Toposens TS3-Sensor Configuration Guide

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Document Version

Revision	Date	Changes
V 1.0	08/2020	Initial release

PRELIMINARY PROTOTYPE

⚠️

**The Sensor configuration changes the behavior and the data quality.
The Sensor can not be damaged by configuration.**

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Configuration

The flexible sensor configuration enables the adaption of the systems detection properties to a wide variety of possible use case applications and environmental situations. Those parameters can be comfortably adjusted in the TS3-Visualizer and via serial commands.

Number of Pulses	
Command	sPuls
Effect	Sets number of ultrasonic pulses emitted by the piezo transducer in each 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

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

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

## Sensor Functionality Explanation
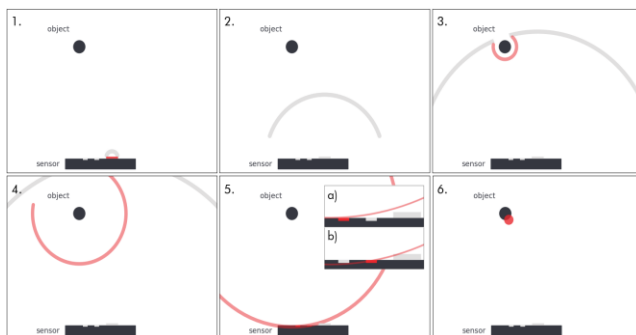
[1] the transducer (red) sends out an ultrasonic pulse, [2] the wave is carried forward by the air molecules, [3] the wave is reflected by an object, [4] a portion of the echo is directed back to the sensor, [5] the echo is sequentially captured by the microphone array, arriving first at (a) the left 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.

The algorithmic parameters exposed for user manipulation change the sensitivity, selectivity and stability of the point cloud. While it is possible to set all parameters to high values or use the trial and error method the following explanations seek to help the user to understand the influences.

Graphic Explanation

To visually demonstrate the influence of the parameters, the following substitute graphic is used. The red arrow indicates the sensor position and heading, while the red dots show the actual object positions (e.g. pole or sphere in this case). The size of the red circles indicate the size of the real objects while the grey circles indicate the sensors perception of the acoustic reflection. Less visible, brighter colored circles indicate less "loud" echoes. In the following explanations, a single parameter is changed at a time.
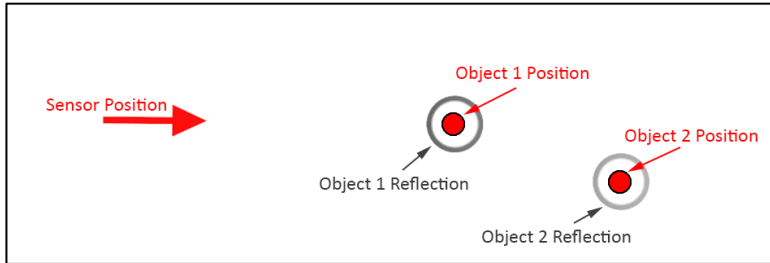
The size of the circles indicates the detected position of the echo. Bigger circles indicate less accuracy while the brightness indicates echo signal integrity.

If the circles are fusing, this indicated possible echo interference which results in inaccurate detection.

Number of Pulses

The most comprehensible modifiable value is the length of the transmitted acoustic signal. Due to the resonance of the transducer, longer signals equal a higher power for the transmission signal. This directly impacts the maximum detection distance of the system. Longer pulses with higher amplitude can result in lower accuracy.

| 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

The transmission signal length influences the maximum detection distance, the returned signal strength and the selectivity. Longer signals carry more power but also fuse smaller object in close proximity to the sensor.

