Flow EVM
- TDC1000-TDC7200EVM : Ultrasonic Water Flow/Level/ Concentration EVM

Benefits

- Low power consumption saves battery replacement costs due to longer battery life
- Programmability to adapt to multiple applications and varying tank or pipe sizes
- TI provides the entire system design: AFE, TDC, MCU, wireless, power, & source code
- TDC1000-Q1 is the only automotive qualified ultrasonic AFE on the market



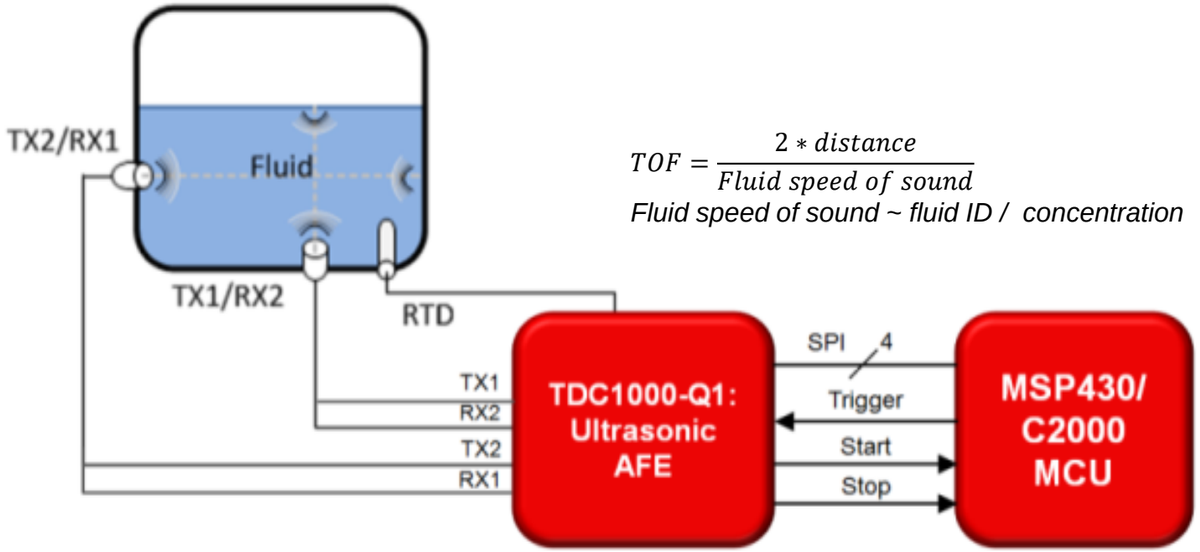
Ultrasonic Level Sensing and/or Powertrain Fluid Concentration Sensors

EE Requirements

- Cost-competitive; transitioning to much smaller form factors
- Millimeter level sensing accuracy within the range of 10mm to approximately 2 meters
- Front end solution that is unaffected by fluid properties (corrosiveness, viscosity, etc.)

TI Value Proposition

- Ultrasonic solution, unaffected by fluid properties, boasts a STOP Cycle-to-Cycle Jitter of 50 ps_{RMS} with a measurement range of up to 8ms. This translates to mm, if not μm level sensing accuracy for a range of up to 3-4m in fluids
- Programmability provides flexibility; allows for a set hardware BOM across multiple different designs
- Integrated AFE, providing competitive cost and a form factor of 6.4mm x 9.7mm (TSSOP)



$$TOF = \frac{2 * distance}{Fluid\ speed\ of\ sound}$$

Fluid speed of sound ~ fluid ID / concentration

Want to learn more? Check out these links:

- TIDA-00322 : Automotive Ultrasonic Fluid Level/Quality Ref Design
- TDC1000-C2000EVM : Ultrasonic for Level and Concentration EVM
- TDC1000-TDC7200EVM : Ultrasonic Water Flow/Level/ Concentration EVM
- TDC7200 EVM

