Chirp Microsystems

CH-101 SmartSonic Evaluation Kit Users Guide

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1 USING THE CH-101 ULTRASONIC SENSOR

1.1 PRINCIPLES OF OPERATION

Measuring Distance Using Time of Flight

Most of us have had the experience of seeing a lightning bolt and then using the delay between the flash and the arrival of the thunder to estimate how far away the lightning strike was. For many, the initial flash triggers an immediate response of counting the seconds until the thunder is heard. If we happen to know a rough estimate of the speed of sound (e.g. 3 seconds per kilometer, or 5 seconds per mile), we can easily convert the observed time into a useful approximate distance.

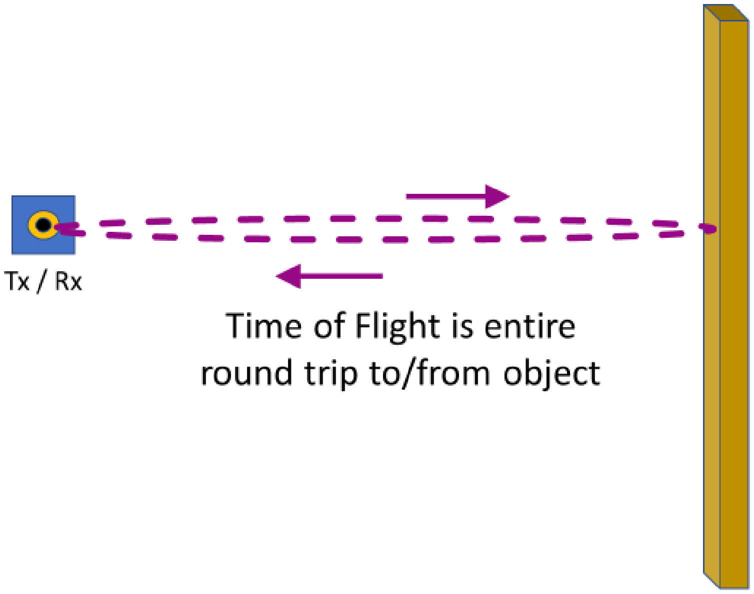
The CH-101 ultrasonic sensor uses this same approach, measuring the time it takes for sound to arrive after a known event, to determine distances at much closer ranges and with high accuracy. This elapsed time is known as the “Time of Flight” (ToF).

The CH-101 sensor is an ultrasonic transceiver, meaning that it can both transmit and receive ultrasound signals. Unlike various type of passive sensors which simply measure their surrounding conditions, the CH-101 actively injects a signal into its environment. To perform a basic distance measurement, the sensor will emit a very brief pulse of ultrasound. It then immediately enters a “listening” state, in which it samples the received sound, attempting to identify an echo of the pulse that has been reflected off an object in the sensor’s vicinity. If an ultrasound pulse is identified, the sensor will analyze the signal to determine the timing and then report the ToF of the received pulse. The actual distance travelled by the ultrasound during the ToF can then be calculated based on the speed of sound.

Sensor Configurations

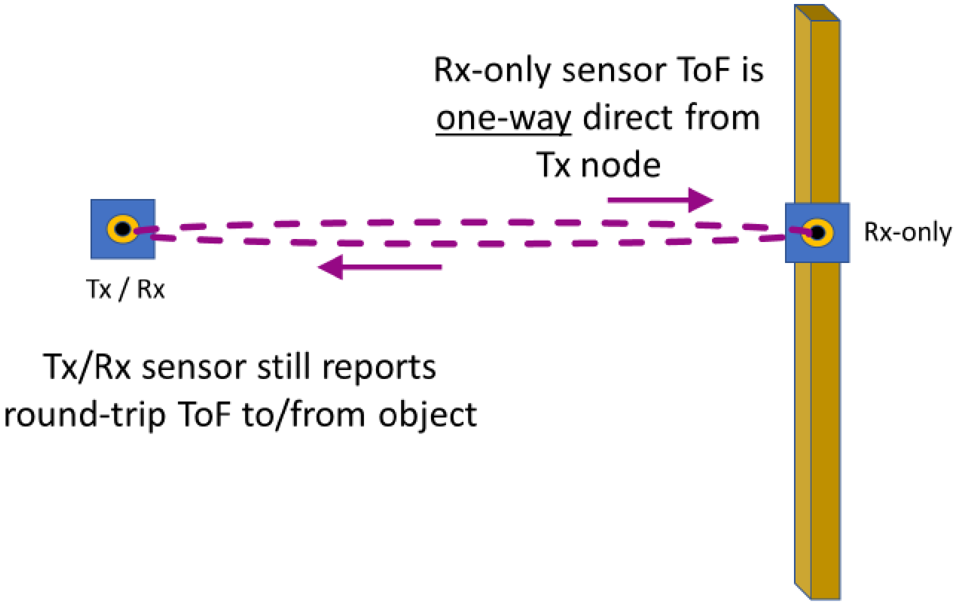
A CH-101 device may be used alone or in combination with one or more other sensors.

The most basic configuration is a single CH-101 device. In this arrangement, the sensor will both transmit and receive ultrasound to perform the measurements. The device will listen for an echo of its own ultrasound signal, calculate the ToF for the received echo, then notify the host system that the measurement has completed. This is often simply called “pulse-echo” operation.

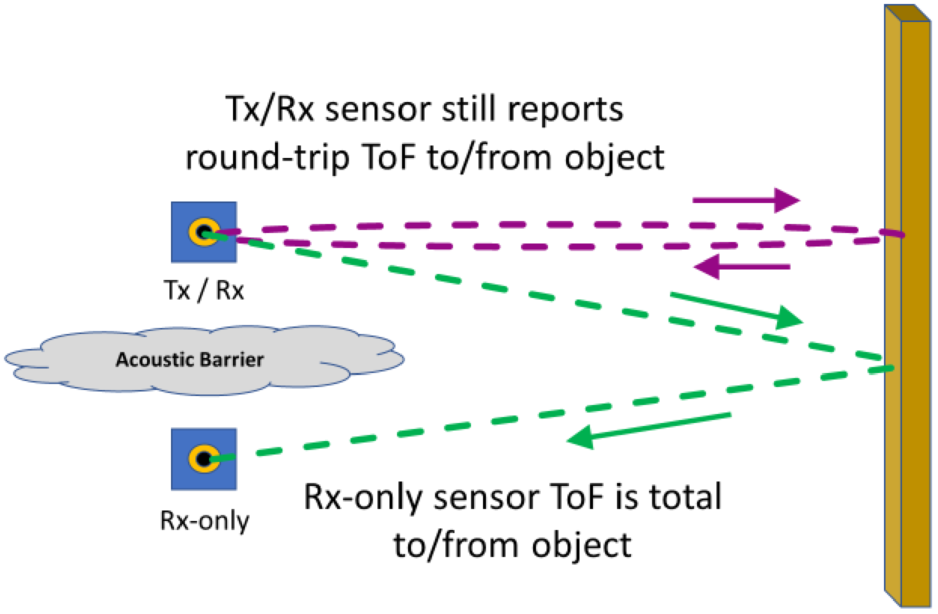


In other applications, multiple CH-101 devices may be used together, in what is often called “pitch-catch” operation. One sensor generates an ultrasonic pulse and waits for an echo, as in the single-device configuration. One or more other sensors are operated in “receive-only” mode, so do not generate ultrasonic pulses – they simply listen for the pulse from the first device. All devices (the transmitting sensor and all receive-only sensors) are synchronized so that the receive-only nodes will start their sampling when the first sensor transmits. All devices then process the received signal, calculate the ToF, and report to the host system.

There are two basic approaches to using a pair of sensors together (one transmitting and another receiving). In some cases, the two sensors are attached to two different objects, and the distance being measured is the direct distance between the two objects. In this situation, the important data values are the range measurements from the receive-only device. The ToF measured in this case is the one-way, direct path between the transmitting and receiving sensors. This mode of operation gives the best performance in terms of measurement accuracy and stability.



The other way two or more sensors may be used in pitch-catch operation is for the devices to be mounted to the same object, and the ultrasonic signal is reflected off another object. The receive-only sensor will measure and report the total ToF for the path from the transmitting sensor, bouncing off the target object, and then back to the receiving sensor. Depending on the relative positions of the two sensors and the target object, this distance may differ significantly from a simple single-sensor echo path. Note the use of an acoustic barrier to prevent the ultrasound pulse from travelling directly between the sensors.



Sensor Sampling and Operating Frequency

When a CH-101 sensor is making a measurement, it repeatedly samples the ultrasonic receiver and records each sample's amplitude of sound in the proper frequency range. So, a single measurement actually consists of many (up to 150) individual sample values. The sensor samples are driven by an internal clock in the CH-101.

Each CH-101 has a natural resonant frequency, which is normally used as the sensor clock's operating frequency. For CH-101 devices, this is generally around 175kHz. This operating frequency is then used to drive the ultrasonic sampling, at a rate of one sample for every 8 clock cycles (see Section 1.5 below).

