TOPOSENS

Toposens TS3 Datasheet
Operation Manual and Technical Specifications

Regulations

This device requires no regular maintenance. In the event that the device becomes damaged or is inoperable, repair or service must be handled by authorized, factory-trained technicians only. This device should not be modified or operated without its housing.

Document Version

Revision	Date	Changes
V 1.0	07/2020	Initial release
V 1.1	07/2020	Minor corrections

Disclaimer

PRELIMINARY PROTOTYPE

⚠

The Sensor is delivered as a development snapshot and is thus considered a prototype. Future iterations of Toposens products are not to be compared to this device!

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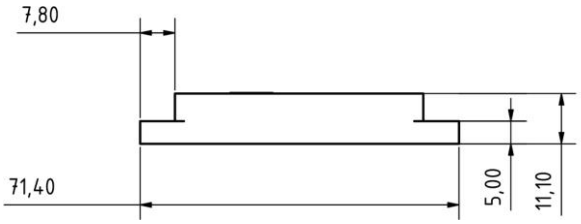
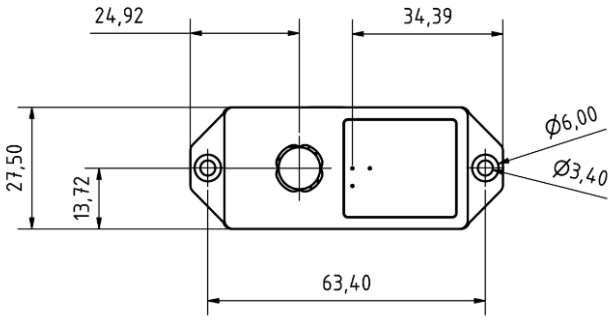
Table of Contents

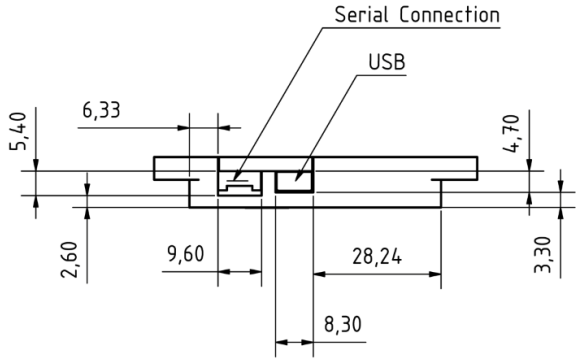
Specifications

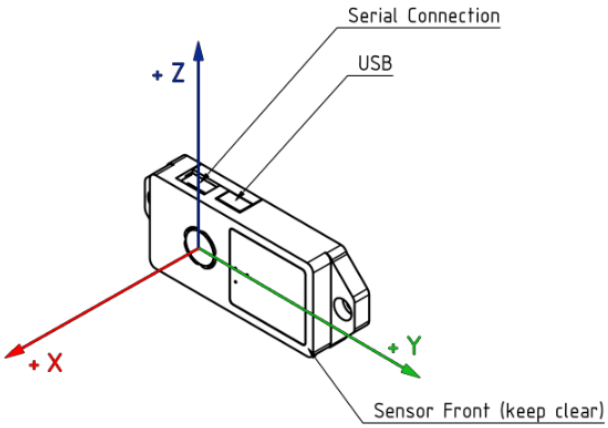
Physical

Specification	Measurement
Size (LxWxH)	72 x 28 x 12 mm (2.8 × 1.1 × 0.5 in.)
Weight	20 g (0.70 oz.)
Operating temperature	0 to 60°C (32 to 140°F)
Relative humidity	5% - 95% (not condensing)









Electrical

Parameter	Specification
Supply Voltage (Vin)	Molex-Microlock-Serial 3.3 VDC / USB 5.0 VDC
Power Consumption	250 mA (typical)

Acoustic Properties

Parameter	Specification
Frequency	40 kHz ± 1kHz
Sound Pressure Level	120 dB SPL @ 30 cm
Mode of Operation	Pulsed (20 pulses max, cyclic)
Ultrasonic transmission by industry standard.	