Short (1-3) = Low Amplitude/Length Signal
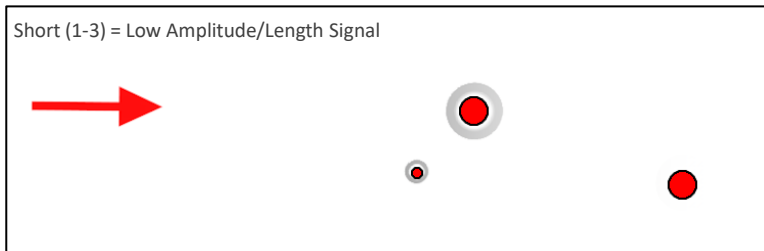
Short signals result in better discrimination properties regarding close ranged detection of objects. Objects in a further distance can't be detected if the reflected energy is lower than the configured threshold.

Medium (4-7) = Medium Amplitude/Length Signal
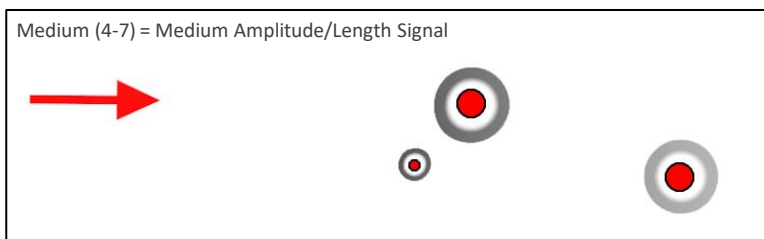
Medium signals are the best all round fit for most use cases. Objects at a further distance have a chance of being detected, while close objects can still be recognized as separate ones.

Large (8-20) = Large Amplitude/Length Signal
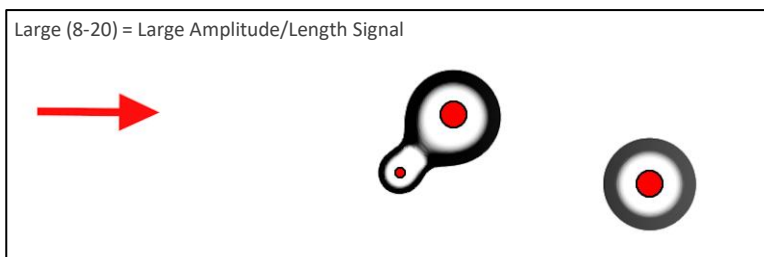
Large signals enable the recognition of objects farther away from the sensor. Please note the "fusion" of close ranged objects due to the loud and long transmission pulse. This effect can't be compensated for by other parameters.
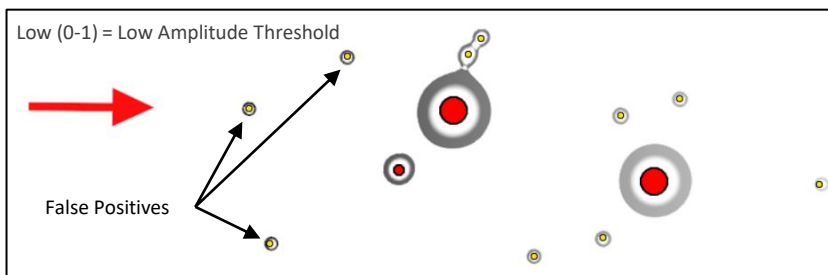
Echo Rejection Threshold

The Echo Rejection Threshold configuration parameter describes the lower cutoff, which tells the sensor the minimum amplitude of received echoes to be processed. Due to the automatic noise reduction, this value is not equal to the points volume value.

| 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 of 1

⚠️ **Due to the prototype characteristic of the sensor, the sensors threshold is of a linear nature and will not adjust to the measured distance.**

Low (0-1) = Low Amplitude Threshold

False Positives

Low values for the echo rejection threshold result in lots of instable points. Those points are not necessarily noise but small reflections which can not be located continuously.