The specific frequency used by an individual sensor is set during power-up and initialization, during the device's built-in self-test (BIST). The frequency value may be calculated from device registers read over I²C. In SonicLink, each sensor's frequency is displayed in the console window. Embedded applications may obtain the sensor frequency using the Chirp API and driver.

Because the timing of the individual samples within a measurement is based on the sensor's specific operating frequency, the exact sample timing will vary slightly between devices. This becomes significant when the sample offsets (in time) need to be converted to physical distance, because the physical distance represented by the offset between samples will vary slightly. Therefore, the device's operating frequency is a component in the calculations when interpreting the reported range value from the sensor, which is expressed in terms of a sample index. See "Converting Between Sample Index and Range," below.

The CH-101 device clock is calibrated against a known time base during device initialization. This is done by applying a pulse of known duration (typically 100 milliseconds) to the sensor's INT line. The device will return a clock count value which corresponds to the calibration pulse length. This count value is later used in the range calculation, along with the duration of the calibration pulse, to establish an accurate conversion between the internal sensor sample offsets and physical distance.

Amplitude Scans (A-Scans)

When examining ultrasonic sensor data, a very useful visualization tool is the Amplitude Scan, or A-Scan. An A-Scan is a graph in which the Y-axis represents the amplitude of received ultrasound, and the X-axis represents the individual samples from the measurement. Because the individual samples are evenly spaced in time, the X-axis therefore also represents the distance travelled by the ultrasound pulse.

A-Scans have an important advantage over a simple range value, because it is possible to observe the entire trace of sampled data. Multiple different target objects whose reflections show up in the trace can be viewed simultaneously. Often, this is very helpful in understanding the range values that are reported and how multiple objects may affect the ultrasound.

SonicLink provides a built-in display of A-Scan data for connected sensors.

I/Q Data

The amplitude data from the sensor may be read by an external host system via the I²C connection. This data describes the (up to) 150 samples that make up a full measurement cycle. Each individual sample is reported as a pair of values, I and Q, in a quadrature format.

To convert any given I/Q pair to the amplitude of that sample, square both I and Q, and take the square root of the sum:

$$\text{Amplitude} = \sqrt{(I^2 + Q^2)}$$

Amplitude values in the CH-101 are expressed only in internal ADC counts (least-significant bits, LSBs) and are not calibrated to any standard units.

Each sample I/Q pair consists of two signed 16-bit integers. So, a complete CH-101 A-Scan will contain up to 600 bytes of data (150 samples x 4 bytes per sample). When the I/Q data is read from the sensor, the additional time required to transfer the I/Q data over the I²C bus must be taken into account when planning how often the sensor can be read (sample interval). It is important that any data I/O to the sensor, including reading the I/Q data, completes before a new measurement cycle is triggered.

The number of samples used in the I/Q trace is determined by the maximum range setting for the device. If it is set to less than the maximum possible (1m), not all 150 samples will contain valid data.

1.2 SENSOR OPERATING MODES

Free-Running (Self-Timed) Transmit/Receive Mode

When the sensor is in Free-Running mode, it uses a periodic timer based on the sensor's internal real-time clock (RTC) to control the overall pattern of operation. The timer is set to a specific delay corresponding to the sensing interval. When the timer expires, the sensor will wake up and begin an ultrasonic range measurement. When the measurement is complete, the sensor will notify the remote host device by asserting the INT line.

Free-running mode may only be used by individual sensors operating independently – multi-sensor configurations must use one of the triggered modes described below.

The internal RTC used in Free-Running mode provides good accuracy, but it is not as stable as a crystal-controlled oscillator typically found on a microcontroller board. Therefore, hardware-triggered mode (see next section) should be used for critical timing applications.

Note: *Free-Running mode may not be selected in SonicLink. It is available for embedded applications using the Chirp API and driver.*

Hardware-Triggered Transmit/Receive Mode

In many applications, the ultrasonic measurements require more exact timing than the sensor's internal RTC provides in free-running mode, or the sensor operation needs to be coordinated with other application activities. In these cases, the sensor's measurement cycle can be initiated by using a hardware trigger, in which the remote host device asserts and then releases the INT line. When the sensor detects that the INT line has been asserted, it will begin a measurement cycle.

The most typical mode for a single sensor is Hardware-Triggered Transmit/Receive (Tx/Rx). In this mode, the sensor will generate an ultrasonic pulse when it is triggered by the INT line from the host. The sensor then listens for a response (echo) for an amount of time based on the maximum range setting of the device. When the measurement cycle is complete, the sensor will notify the host by asserting the INT line. Note that the INT line operates in two directions when used in hardware-triggered mode – first as an input to the sensor (output from host) to initiate the measurement, and then as an output from the sensor (input to host) for the measurement-complete notification.

Generally, the host application will repeatedly trigger the sensor based on the host's periodic timer that can maintain an accurate sensing interval. Conversely, the application may wait until specific conditions are met, then initiate an isolated measurement.

Hardware-Triggered Receive-Only Mode

When more than one ultrasonic sensor is used, they may be configured so that one device operates in hardware-triggered Tx/Rx mode as described above, and one or more other sensors operates in hardware-triggered Receive-Only mode (Rx-only). In this case, all sensors are triggered by the remote host simultaneously via their INT lines. The single Tx/Rx node generates an ultrasonic pulse and listens for an echo as normal. All Rx-only nodes will simultaneously begin their own listening periods, but without sending an ultrasonic pulse. Instead, the Rx-only sensors simply wait to detect the pulse that was sent from the Tx/Rx sensor (either directly, or as an echo off another object).

When each sensor completes its measurement cycle, it will notify the remote host by asserting its INT line.

Idle Mode

If the sensor will not be used by the application for an extended period, it may be placed into a low-power Idle mode. No sensing will be performed when in Idle mode. To resume sensing operation, the sensor must be placed into one of the regular modes (see above).

Note: *Idle mode may not be selected in SonicLink. It is available for embedded applications using the Chirp API and driver.*

1.3 SETTING THE MAXIMUM RANGE

The CH-101 sensor has a configurable full-scale range (FSR), meaning that the application may set the maximum distance at which the sensor will detect an object. Any value up to the rated maximum range for the device may be specified.

Range setting values refer to the one-way distance to a detected object.

In practice, the FSR setting controls the amount of time that the sensor spends in the listening (receiving) period during a measurement cycle. Therefore, the FSR setting affects the time required to complete a measurement. Longer full-scale range values will require more time for a measurement to complete.

1.4 SETTING THE SAMPLE INTERVAL

Most applications require sensor measurements at regular intervals. The CH-101 sensor provides both internal and external timing options to implement a sample interval.

Free-Running vs. Hardware-Triggered

In Free-Running (Self-Timed) mode, the CH-101 uses an internal clock (RTC) to autonomously establish the sampling period. The wake interval is set by writing to a specific register in the sensor. The sensor will then periodically wake up, perform a measurement, notify the host, and go back to a low-power sleep mode. No interaction with the remote host is required.

In the Hardware-Triggered modes (either Tx/Rx or Rx-only), the sensor is awakened (triggered) by the INT line being asserted by the remote host system, performs its measurement, notifies the host system, and then goes back to low-power sleep. The remote host system is responsible for setting up a periodic timer to initiate the sensor measurements on the desired schedule.

Processing Time Requirements

When deciding on a sample interval, it is important to allow enough time for a full measurement cycle, including all data output from the sensor, to complete before the next cycle is initiated. If a new measurement cycle is begun while the sensor is still outputting data, the current measurement may be corrupted.

The largest variable in the sensor processing timing is the maximum range setting. The maximum range setting determines how much time the sensor will spend listening for a detected ultrasonic pulse, once the cycle has been initiated. Each meter of range represents two meters of sound travel (both to and from the target object), so requires about 6 milliseconds of listening time.

When the listening period completes, the sensor processes the received signal. Typical processing time is approximately 5 milliseconds.

The Static Target Rejection (STR) feature, if used, requires additional processing time. STR filters out static objects from the reported data over a specified portion of the overall range. The processing time requirements will vary based on how many samples are included in the STR processing. For long STR range values (i.e. the full 150 possible samples), the additional processing time may be up to 3 milliseconds.

Note: *When STR is enabled in SonicLink, the STR range is always set to match the selected full-scale range for the sensor.*

The maximum range setting and STR will both affect how long the sensor takes to notify the host system that a measurement is complete.

If the I/Q data is read from the sensor after each measurement, the transfer time over the I^{2}C bus is also very important. For a full 150 samples (i.e. for a sensor operating at the maximum range setting of 1m), the total transfer time is approximately 19 milliseconds. The I/Q readout must be completed before a new measurement begins.