Performance

Parameter	Specification
Acoustic Transmission Frequency	40 kHz
Operating Range	20 cm - 500 cm*
Opening Angle	120°
Distance Resolution	± 30 mm
Distance Accuracy	± 10% of distance measurement
Angular Resolution	3° (= 40 angular steps over 120°)
Refresh Rate	20 Hz typical
Latency	Approx. 50 ms

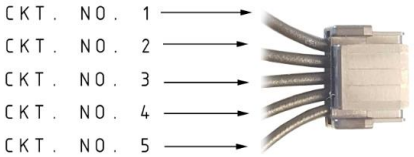
* False positives present below 20 cm

Interface

Parameter	Specification
User Interface	USB Serial Connection (UART)
USB	Mini-USB-B-Port Virtual COM-Port UART-Bridge [Silicon Labs CP210x OnBoard]
Serial Connection (UART)	Molex Microlock Connector 576000 Baud No Parity 8 Data / 1 Stop - Bit
Logic Level (@3.3Vdc)	Low: ~1.2 V | High: ~1.9 V

Wiring Serial Connection

Pin/Connector Number	Function
Contact No. 1	Not Connected
Contact No. 2	TX Sensor Side
Contact No. 3	RX Sensor Side
Contact No. 4	Ground
Contact No. 5	Supply Voltage 3.3 VDC



Molex Part-No: 505567-0571

Operational Information

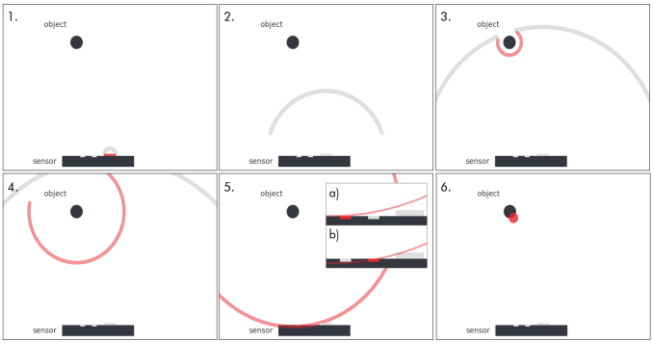
Technology

Toposens' 3D Echolocation Sensor work by combining the time-of-flight principle of conventional ultrasonic sensors with triangulation and advanced signal processing algorithms.

At the beginning of each measurement cycle, the transducer on the sensor sends out an ultrasonic pulse. This pulse is reflected by surrounding objects and received by an array of microphones on the sensor. Based on the time of flight of echoes arriving at the individual microphones, the origins of the echoes are calculated as 3D coordinates. These 3D coordinates are put out at the end of each measurement cycle.

Theory of Operation

[1] the transducer (red) sends out an ultrasonic pulse, [2] the wave is carried forward by the air molecules, [3] the wave is reflected by an object, [4] a portion of the echo is directed back to the sensor, [5] the echo is sequentially captured by the microphone array, arriving first at (a) the left microphone, and then at (b) the right microphone, [6] a 3D location of the echo's origin (light red) is determined from the signal's time-of-flight and the delay between microphones receiving the echo.



Interface

The USB- and Serial Connection must not be used simulatiously – This can damage the Sensor and connected Devices

The data stream for both output connections is identical. Both connection modes support all configurations and modes.

Data Frame

The sensor outputs the measurements as a list of points in a human readable ASCII format.

S000000P0000X00285Y-0184Z-0374V00050....E

Frame Delimiter	Point Delimiter	X [mm]	Y [mm]	Z [mm]	V [no Unit]	Frame Terminator
S000000	P0000	X00285	Y-0184	Z-0374	V00050	E

Each measurement data frame starts with S000000 and ends with E, while individual points in a frame are separated by P0000. If noise is detected during the measurement, the affected frames are flagged with the frame delimiter S100000.

Data contained in each point: coordinates x, y & z in millimetres; relative signal strength v in range 0 to 255.