Medium (2-4) = Medium Amplitude Threshold
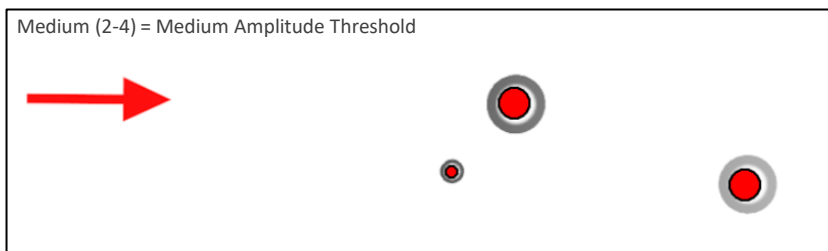
Medium values allow for the most versatile sensor configuration. Noise is not as prominent as with lower values, but false positives can still occur.

Medium (5-20) = High Amplitude Threshold
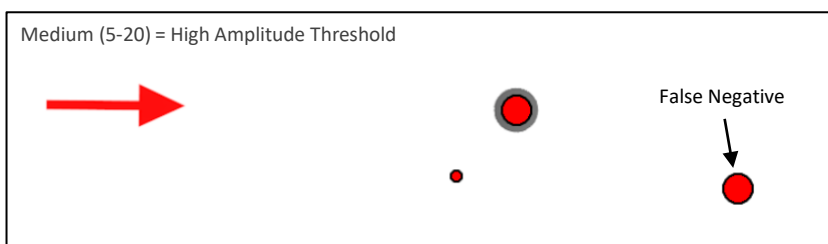
False Negative

High threshold values enable the detection of larger objects at medium distances with almost no false positives. Please note the rate for false negatives is increased.

⚠️ **Threshold settings of 0 are not recommend due to noise issues. Settings between 2 and 5 have the biggest impact.**

Peak Detection Window

The Peak Detection Value defines the length of echoes processed into a single object. This value enables the fusion of complex surfaces into less points. Additionally noise can be filtered out even when using small echo detection thresholds. Additionally the stability of the point detection is enhanced due to more echo location data being processed.

| 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 window width size of the the object filter
Applicable Values	Default = 3, min. = 1, max. = 5
Example	**CsPeak00003\r** for size of 3

Please note the tendency of smaller objects to fuse when higher values are configured. Smaller objects with similar relative position to the sensor as bigger objects are fused with the bigger object. Note that each object fusion will change the resulting coordinates of the bigger objects weighted by the amplitudes of both objects. Smaller objects in close proximity to bigger objects tend to disappear if the window size is set to values above 2.

Small (1-2) = Small Window Size
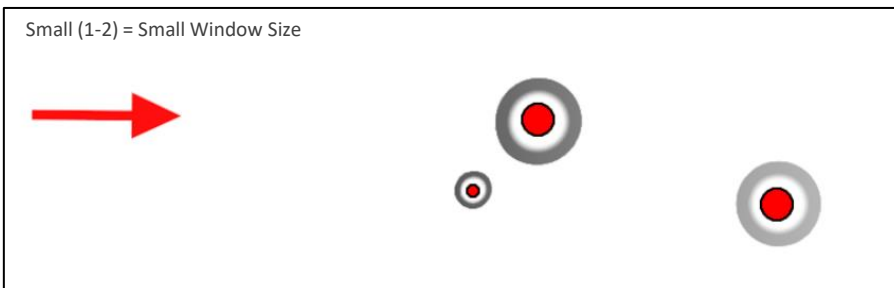
The Small and Medium configuration fits best for most purposes. A value of 1 is best for close range applications.