1.5 MEASURING RANGE (DISTANCE)

How the Sensor Reports Range

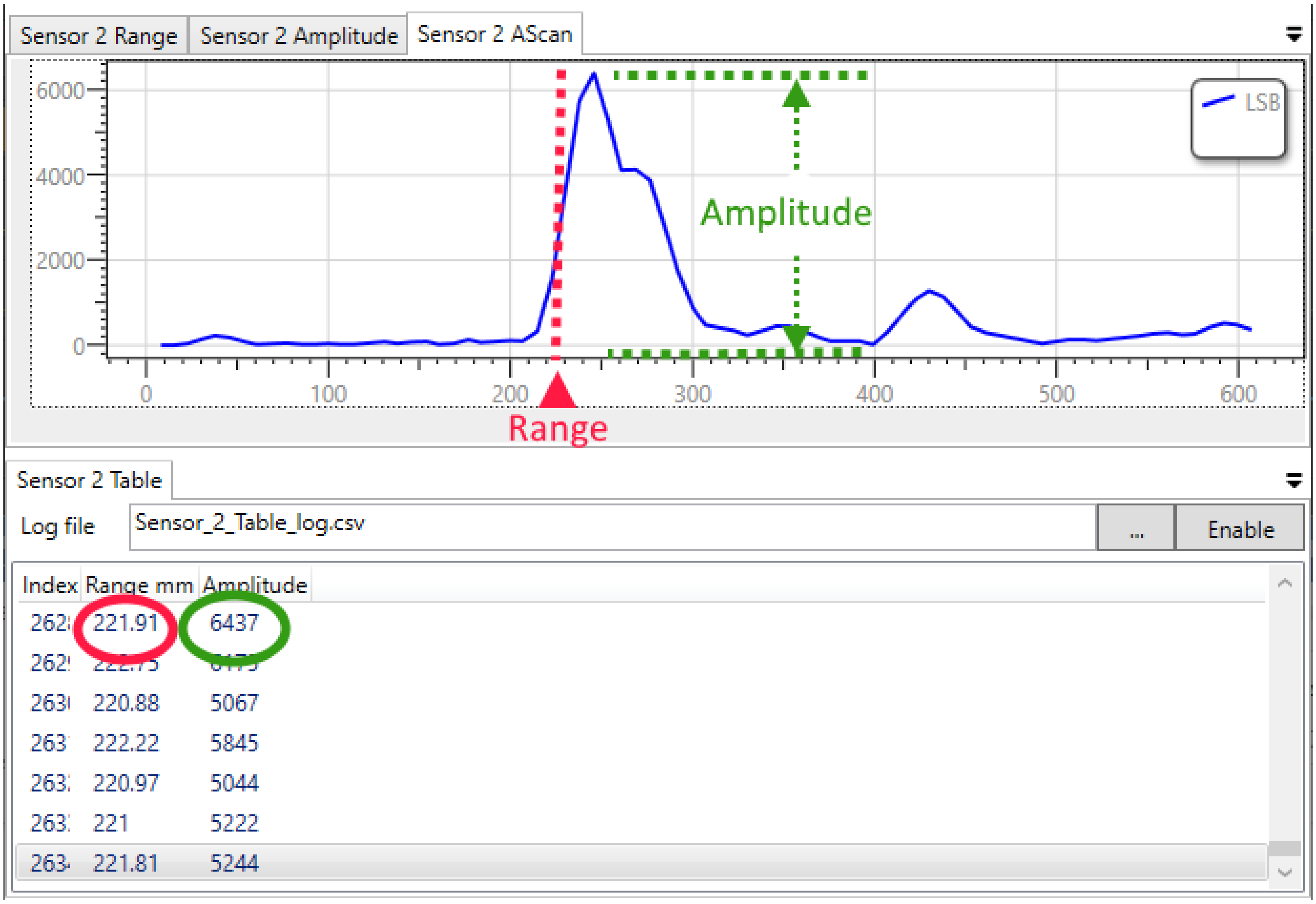
After the CH-101 sensor completes its listening period, it analyzes the captured I/Q data to identify signals that represent objects in its field of view. Those objects may be located in different directions from the sensor, but they are combined into a single record with one amplitude value for each sample.

The sensor determines the presence of an object by comparing the amplitude of each sample within the captured I/Q data against a threshold value. The threshold value that is used may vary across the range of the device, to compensate for the weaker signals from far-away objects. When the amplitude of the signal exceeds the corresponding threshold value, an object has been detected and will be reported. The resulting ToF range (mm) and amplitude (LSB) can be read out as 16-bit values from the sensor.

Because the ultrasonic pulse emitted by the CH-101 is very brief, it creates a sharply defined signal in the received amplitude values, as can be seen in the A-Scan examples in this document. The CH-101 signal processing is designed to report a range value corresponding to the “leading edge” of the pulse, i.e. a point mid-way during its rise before reaching a peak. Because this midpoint will typically fall between discrete samples, the CH-101 interpolates between sample values when calculating the range. As a result, the CH-101 range output has finer resolution than the spacing between I/Q samples.

The CH-101 will report the maximum amplitude of the pulse at its peak.

The following image shows an A-Scan plot with a single target object. The red line indicates the reported range (in mm) and the green lines indicate the reported amplitude value. Below the A-scan plot, the sensor data table shows the measured range and amplitude values returned by the sensor.



Log file: Sensor_2_Table_log.csv

Index	Range mm	Amplitude
262	221.91	6437
262	222.75	6175
263	220.88	5067
263	222.22	5845
263	220.97	5044
263	221	5222
263	221.81	5244

When multiple objects are in the field of view of the sensor, there may be multiple received signal pulses which exceed the corresponding threshold values. In this case, the CH-101 always reports the closest object which exceeded its threshold. Even if there is a farther, larger amplitude object signal, only the closest object will be reported. (To help manage the sensor's behavior in such a situation, see the discussion of Static Target Rejection, below.)

Converting Between Sample Index and Range

The sensor operates internally on samples driven by its own internal clock, whose frequency will vary somewhat from one device to another. As a result, the time between samples (and therefore the physical distance each sample index represents) will be different. So, the operating frequency of the device must be included in any conversions between internal sample index-based values and real-world physical distance.

To convert a sample index to a range value, you must also know the device's operating clock frequency, $\boldsymbol{f_c}$. The sensor obtains a sample every 8 clock cycles, so the actual internal sample rate ($\boldsymbol{f_s}$) equals $\boldsymbol{f_c / 8}$, and the actual time interval between samples ($\boldsymbol{t_s}$) equals $\boldsymbol{8 / f_c}$.

Note: *When using the Short-Range Firmware, the internal sample rate is* $\boldsymbol{f_c / 2}$*, because of a higher sampling rate. The following formulae should be adjusted accordingly. See the discussion of Short-Range Operation, below.*

The formula to convert a sample number into the corresponding time of flight (ToF) in seconds is:

$$\text{ToF} = \textit{sample\_number} * \boldsymbol{t_s}$$

$$= \textit{sample\_number} * (8 / \boldsymbol{f_c})$$

Note that this calculation returns the total ToF. So, if the range that is being reported is based on the echo off an object, it represents the total distance both to and from the object (round-trip). To obtain a one-way distance from an echo's round-trip ToF, the range value must be divided by 2.

The speed of sound is 343 meters per second.

The formula to convert a sample number into the corresponding one-way physical distance in meters is:

$$\text{Distance} = (1/2) * 343\ \text{m/s} * \text{ToF}$$

$$= (1/2) * 343\ \text{m/s} * \textit{sample\_number} * (8 / f_c)$$

Example:

CH-101 device has an operating frequency (f_c) of 176,000 Hz.

Calculate the one-way distance (range) corresponding to sample number 25:

$$\text{Distance} = (1/2) * 343\ \text{m/s} * \textit{sample\_number} * (8 / f_c)$$

$$= (1/2) * 343\ \text{m/s} * 25 * (8 / 176000)$$

$$= 0.1948\ \text{meters}$$

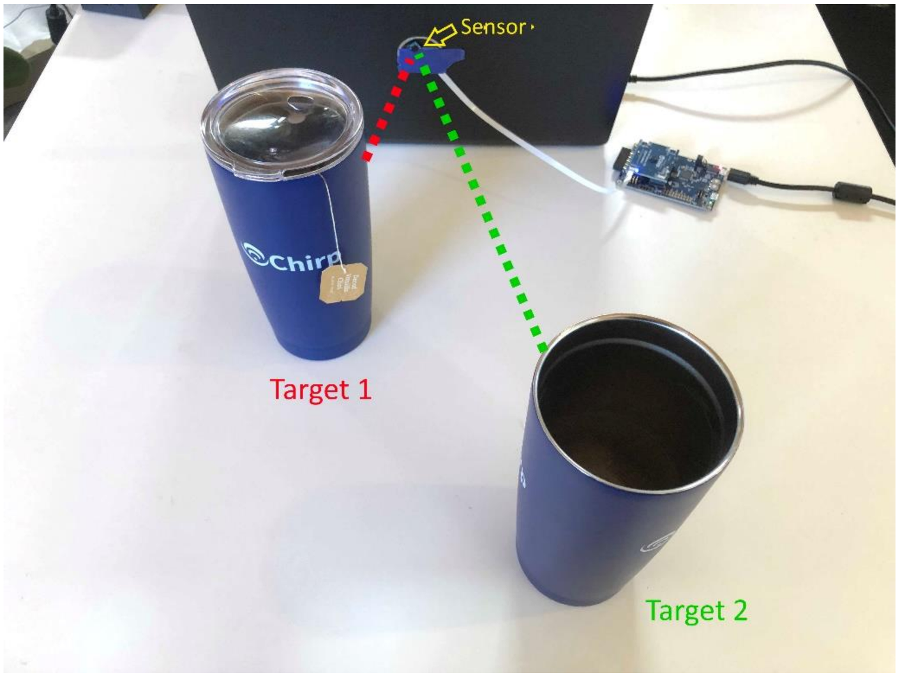
$$= 194.8\ \text{mm}$$

An embedded application can use functions provided in the Chirp API and Driver to perform these calculations.