Commands and Acknowledgment Messages

There are two types of commands, that can be sent to TS3: "Set"- and "Get"-commands. "Set"-Commands change the sensor's settings and trigger an acknowledgment message, which is returned by the sensor. "Get"-Commands issue a request, which retrieves current settings and information from the sensor.

- **TS3 only receives a single command at a time**
- **Default values for parameters are applied at start up.**

In case multiple commands are to be sent to TS3 at once, it is necessary to wait for the acknowledgment message for each respective command before issuing the next command.

Available "set"-Commands

"Set"-commands change the sensor's settings. When executed the sensor answers with an acknowledgement.

Structure for each command: C <command> <value> \r
Length of string: C**********\r = 13 characters

Echo Rejection Threshold	
Command	sReje
Effect	Sets the minimum amplitude for echoes above which they are considered valid detections. A low value will result in a higher number of detections but also a higher probability of false detections
Parameter	5-digit unsigned integer representing the threshold
Applicable Values	Default = 1, min. = 0, max. = 20
Example	**CsReje00001\r** for a threshold offset of 1

Noise Indicator Threshold	
Command	sNois
Effect	Sets a threshold which is applied to the normalized noise level readings from the raw ADC signals. Detections above this threshold are flagged as "noisy"
Parameter	1.4-digit unsigned float representing the threshold
Applicable Values	Default = 0.5, min. = 0.0000; max. = 0.9999. Please note: only values between 0 and 0.9999 are recommended
Example	**CsNois05000\r** for a mark threshold of 0.5

Number of Pulses	
Command	sPuls
Effect	Sets number of ultrasonic pulses emitted by the piezo transducer in every transmission cycle. Increasing the value will allow the detection of objects that are further away, decreasing it will increase the quality of detections in close range
Parameter	5-digit unsigned integer representing the number of pulses to be sent out
Applicable Values	Default = 8, min. = 0, max. = 20
Example	**CsPuls00010\r** for 10 pulses

Peak Detection Window	
Command	sPeak
Effect	Sets the kernel size (window width) that is applied on raw ADC signals to detect valid echoes (peaks in the raw ADC signal). A low value will allow for better separation of multiple objects that are close to each other. A high value will result in "smoother" and more stable detections
Parameter	5-digit unsigned integer representing the size of the the object filter
Applicable Values	Default = 3, min. = 1, max. = 5
Example	**CsPeak00003\r** for size of 3

Temperature	
Command	sTemp
Effect	Sets the temperature value used to calibrate the speed-of-sound measurement.
Parameter	5-digit signed integer representing temperature value as a two-digit number with one decimal place.
Applicable Values	Default = value from internal temperature sensor, to use internal value send command: CsTemp-1000\r, for external values: min. = -40°, max. = 85°C.
Example	**CsTemp00220\r** for temperature of 22°C

Acknowledgement Messages

Acknowledgment messages are sent once the associated command has been processed. Structure for each acknowledgment message:

S <command number> C <repetition of command value> E
Length of string: S00000*C*****E = 14 characters.

Echo Rejection Threshold Acknowledgement	
Message	S000001C*****E
Associated Command	sReje
Example	Message **S000001C00001E** acknowledges that echo rejection threshold parameter has been set to 1 by command CsReje00001\r

Noise Indicator Threshold Acknowledgement	
Message	S000002C*****E
Associated Command	sNois
Example	Message **S000002C05000E** acknowledges that noise indicator threshold parameter has been set to 0.5by command CsNois05000\r

Number of Pulses Acknowledgement	
Message	S000003C*****E
Associated Command	sPuls
Example	Message **S000003C00010E** acknowledges that number of pulses parameter has been set to 10 by command CsPuls00010\r

Peak Detection Window Acknowledgement	
Message	S000004C*****E
Associated Command	sPeak
Example	Message **S000004C00003E** acknowledges that peak detection window parameter has been set to 3 by command CsPeak00003\r

Temperature Acknowledgement	
Message	S000005C*****E
Associated Command	sTemp
Example	Message **S000005C00220E** acknowledges that temperature parameter has been set to 22.0° C by commandCsTemp00220\r