TI Devices	TI's primary differentiation vs. competitor part
TDC1000-Q1 + TDC7200	TI's TDC10xx-Q1 parts remain the only automotive qualified analog front ends for ultrasonic level sensing. The integration this provides serves as a key advantage in solution size and cost.
TDC1011-Q1	

TIDA-00322

Automotive Ultrasonic Fluid Level/Quality Measurement Reference Design

Features

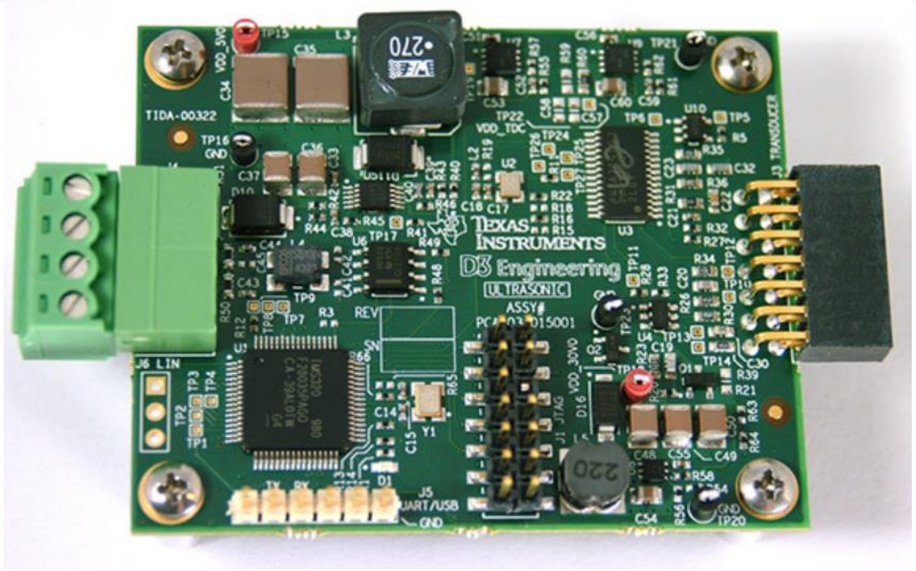
- Dual channel analog-front-end for ultrasonic sensing
  - TDC1000 for transducer driver and ultrasonic time of flight measurement
- External RTD Measurement to monitor temperature changes that affect the medium's speed of sound
- Input voltage range of 6V to 40V with reverse battery protection
- High voltage circuit to drive the transducer with 30V to penetrate deeper tanks

Benefits

- Solution is automotive tailored
  - Automotive qualified Bill of Material
  - CAN transceiver for flexibility of adding future CAN stack
- This reference design can also be used with the TDC1000 for industrial/consumer applications