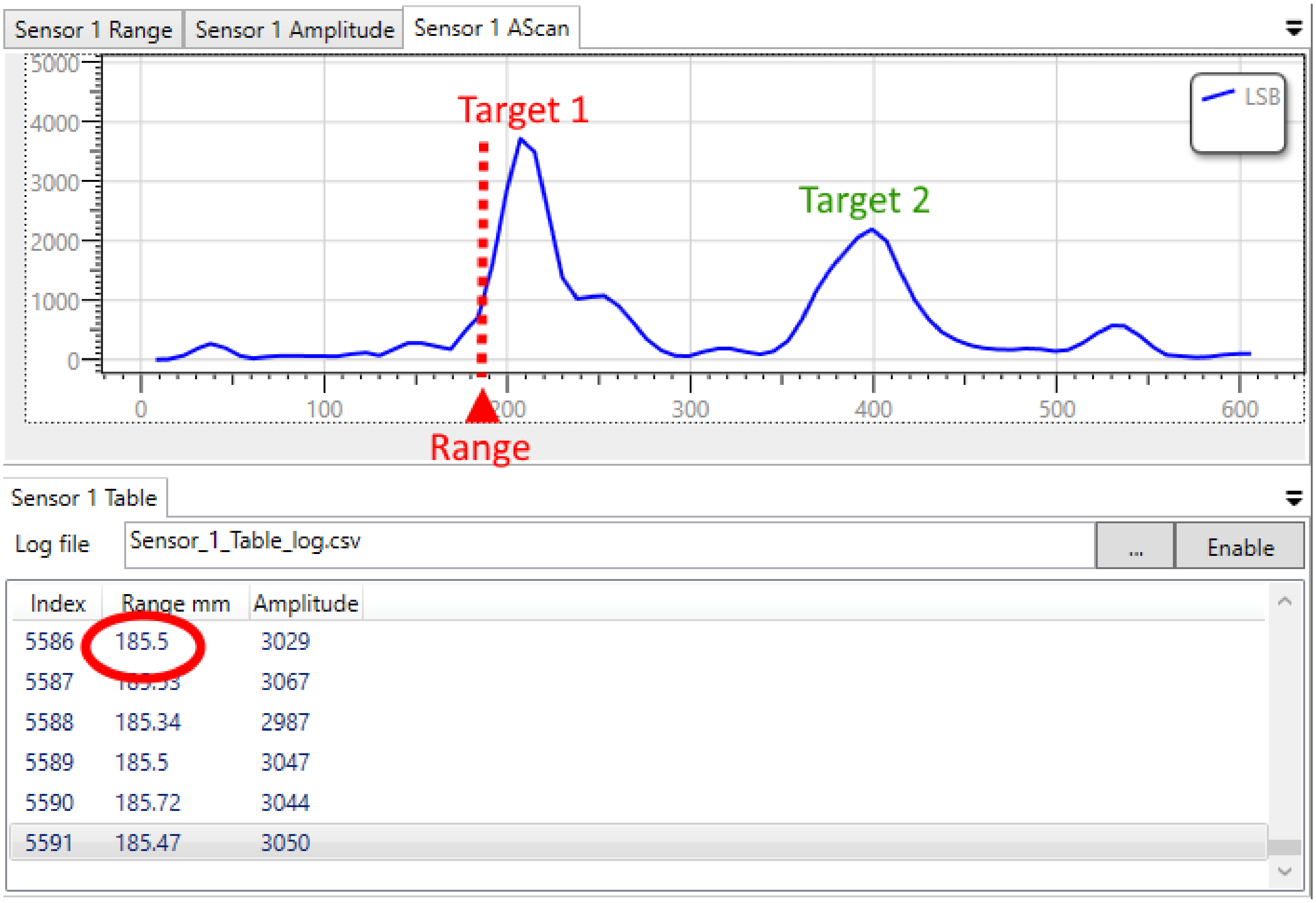
1.6 UNDERSTANDING A-SCAN DATA

A-Scan data is very useful when trying to interpret readings from the CH-101 sensor, especially in cluttered environments. This example shows a simple case with two similar target objects at different distances from the sensor, and what the A-Scan display will indicate.

In this example, a CH-101 sensor is connected to a SmartSonic board by a flex ribbon cable and attached to a mounting plate facing horizontally. Two drinking cups are placed on a table within the sensor's field of view at slightly different distances, as shown in the following photo:



The A-Scan captured from this set-up looks like this:



Log file Sensor_1_Table_log.csv

Index	Range mm	Amplitude
5586	185.5	3029
5587	185.53	3067
5588	185.34	2987
5589	185.5	3047
5590	185.72	3044
5591	185.47	3050

The A-Scan shows that the reported range value is the distance to Target 1, because it is the first (closest) object that was detected. Although the amplitude of the Target 1 signal is stronger than Target 2, that is not the basis for the decision which target to report. Even if the Target 2 signal were stronger, the reported range would still refer to Target 1.

Note that, because the amplitude of the echo signal decreases with the square of the distance, it would be unusual for the farther of two identical targets to return a higher amplitude signal. However, this may be a consideration when observing smaller targets with a larger object in the background.

For applications where the sensor is used to find the range to the closest target, Chirp recommends that customers use the range output and not the I/Q data output, as this enables operation at high sample rates and with low power consumption. Transferring the I/Q data over I²C is time-consuming (19 ms with 1 m FSR) and also increases the power consumed by the CH-101. For such applications, the A-Scan display of the I/Q data is intended to be used as a debugging and development tool only.

However, some customers may want to develop more complicated algorithms that required the use of a complete I/Q trace to improve single target identification or enable multi-target tracking. For such algorithms, the host application may read the full I/Q (A-Scan) data and analyze it with whatever custom algorithm is appropriate.

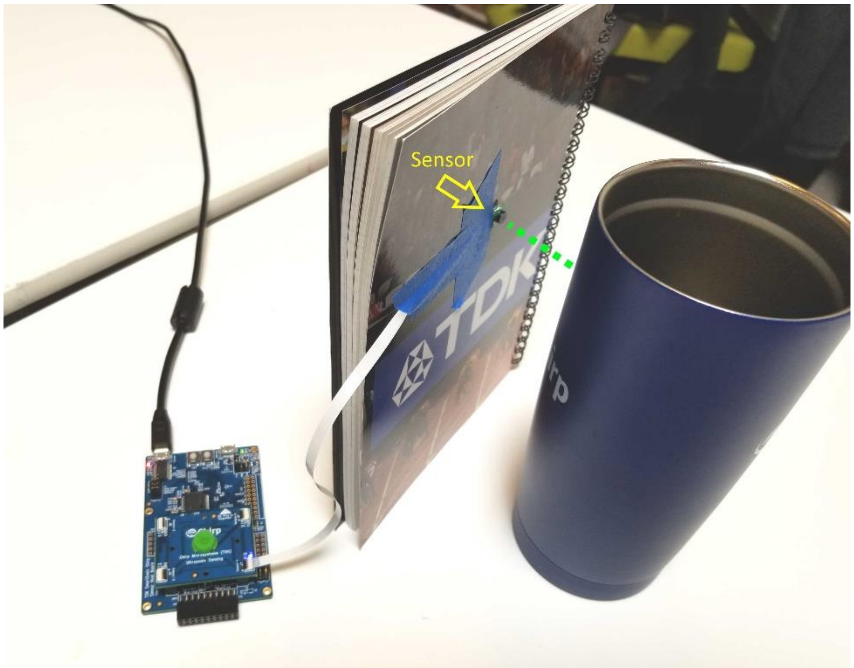
1.7 SHORT RANGE OPERATION

When a target is too close to the CH-101 sensor, the target will be detected but the range output may not be accurate. The minimum distance for accurate range output is different for static (non-moving) targets and moving targets; moving targets can be detected at closer range because they are easier to detect than static targets. When programmed with the General Purpose Rangefinder (GPR) firmware, the range output is accurate for a static target at a minimum distance of 100 mm. When an object is closer than 100 mm from the sensor, the range output will indicate approximately 100 mm range.