Special Case: Mode Command

This "set"-command allows to put the sensor into a specific scan mode. There are two currently available:

- Mode 0: continuous scanning, the sensor scans its environment and returns scan messages continuously. (No Ack)
- Mode 1: single scan, the command triggers the sensor to scan only once and return the corresponding scan message. (No Ack)

Scan Mode	
Command	sMode
Effect	Puts the sensor into a specific scan mode.
Parameter	5-digit unsigned integer representing the mode.
Applicable Values	Default = 00000, optional = 00001. Continuous scan mode is default.
Example	**CsMode00001\r** for 'single scan' (=polling) mode.

Available "get"-Commands

Structure for each command: C <command> \r
Length of string: C*****\r = 8 characters

Firmware Version	
Command	gVers
Effect	Returns the firmware version uploaded on the TS3
Parameter	String containing 5-digit value for Version.
Answer	CgVers\r returns for example **Version:00008**

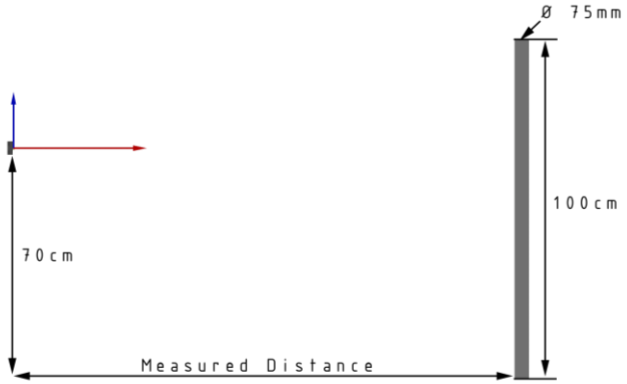
Parameter Configuration	
Command	gConf
Effect	Returns the current parameter configuration set in the sensors firmware.
Parameter	String containing 5-character values for Reje, Nois, Puls, Peak, Temp.
Answer	CgConf\r returns for example: **Reje:00001;Nois:05000;Puls:00010;Peak:00003;Temp:00220**

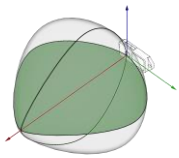
Typical Performance Characteristics

Horizontal Field of View (FOV)

Setup for Horizontal FOV-Measurement	
Sensor Position	
Height	70 cm (27.5 in.)
Orientation	Sensor XY-plane parallel to ground
Target Pole	
Height	100 cm (39.4 in.)
Diameter	Ø 75 mm (2.9 in.)

The pole is positioned in the field of view of the sensor. The sensor data stream is analysed for reliable detections of the pole (pole visible in every output frame). Two different sensor configurations* are documented.