Tools & Resources

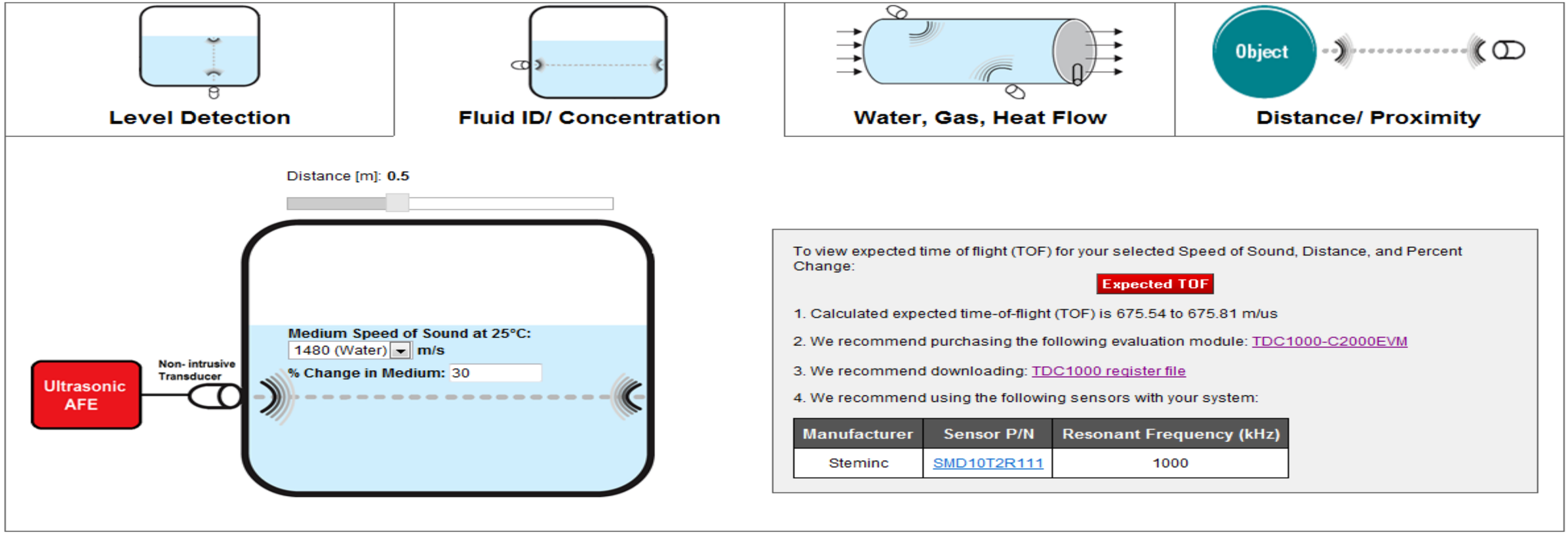
- TIDA-00322 Design Overview
- TIDA-0032 Test Results
- TDC1000-C2000 EVM and EVM GUI
- TIDA-00322 Design Files



TDC WEBENCH Widget

Selection Tool

- Helps select the most relevant EVM
- Recommends what transducer to pair with TDC device
- Downloads TDC1000 register file for the appropriate application



TDC1000-TDC7200EVM

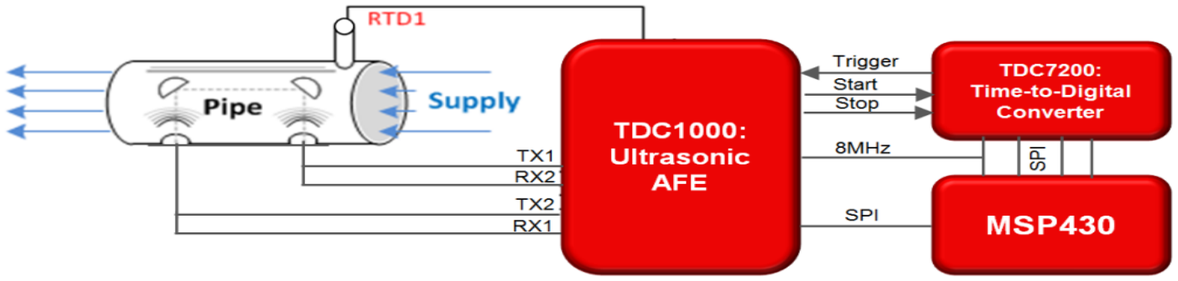
Ultrasonic AFE Evaluation Board for Flow Applications

EVM Features

- Evaluation for both TDC1000 Ultrasonic AFE and TDC7200 time-to-digital converter
- On-board MSP430F5528 to process data
- User-friendly GUI Interface
- Powered by USB
- Connectors for 2 transducers & 2 RTD sensors
- 4-layer with components on top layer
- Probe connections for START, STOP, COMPIN
- 80 mm x 65 mm PC Board