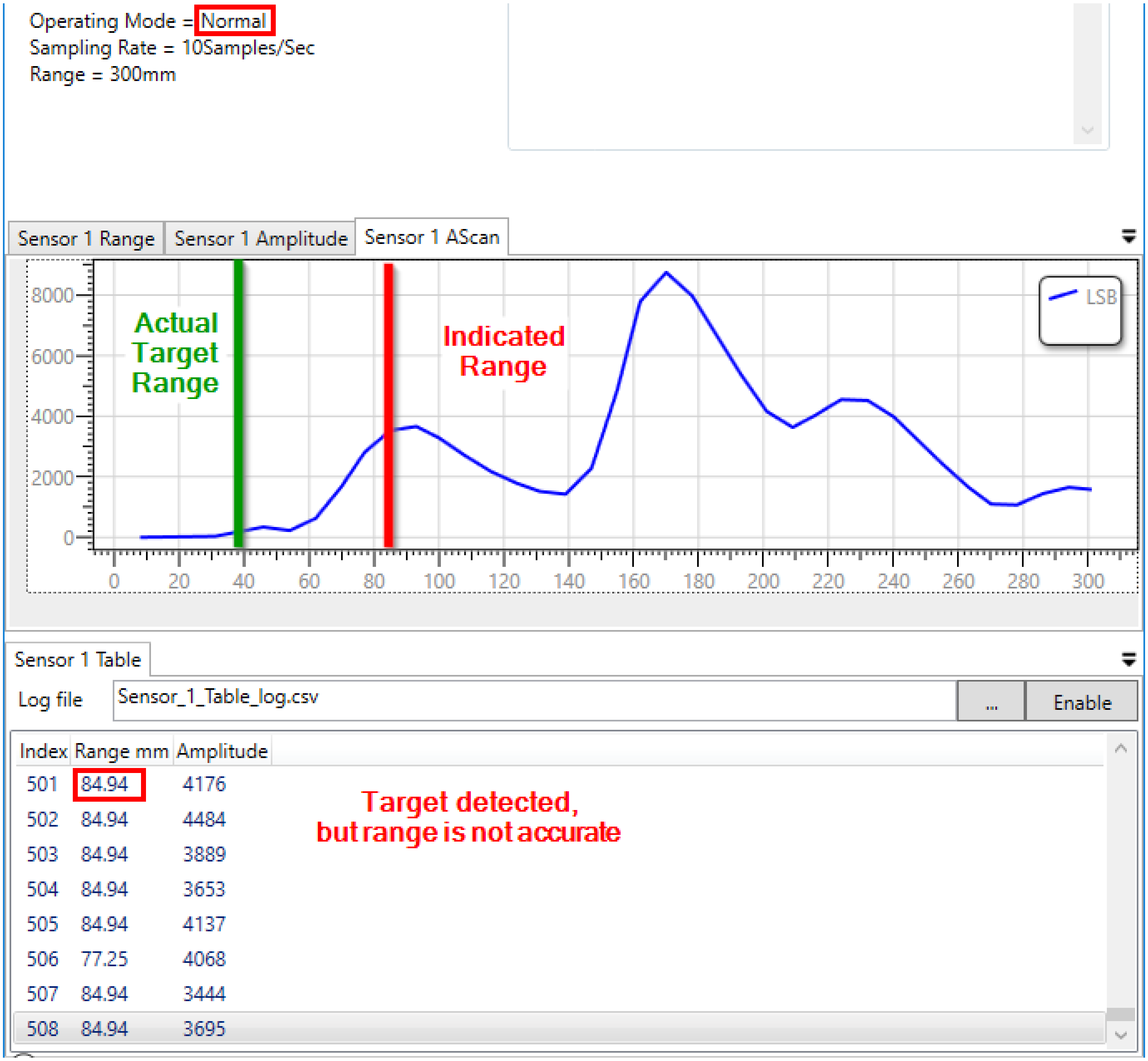
The CH-101 sensor may also be programmed with Short Range firmware to operate in a special short-range mode to optimize the range measurement accuracy for objects at close range. This is not a runtime-selectable option – it must be enabled by initializing the CH-101 device with an alternate Short Range firmware image during system startup. SonicLink allows selection of Short-Range or Normal (GPR) mode during sensor configuration.

In short range mode, the CH-101 range output is accurate for moving objects at a minimum range of 20 mm, although the best performance requires a minimum distance of 40 mm. When an object is closer than 20 mm, the range output will indicate 20 mm range. When in short-range mode, the CH-101 samples at four times the normal rate, to obtain more data during the shorter ToF. As a result, the maximum possible FSR of the sensor is also reduced by a factor of four, to 250 mm.

The following photo shows an example setup with a CH-101 sensor aimed at a drinking cup target. The actual distance between the sensor and the cup is approximately 38mm (1.5 inches).



At this close range, a CH-101 device in normal mode will detect that an object is present, but it will be unable to report an accurate range measurement. Typically, a relatively constant range value, corresponding to the low-end of the device’s reporting range (approximately 100 mm), will be returned. In the following image, the A-Scan output from a sensor in normal mode is shown, along with the (inaccurate) range measurement values.



Operating Mode = Normal
Sampling Rate = 10Samples/Sec
Range = 300mm

Actual Target Range

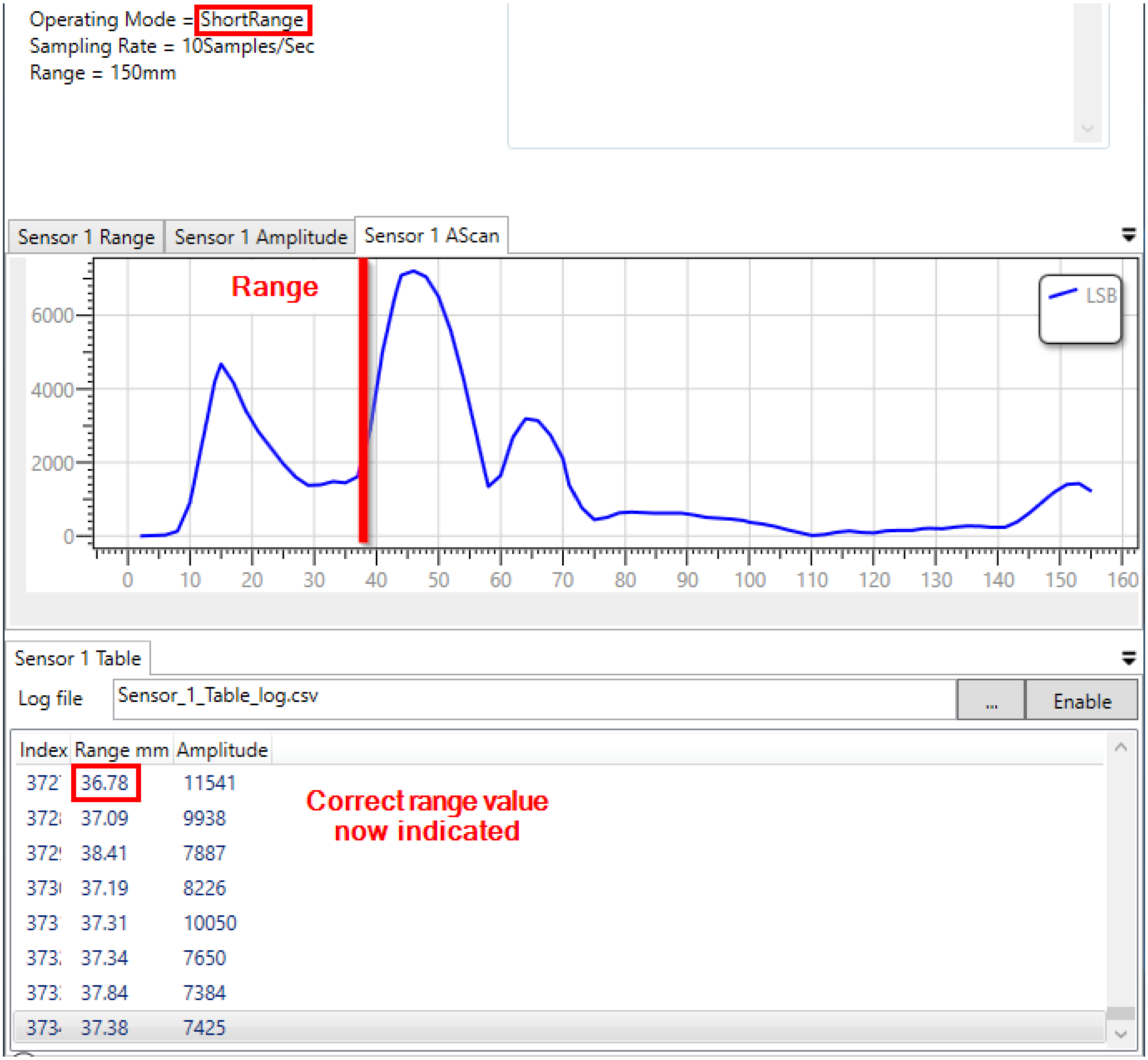
Indicated Range

Log file: Sensor_1_Table_log.csv

Index	Range mm	Amplitude
501	84.94	4176
502	84.94	4484
503	84.94	3889
504	84.94	3653
505	84.94	4137
506	77.25	4068
507	84.94	3444
508	84.94	3695

Target detected, but range is not accurate

If short-range mode is enabled (by changing the device configuration in SonicLink), the CH-101 is now able to accurately measure the distance to objects at closer range. The following image shows the A-Scan for a device in short-range mode, with the same setup as above.