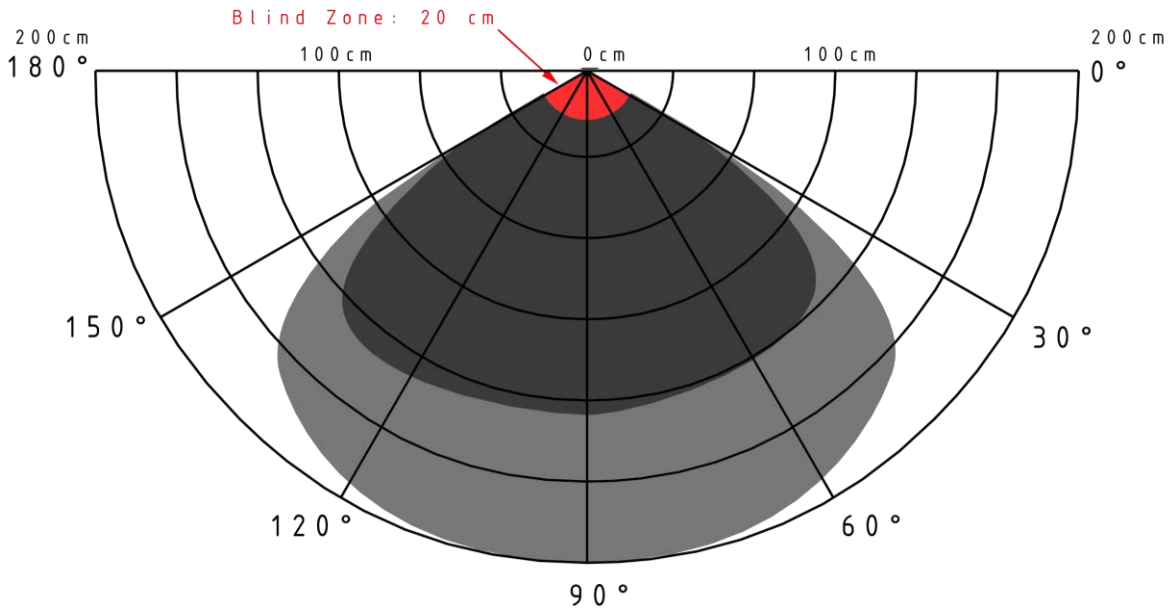




Horizontal Field of View Diagram

Sensor Configuration*	Area Color	Number of Pulses	Peak Window	Echo Rejection
Configuration 2	Dark gray	5	1	3
Configuration 3	Light gray	7	1	2

* Both configurations can be found as “Suggested Configurations” in the Toposens-Visualizer



⚠ **Blind Zone: This area is prone to false positives. Sensor outputs all detected points from 0 – 500 cm (0-197 in.)**

⚠ **Max. Detection Distance: Echoes from large orthogonal surfaces (e.g. walls) can be detected at 500 cm (197 in.)**

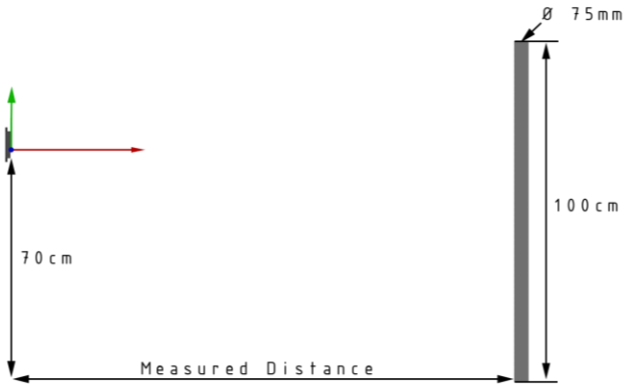
⚠ **Configuration: Opening angle and max. detection distance dependent on configuration, target size and angle of reflection.**

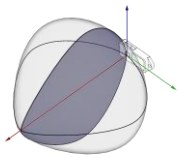
Typical Performance Characteristics

Vertical Field of View (FOV)

Setup for Vertical FOV-Measurement	
Sensor Position	
Height	70 cm (27.5 in.)
Orientation	Sensor XZ-plane parallel to ground
Target Pole	
Height	100 cm (39.4 in.)
Diameter	Ø 75 mm (2.9 in.)

The pole is positioned in the field of view of the sensor. The sensor data stream is analysed for reliable detections of the pole (pole visible in every output frame). Two different sensor configurations* are documented.