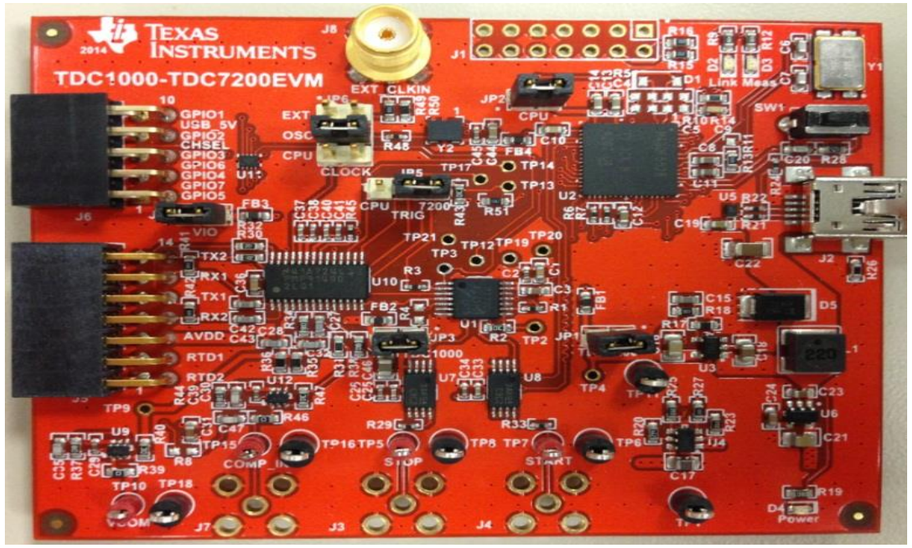
Applications

- Flow: Water, gas, heat, CPAP
- Fluid level / identification / concentration
- Proximity/distance



Benefits

- Picosecond timing accuracy with TDC7200 to detect zero flow
- Low power consumption to improve system battery life
- GUI Interface allows simple programmability to adapt to multiple applications and varying tank or pipe sizes
- Ease-of-use: No external power supply needed
- Low BOM cost solution



TDC1000-C2000EVM

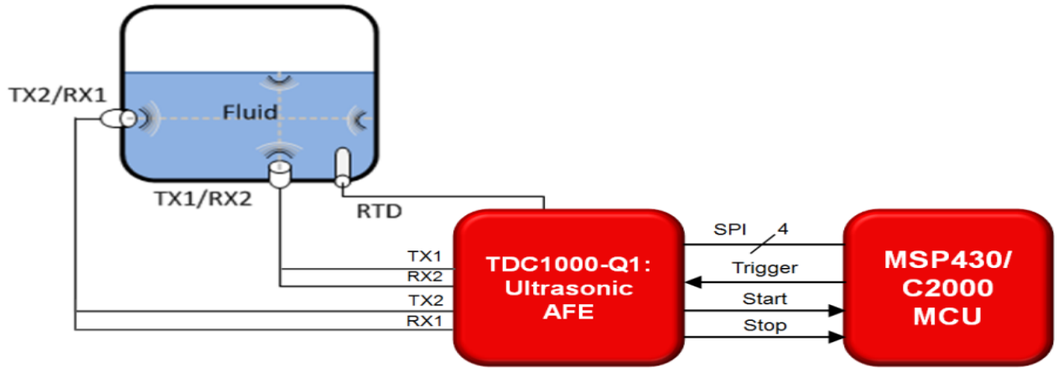
Ultrasonic AFE Evaluation Board for Automotive Applications

Features

- Evaluation for TDC1000-Q1 Ultrasonic AFE
- On-board C2000 MCU to process data
- User-friendly GUI Interface
- Powered by USB
- Connectors for 2 transducers & 2 RTD sensors
- 4-layer with components on top layer
- Probe connections for START, STOP, COMPIN