Operating Mode = ShortRange
Sampling Rate = 10Samples/Sec
Range = 150mm

Log file Sensor_1_Table_log.csv

Index	Range mm	Amplitude
372	36.78	11541
372	37.09	9938
372	38.41	7887
373	37.19	8226
373	37.31	10050
373	37.34	7650
373	37.84	7384
373	37.38	7425

Range

Correct range value now indicated

1.8 STATIC TARGET REJECTION (STR)

Static Target Rejection (also known by its acronym, STR) is a runtime option available on GPR firmware for the CH-101 that enables the on-chip range-finding algorithm to ignore static objects when determining the range to the nearest moving target. Users often find that the CH-101's wide FoV allows it to detect unexpected or undesirable objects as targets, such as on a cluttered desktop containing coffee cups, computer monitors, and other large, flat surfaces.

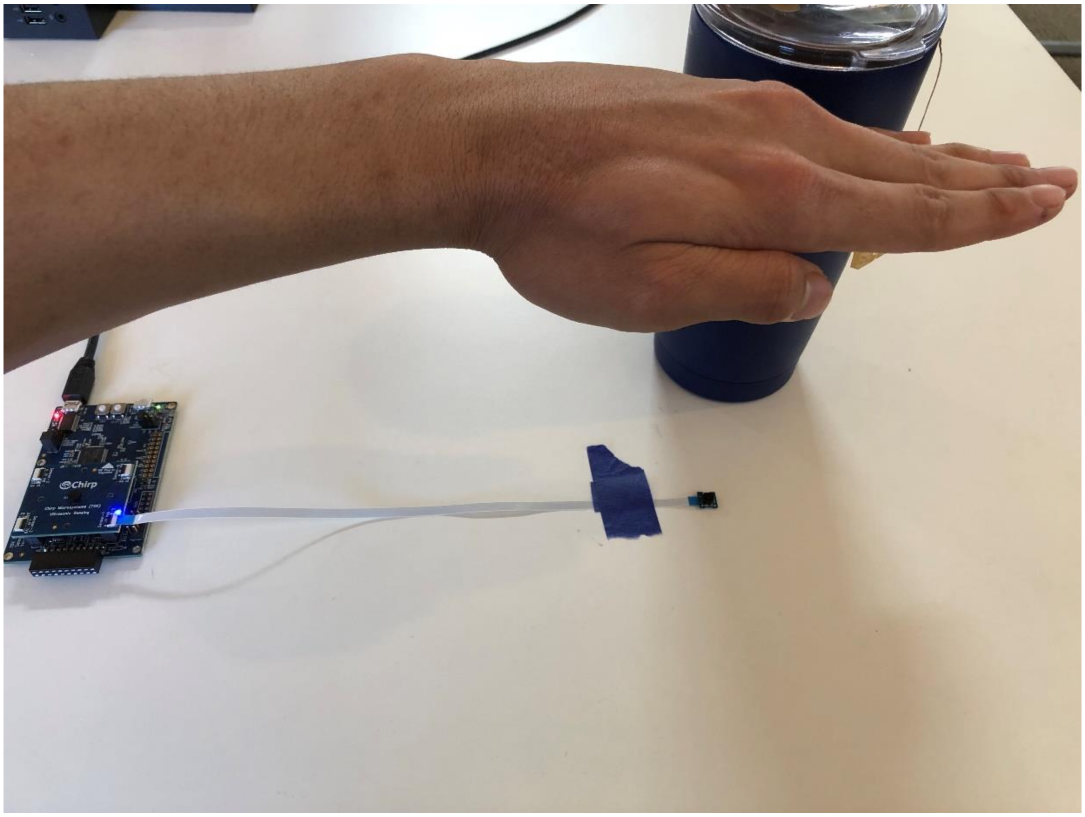
Static Target Rejection works by applying a moving-average high-pass filter over the Full-Scale Range. In normal operating conditions with a stationary CH-101 and a static target, the steady amplitude from the target's echo will allow the filter to reject this signal.

Moving targets will vary in distance and amplitude, and even movements of millimeters can create a detectable signal. Note that, in some cases, such as high airflow around a CH-101, the echo amplitude of a static target can vary enough to register as a target.

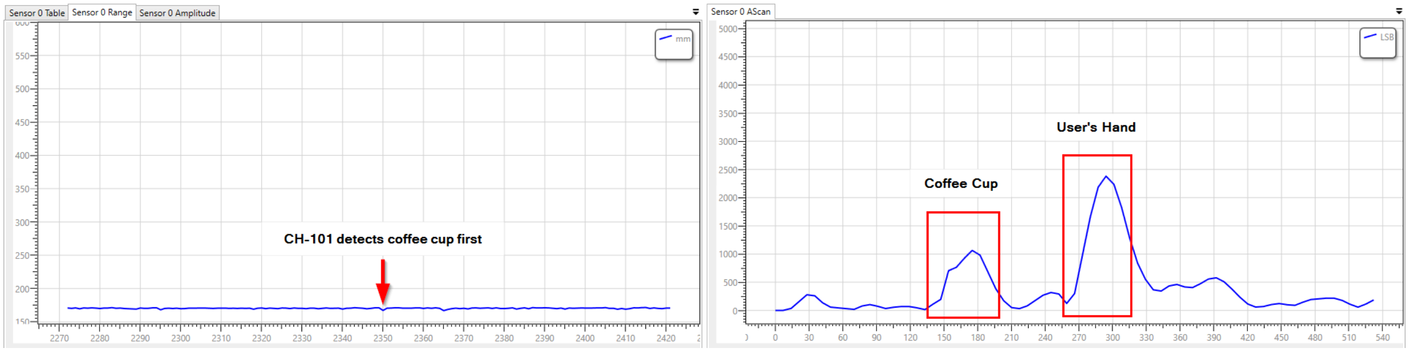
Enabling Static Target Rejection has a negligible impact on power consumption but does require additional processing time by the CH-101, resulting in a slight increase in latency, up to 3 ms for 1 m FSR. For this reason, users should not enable both STR and A-Scan output at the maximum FSR (1 m) and maximum A-Scan sample rate (10 S/s) because the required processing for the STR algorithm and I/Q data transfer time is too long to complete during the 100 ms measurement period.

How to use Static Target Rejection

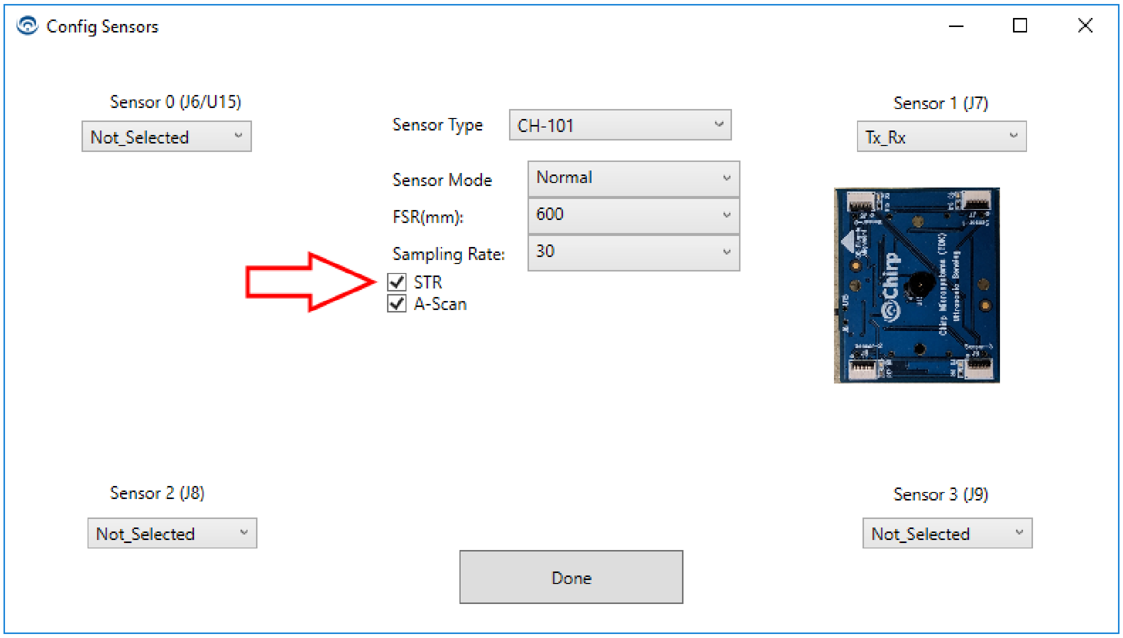
In the following example, a user is trying to detect a moving hand. However, an unexpected nearby target (the coffee cup) stops them from seeing the expected target (their hand).