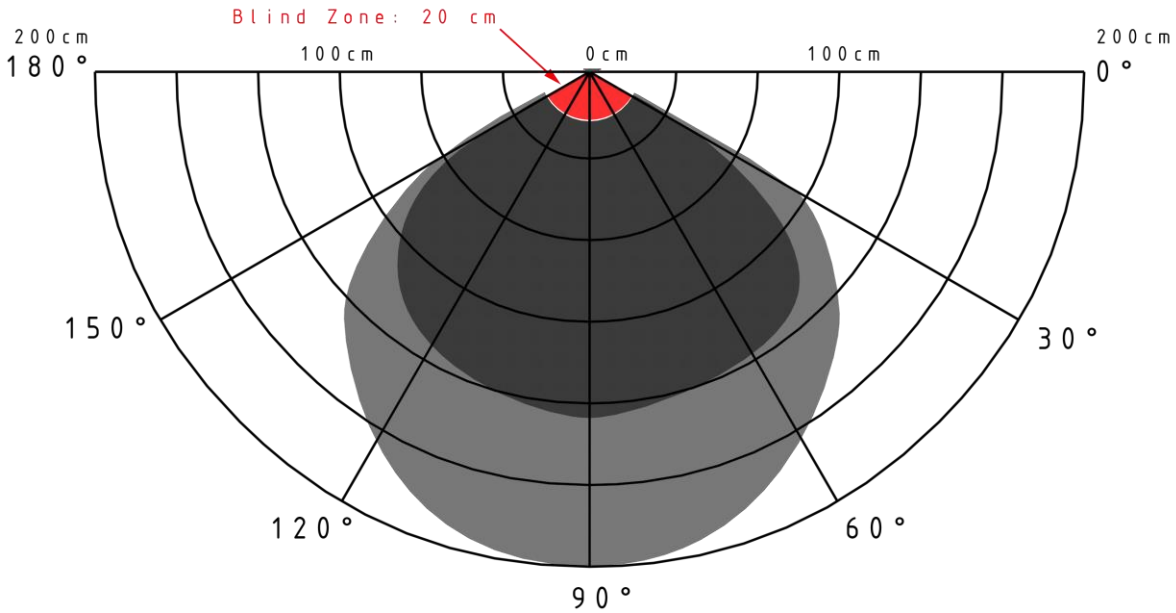




Vertical Field of View Diagram

Sensor Configuration*	Area Color	Number of Pulses	Peak Window	Echo Rejection
Configuration 2	Dark gray	5	1	3
Configuration 3	Light gray	7	1	2

* Both configurations can be found as “Suggested Configurations” in the Toposens-Visualizer



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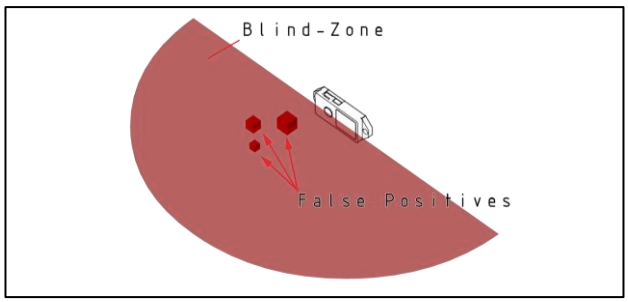
⚠ **Max. Detection Distance: Echoes from large orthogonal surfaces (e.g. walls) can be detected at 500 cm (197 in.)**

⚠ **Configuration: Opening angle and max. detection distance dependent on configuration, target size and angle of reflection.**

⚠ Known Issues

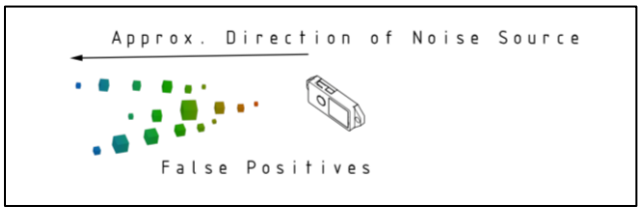
Primary Reflections

The sensor perceives the transmission pulse as reflections in close proximity (0-20 cm / 0-7.8 in.). This effect can be mitigated by adjusting the of the number of pulses and peak window size.



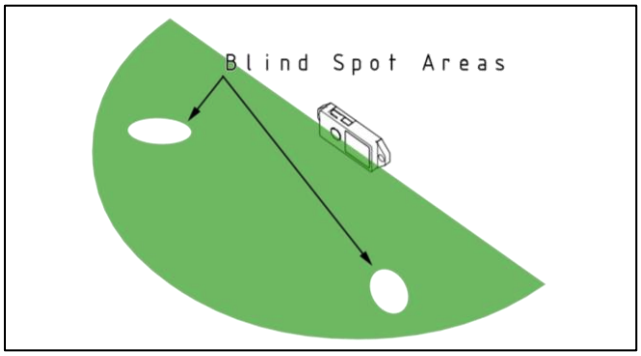
False Positives

Interfering echoes, environmental noise and other ultrasonic sources are visible as false positives. Depending on the duration and amplitude, noise points can occur at random positions.