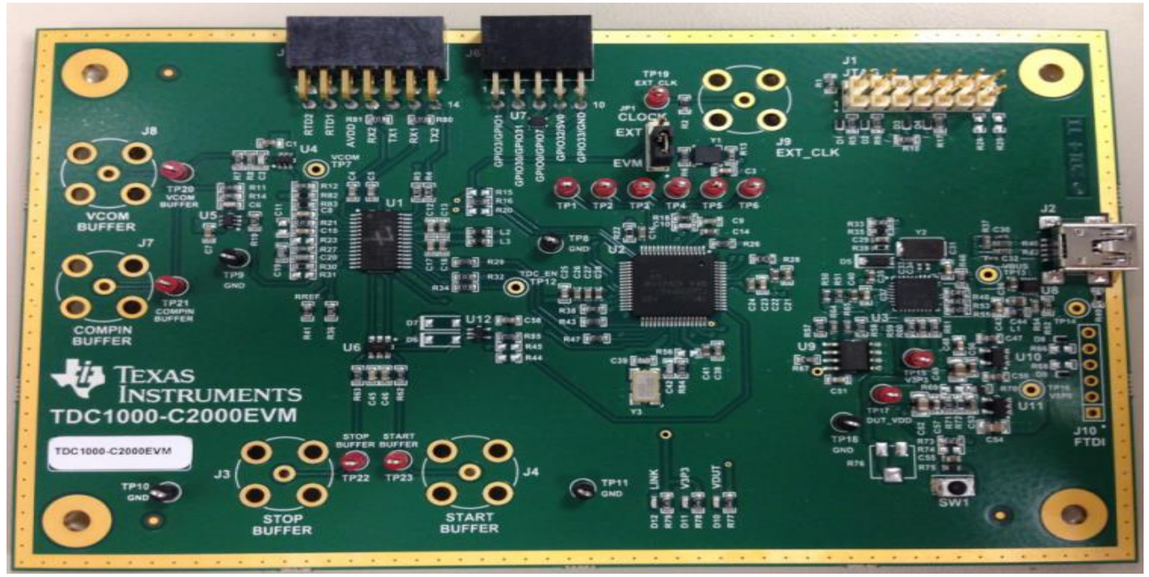
Applications

- Automotive Fluid level / ID / concentration
- Proximity / distance



Benefits

- AEC-Q100 qualified for automotive applications
- Low power consumption to improve system battery life
- GUI Interface allows simple programmability to adapt to multiple applications and varying tank sizes
- Ease-of-use: No external power supply needed
- Low BOM cost solution



Relevant Tools & Resources for TDC1000-Q1
Get started with TI's ultrasonic sensing technology

App Notes

- Design of Analog Interface for Ultrasonic Gas Flow Meter Sensors
- How to Select and Mount Transducers in Ultrasonic Sensing for Level Sensing
- Using Ultrasonic Sensing to Monitor Level in Tanks
- Ultrasonic Sensing Basics for Liquid Level Sensing, Flow Sensing, and Fluid Identification
- Ultrasonic Sensing for Water Flow Meters and Heat Meters
- Measuring an RTD Sensor with the TDC1000 and TDC7200 for Ultrasonic Sensing

E2E/Blog Posts

- Four considerations when choosing a sensing solution for liquid-level measurement
- Why are flow meter manufacturers switching from mechanical to ultrasonic?
- How are washing machines like bats? Using sound to improve our lives.
- LaunchPad @ CES 2015 // Internet-connected water level monitoring system using TDC1000

User Guides

- TDC1000-GASEVM and TDC1000-BSTEVM Kit User's Guide (Rev. A)
- TDC1000-TDC7200EVM User's Guide (Rev. A)
- TDC1000-C2000EVM User's Guide