Looking at the A-scan view, the user can clearly see what's happening; the coffee cup (at ~170 mm range) is closer than the user's hand (at ~280 mm range), so the CH-101 dutifully reports the nearest target.



By opening the “Config Sensors” menu, the user enables Static Target Rejection:


Config Sensors

Sensor 0 (J6/U15): Not_Selected

Sensor Type: CH-101

Sensor 1 (J7): Tx_Rx

Sensor Mode: Normal

FSR(mm): 600

Sampling Rate: 30

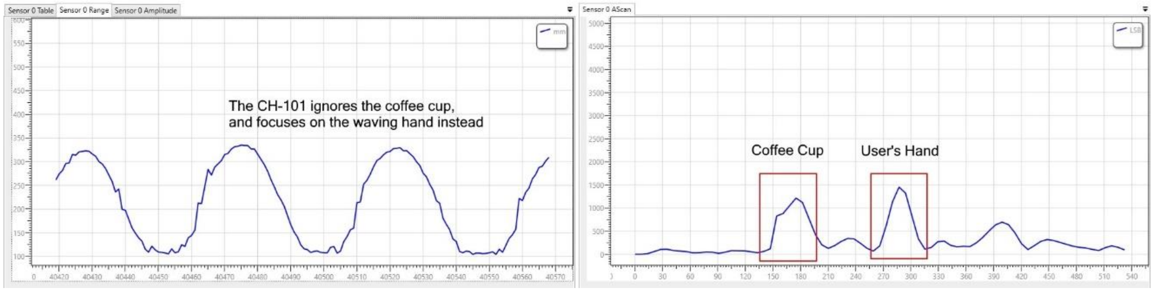
☑ STR

☑ A-Scan

Sensor 2 (J8): Not_Selected

Sensor 3 (J9): Not_Selected

With Static Target Rejection set, the user restarts data collection. The user waves their hand over the sensor to confirm that Static Target Rejection is working as expected, and the range output tracks the moving hand’s motion.



1.9 USING DIFFERENT SENSOR CONFIGURATIONS

Pulse-echo and Pitch-catch Configurations

The CH-101 normally operates in pulse-echo (PE) mode, where a single sensor emits ultrasound (transmit), and then listens for echoes (receive). This is the simplest operating mode, as it requires only one sensor, and the sensor automatically switches from transmit to receive. However, there are cases where pulse-echo operation is not ideal; the CH-101 cannot transmit and receive simultaneously, so targets very close to the sensor will not be detectable (the CH-101 will still be emitting ultrasound when nearer echoes return). Additionally, 2D/3D triangulation of targets is not possible with a single sensor.

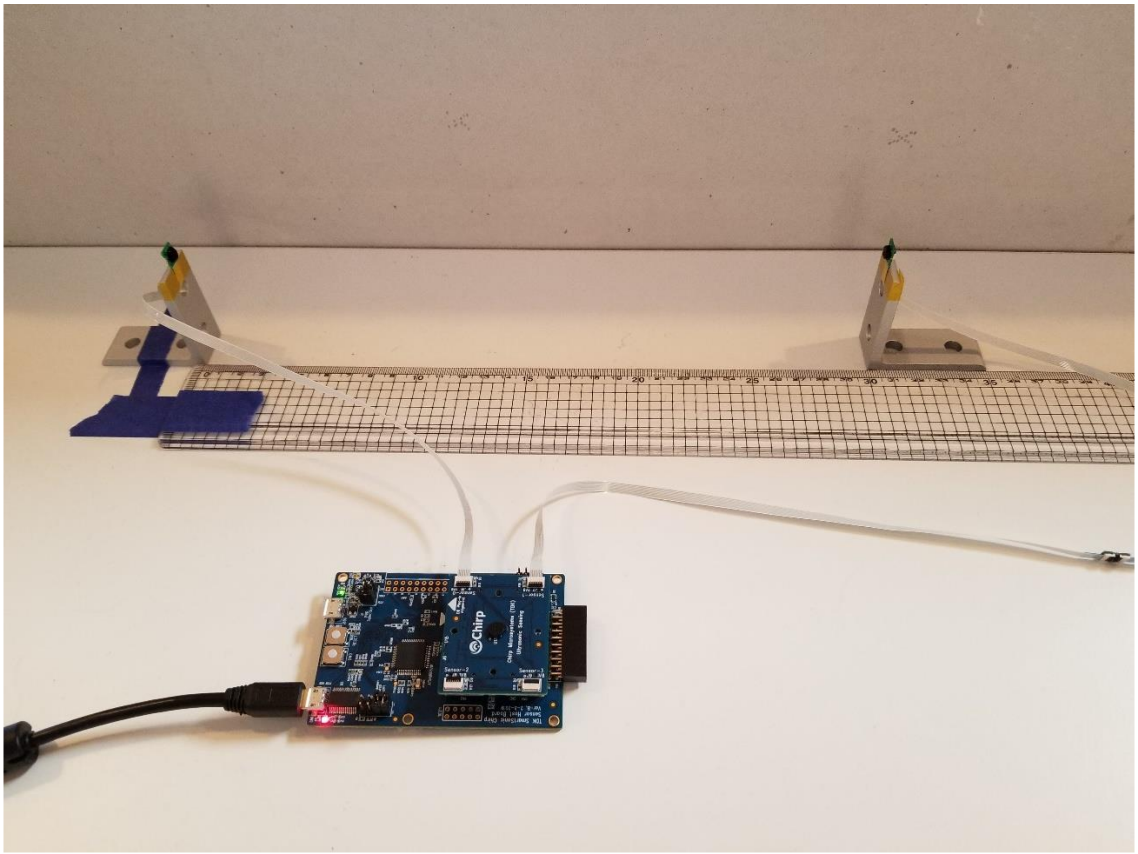
When multiple CH-101 sensors are present, they can also operate in pitch-catch mode, where one sensor acts as a transmitter, and all other sensors act as receivers. There are two types of pitch-catch operation: direct transmission pitch-catch (DPC) and reflected transmission pitch-catch (RPC). Both types of operation are configured the same way and generally enable a smaller minimum detection distance but differ in their physical implementation and interpretation of results. SonicLink enables both types of operation by setting one CH-101 to transmit/receive (Tx/Rx) mode, and all other sensors to receive only (Rx only).

In direct transmission pitch-catch mode, two (or more) CH-101 sensors are oriented towards each other, and the direct path between sensors is recorded as the range. Fundamentally, Chirp's SonicTrack™ and SonicSync™ solutions use CH-101s operating in this mode. This mode has increased maximum range, as one meter of pulse-echo distance is two meters of round-trip distance. This mode also benefits from near immunity to multipath interference; the shortest path between two points will always be a straight line between those points—any multipath interference will necessarily be a longer distance and lower amplitude than the true signal. In this mode, the range reading from the Tx/Rx sensor can be ignored.

In reflected transmission pitch-catch mode, two (or more) CH-101 sensors are oriented such that the transmission from one sensor will reflect off a target and be received by a different sensor. This mode enables detection targets that may otherwise be undetectable (due to location within the FoV, reflectivity, or other factors). Unlike direct transmission pitch-catch, reflected transmission pitch-catch does not benefit from increased maximum range or multipath interference immunity. Care must be taken during system integration and implementation of RPC-based systems that the direct path between sensors minimizes received amplitude on the receiver(s) and the direct-path physical distance is not in the ROI of potential targets.