Medium (3-4) = Medium Window Size
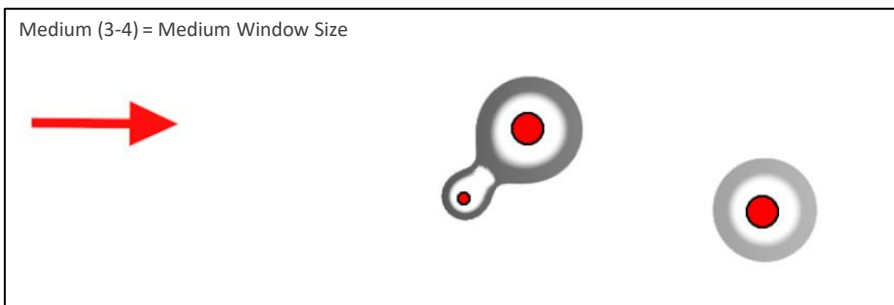
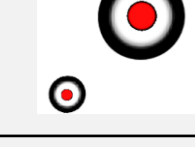On the Medium configuration small objects with proximity to bigger objects can fuse.
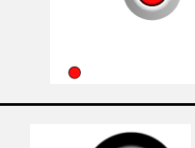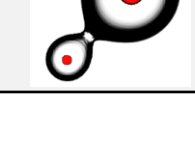
Large (5) = Large Window Size
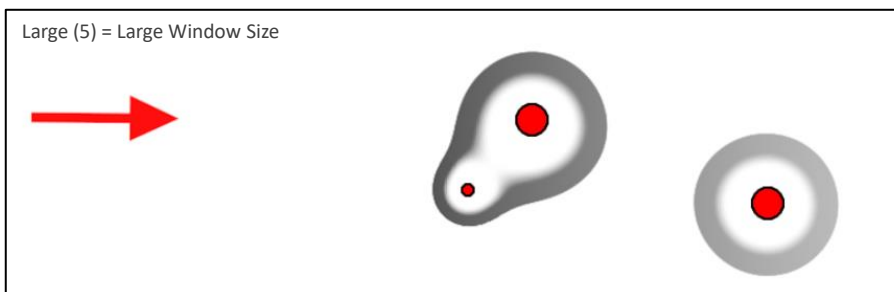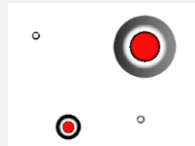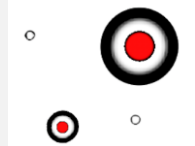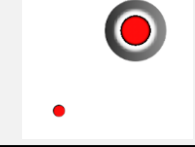
The Large window setting is fusing even bigger objects. It can be used for distance detection to avoid noise.

Configuration Parameter Interaction

The parameter interaction can not be described in full detail. To give an overview reasonable high values are combined with reasonable low values to show the influences of the parameter interaction to the resulting point cloud. In application cases a combination of minimum and maximum values as showed below is not feasible. Medium values work best for most use cases.

> ⚠ **The following parameter combinations are exaggerated to show comprehensible configuration results.**

No.	Pulse	Thre.	Win.	Example
1	**−** (1-3)	**−** (0-1)	**−** (1)	In this configuration, noise will be visible while small objects can be detected and differentiated. Use this or a similar configuration if close range detection of small objects is needed.
2	**+** (8-12)	**−** (0-1)	**−** (1)	Noise will be clearly visible while objects at all distances are detected. Useful for outdoor / clear space use cases with all sizes of objects. Additional post processing likely needed to filter noise.
3	**−** (1-3)	**+** (5-10)	**−** (1)	This setting is enabling the lowest false positive rate while increasing the false negative rate. Good for medium distance obstacle avoidance. Small objects are likely to be ignored if not close to the sensor.
4	**+** (8-12)	**+** (5-10)	**−** (1)	Low noise level combined with a reasonable detection area. Due to the high pulsed volume, accuracy issues may occur.
5	**−** (1-3)	**−** (0-1)	**+** (5)	Due to the high peak detection window, noise level are low. Objects can be detected but in general this setting is a valid option for close range detection.
6	**+** (8-12)	**−** (0-1)	**+** (5)	The long signal in combination with the large peak detection window causes a higher number of fusion between objects in close proximity. Good for outdoor / free space use cases with big objects and low noise levels.
7	**−** (1-3)	**+** (5-10)	**+** (5)	The small signal in combination with the restrictive filters results in less points (more false negatives) while being less accurate due to the low amplitude signal.
8	**+** (8-12)	**+** (5-10)	**+** (5)	All max setting. Not recommended for most use cases but sometimes useful for human interaction (Gesture control, People Detection).