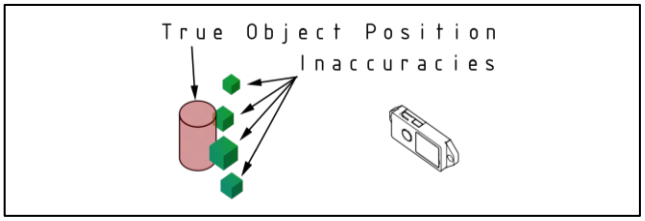
Blind Spot Areas

Destructive interference can occur under certain circumstances. This results in areas, not covered by the sensor. Those areas are of limited spacial expansion of 10 – 20 cm (3.9 – 7.9 in.). Those blind spots occur in a symmetrical pattern.



Accuracy Issues

The calculated position of an echo is dependent on the reflected signal strength received by the sensor. Less energetic signals result in higher positional variance up until the point of imperceptibility.



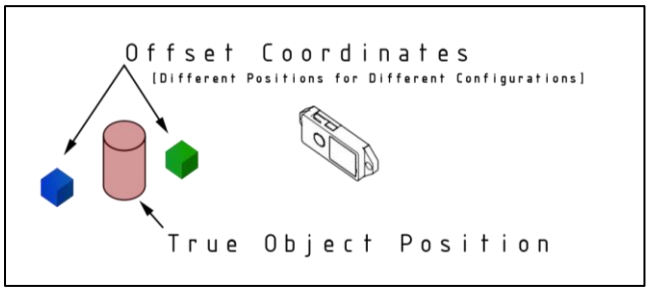
These errors can be mitigated by adjusting the echo rejection threshold to a higher value, with the disadvantage of a diminished detection range and a smaller opening angle.

Refresh Rate Drops

In the presence of continuous environmental noise, the system will wait until noise contamination falls below an acceptable threshold and trigger the next measurement. This will lead to missing frames which in turn reduces the output refresh rate. Configurations with a low echo rejection threshold are more prone to this behaviour.

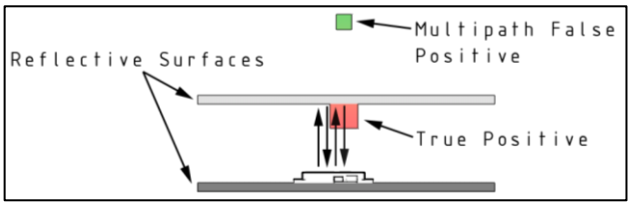
Calibration Issues

The calculated position of an echo is depending on the sensor configuration. The pulse length as well as the selected peak detection window size will add an offset to the actual coordinates.



Multipath Reflections

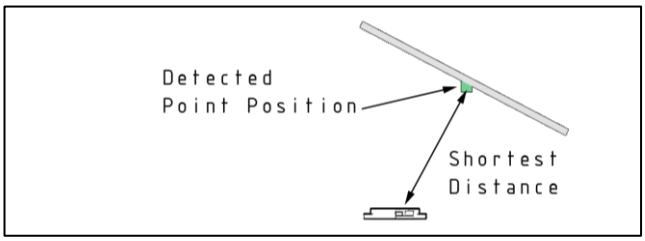
An echo, which is reflected multiple times between two surfaces e.g. in close proximity with the sensor placed in between, will produce false positives .



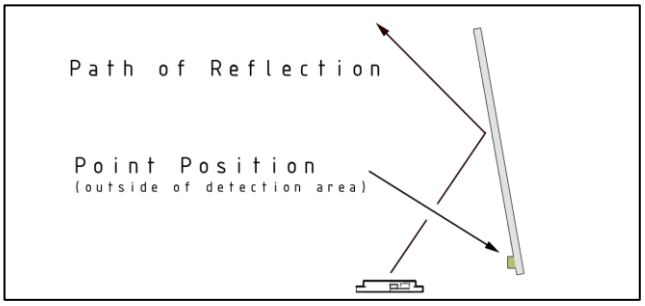
Target Angle

The reflective properties of the target object can influence the detected echo position.