TI Designs/EVMs

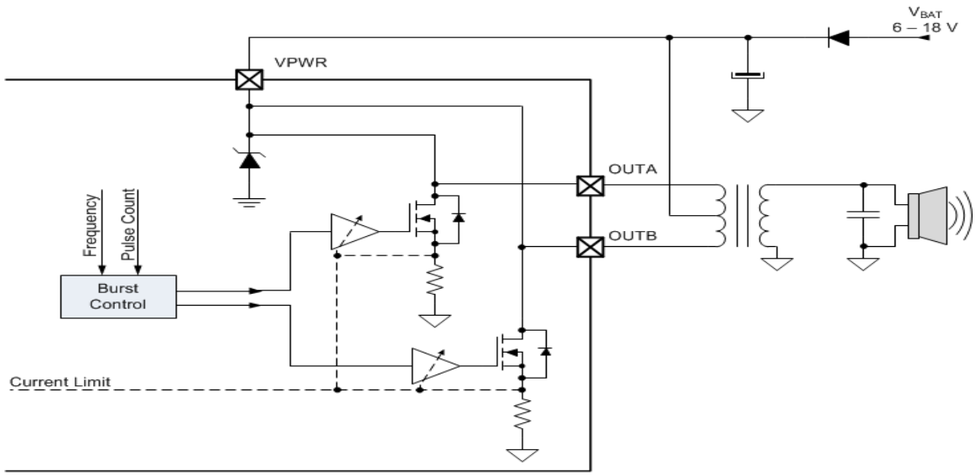
- TIDA-00322 - Automotive Ultrasonic Fluid Level/Quality Measurement Reference Design
- TIDM-ULTRASONIC-FLOW-TDC - Ultrasonic Water Flow Meter Design using Time to Digital Conversion

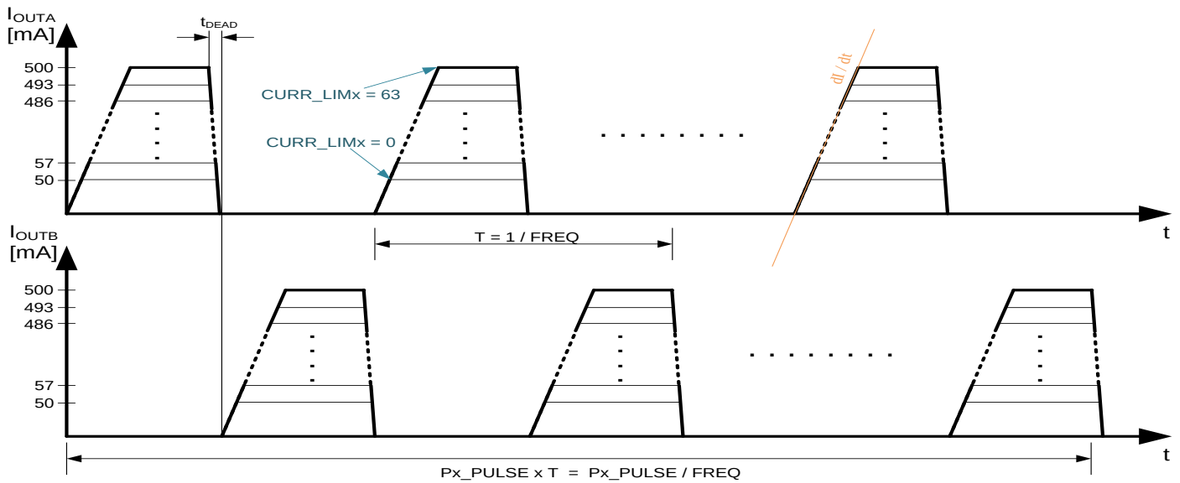
BACK-UP

PGA460: Transmit

ECHO GENERATION

- 5 Ohm Low Side FETs
- Burst signal generated by an internal burst control block
  - Frequency Range: 30 - 80kHz or 180 – 480kHz in 256 steps.
- Current Limit circuit with adjustable threshold 50 – 500mA in 64 steps.
- Adjustable number of pulses between 1 – 32.
- Pulse Dead-Time Control

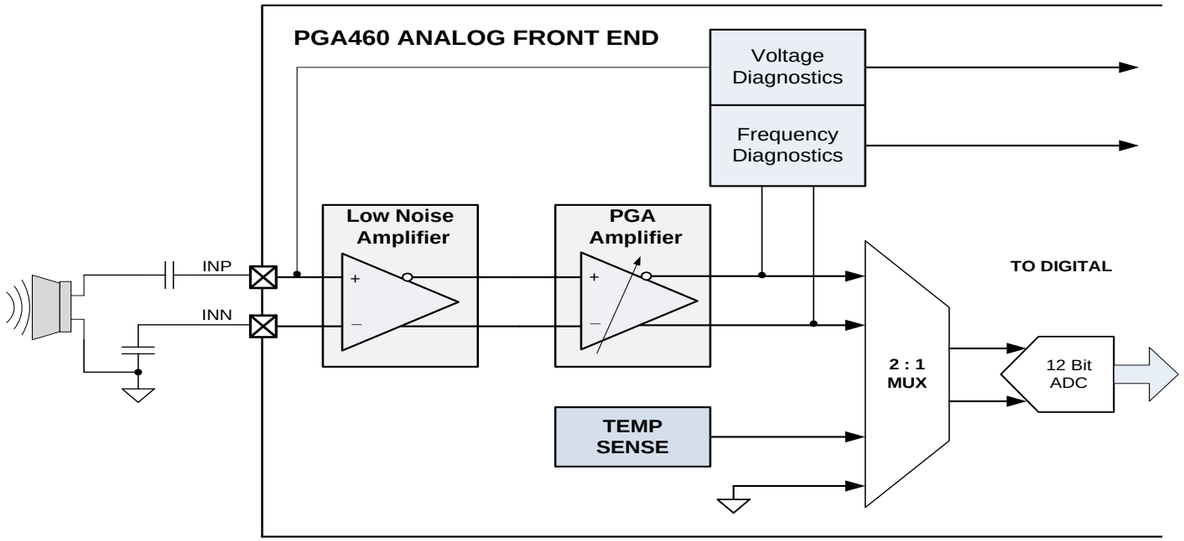


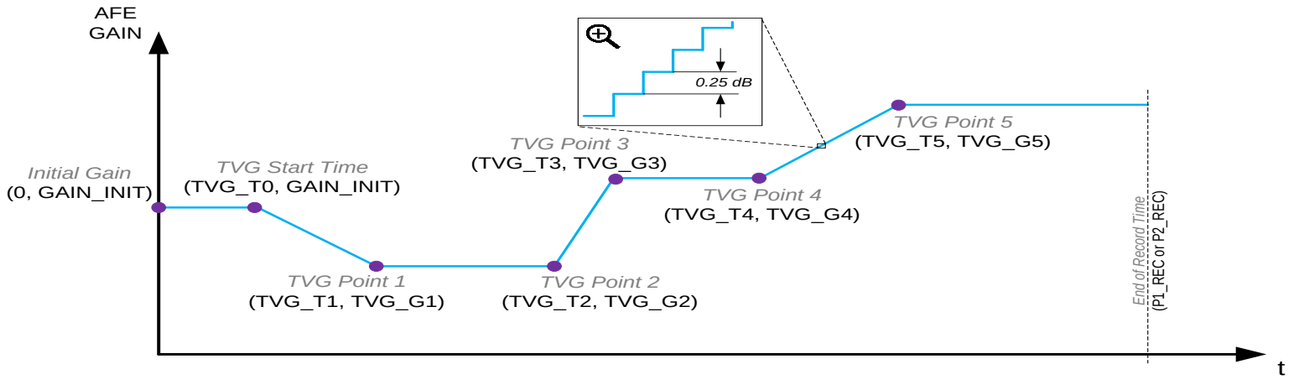


PGA460: Receive, Step 1 – Analog Domain

ANALOG FRONT END

- Low noise amplifier at the input stage allows improved SNR performance
- 32dB to 90 dB (0.5 dB/Step) Programmable Gain Amplifier
  - Time Varying Gain in 6 time assignments
  - Settings stored in EEPROM memory
  - Divided into four ranges
- 12 Bit 1us/Sample ADC
- Analog Signal Output through TEST pin