- Big planar objects (e.g. Walls) will reflect a single echo on the surface of the object with the closest proximity to the sensor.



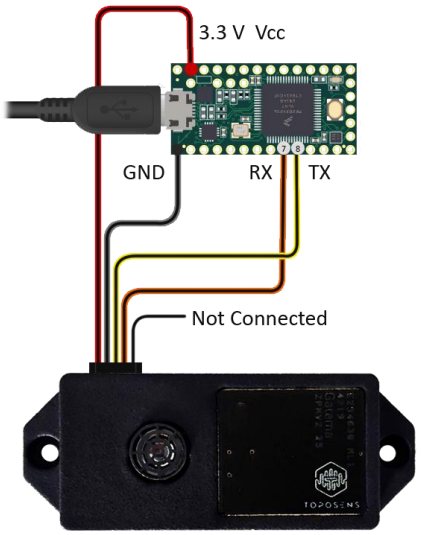
- Big planar objects (e.g. Walls) at certain angles will reflect most of the acoustic energy away from the sensor. Possible detectable positions can be located outside of the field of view of the sensor.



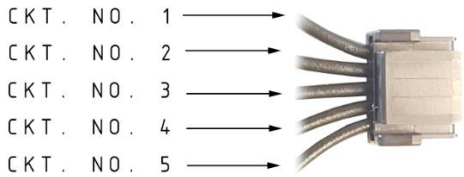
Application Note

Arduino Connection

The sensor can be connected to an embedded system via serial connection. This example shows the connection to a Teensy 3.2 board. This board was chosen due to the high baud rate necessary. The TS3 Sensor is not compatible with low speed MCUs like the Arduino UNO.



Arduino to Sensor Pin Connection	
Sensor Connector Pin	**Arduino Pin**
Contact No. 1: Not Used (GND)	-
Contact No. 2: TX Sensor Side	Pin 7: RX Arduino Side
Contact No. 3: RX Sensor Side	Pin 8 : TX Arduino Side
Contact No. 4: Ground	GND: Arduino Ground Connection
Contact No. 5: Voltage 3.3 V	Vcc: Arduino 3.3V Connection



⚠ The serial connection is not 5 V tolerant

Arduino Library

The Arduino library uses Serial1 to connect to the PC and Serial2 to connect to the sensor. If two sensors are used, Serial3 of the Teensy 3.2 can be connected (Pin 9 for Arduino RX and Pin 10 for TX).

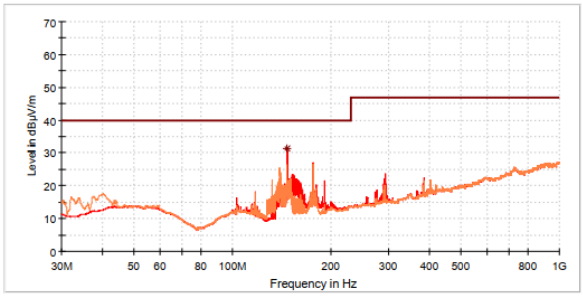
It should be noted that this setup requires polling mode for both connected sensors to avoid interference.

EMC-Analysis

The sensor prototype is not certified under FCC/CE regulations. An EMC measurement was conducted in a certified test institute to ensure electromagnetic compliance.

Compliance is heavily dependent on the cable and MCU/PC used with the TS3-Sensor.

For the following measurements, the USB-Connection was used in combination with an USB-Power-Bank.



Critical_Freqs

Frequency (MHz)	QuasiPeak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
147.150000	31.47	40.00	8.53	---	---	100.0	H	0.0	---

(continuation of the "Critical_Freqs" table from column 16 ...)

Frequency (MHz)	Comment	Corr. (dB)
147.150000	16:57:19 - 06.09.2019	---

Contact

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