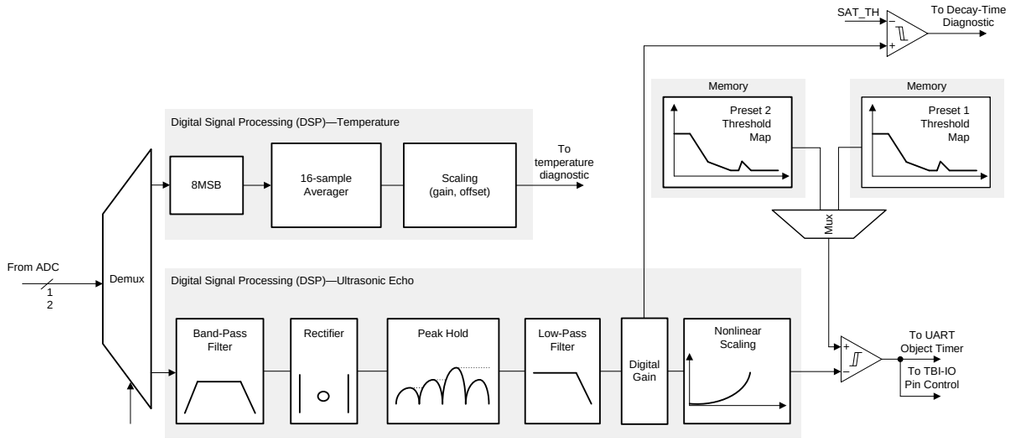


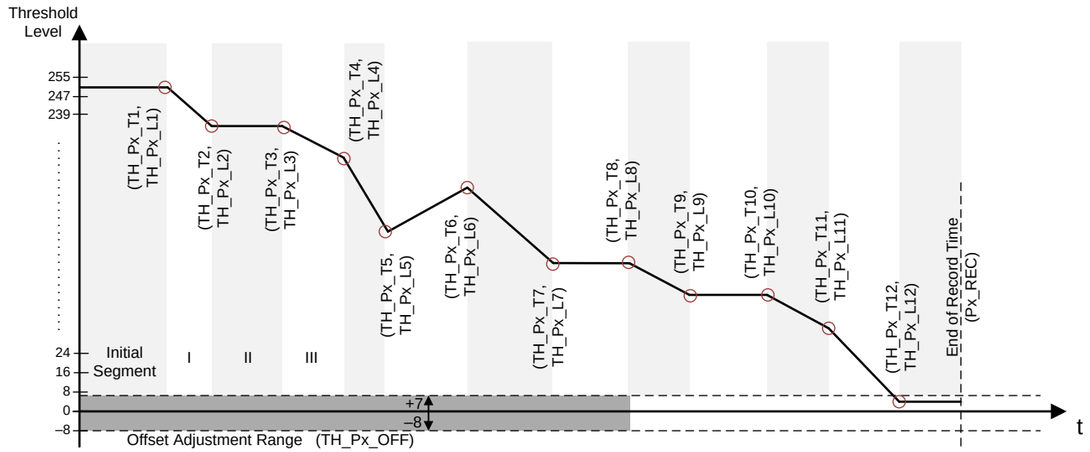


PGA460: Receive, Step 2 – Digitize

DIGITAL SIGNAL PROCESSING

– Band-Pass filter with 2 – 8 kHz Bandwidth
  • 30 – 80 kHz Auto Tuning
  • Manual Tuning for custom Center Frequency and Bandwidth
– Rectifier and Peak Hold for signal demodulation
– Low Pass filter with 1 – 4 kHz bandwidth
– Non-linear sample scaling to improve Signal to Noise profile
– Two Threshold Assignment Maps each with 12 Threshold Settings stored in RAM
– Echo Data Dump Function for Correct Threshold Adjustments





PGA460: Diagnose Ultrasonic Module

SYSTEM DIAGNOSTICS

1. Transducer Voltage Measurement – Measures the excitation voltage on the transducer to ensure that the transformer and transducer are performing properly
2. Decay Frequency Measurement – Ensures that the transducer is resonating correctly, and there are no obstacles on the sensor (mud, snow, ice, dirt, etc…)
3. Decay Time Measurement – Monitors the transducer operation, and checks for sensor obstacles.
4. Noise Level Measurement – Provides system information about the surrounding noise in the environment that might affect the measurement.