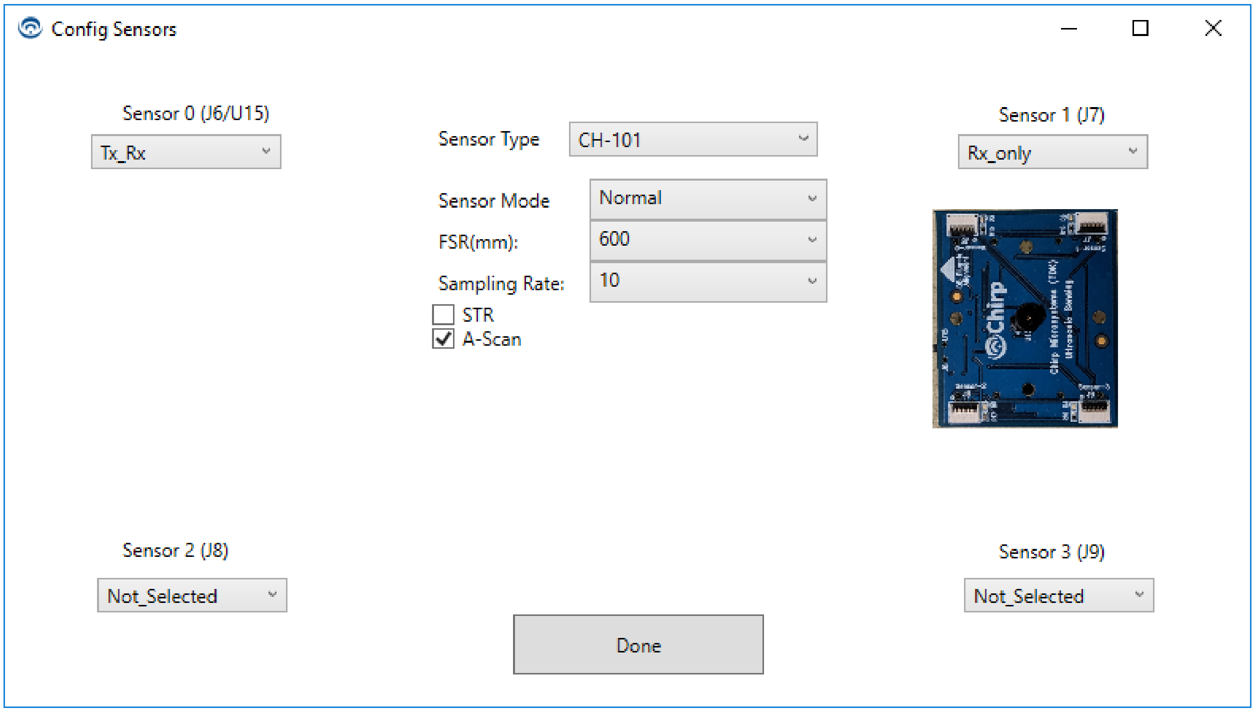
How to set up a direct transmission pitch-catch system

In the following example, we will demonstrate how to set up and evaluate a direct transmission pitch-catch system based on the SmartSonic Evaluation Kit. Using two CH-101-M modules and flat flex cables (FFCs), connect the modules to the FFCs, and then secure the modules to the test system. In the pictures below, we have affixed our sensors to some right-angle brackets to allow the sensors to stand freely.



We start out by positioning the sensors 30 cm apart, based on a ruler added to the setup. From SonicLink, configure Sensor 0 to be the Tx/Rx sensor, and Sensor 1 to be Rx Only.

Note: the current minimum range for DPC configurations is 22 cm.



Config Sensors

Sensor 0 (J6/U15): Tx_Rx

Sensor Type: CH-101

Sensor Mode: Normal

FSR(mm): 600

Sampling Rate: 10

☐ STR

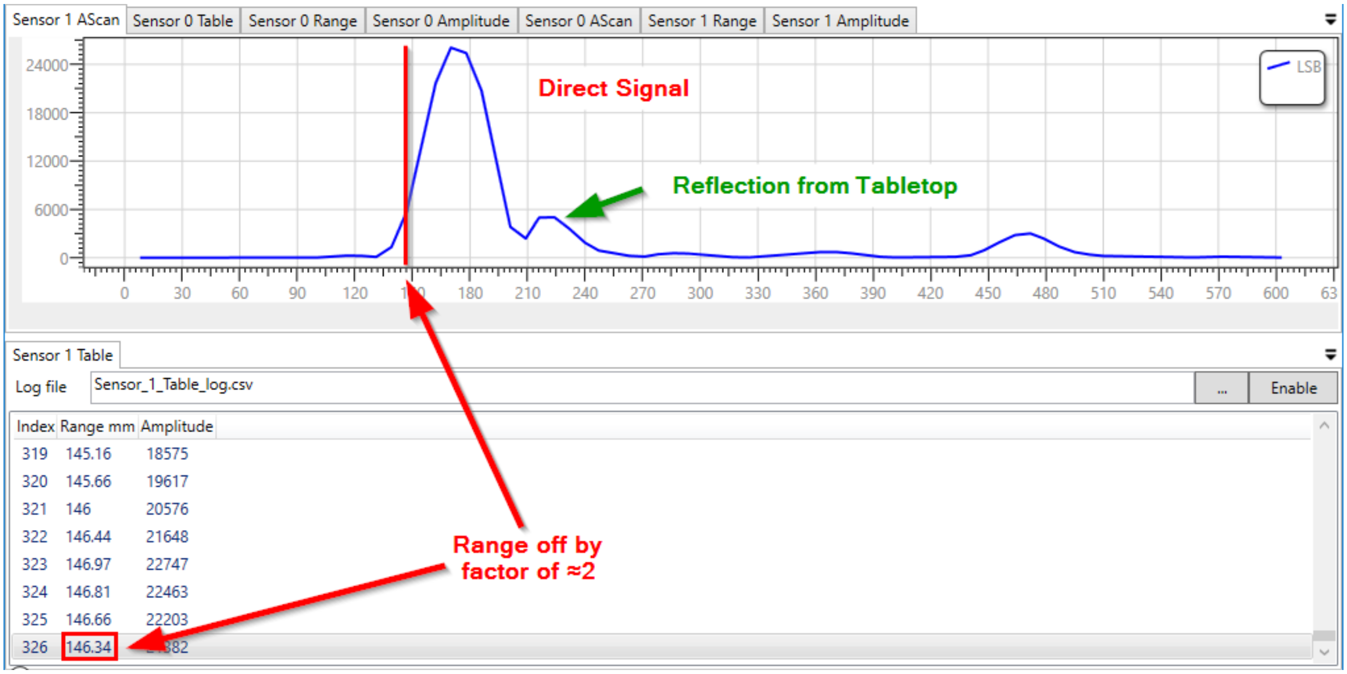
☑ A-Scan

Sensor 1 (J7): Rx_only

Sensor 2 (J8): Not_Selected

Sensor 3 (J9): Not_Selected

For this application, we will focus on the range reported by Sensor 1, the Rx Only sensor. After initializing the sensors and adjusting the display to show the table and A-scan plot, we observe the following:



Sensor_1_Table_log.csv

Index	Range mm	Amplitude
319	145.16	18575
320	145.66	19617
321	146	20576
322	146.44	21648
323	146.97	22747
324	146.81	22463
325	146.66	22203
326	146.34	[illegible]

In the A-Scan, the first pulse corresponds to the direct-path transmission signal, while a smaller, secondary echo corresponds to the reflection from the tabletop. Notice that the reported range is a little less than half of the expected value—when calculating range, the CH-101 measures the round-trip distance and divides that by two to get the true distance. In a DPC configuration, the trip is only one direction, so the division by two creates this range error. Additionally, in a DPC configuration, a static range offset of approximately 10 mm needs to be added to the scaled range, using the following equation:

True Range = 2 * Reported Range + 10 mm

Example:

A CH-101 device in Rx Only mode reports a range of 145 mm.

True Distance = 2 * (145.0) + 10.0

= 300.0 mm

An embedded application can use functions provided in the Chirp API and Driver to return either the one-way or round-trip range, but this feature is not currently supported by SonicLink.

Note: the Chirp API and Driver functions do not correct for the 10 mm static offset; this will be addressed in a future release.

1.10 USING EXTERNAL SENSOR MODULES AND SENSOR BEAM-PATTERNS

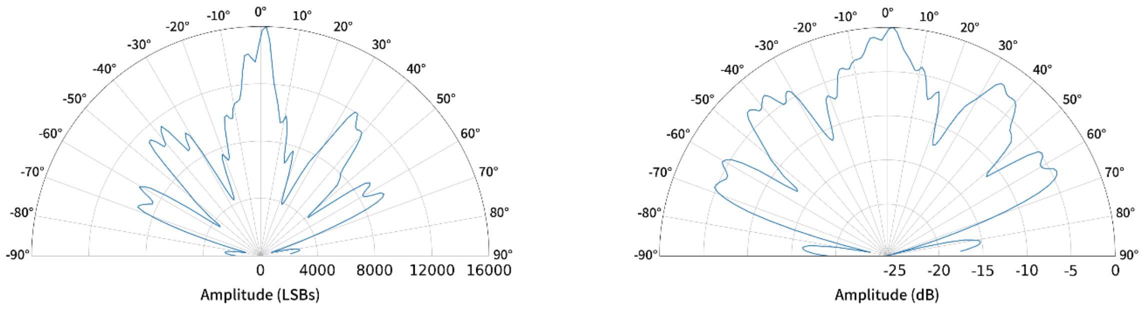
Using external sensor modules

Up to four external sensor modules can be connected to the SmartSonic evaluation board. The MOD-CH101-03-01 sensor module has an omnidirectional acoustic housing with a 0.7 mm diameter acoustic port and a 5.3 mm outer diameter. Because this housing has an omnidirectional beam-pattern, users should take care to keep the area near the sensor clear of other objects which could create reflections in the outgoing and incoming sound waves. For the best acoustic performance, the module should be mounted into a flat surface measuring at least 100 mm in diameter. Consult the MOD-CH101 module datasheet for more information.

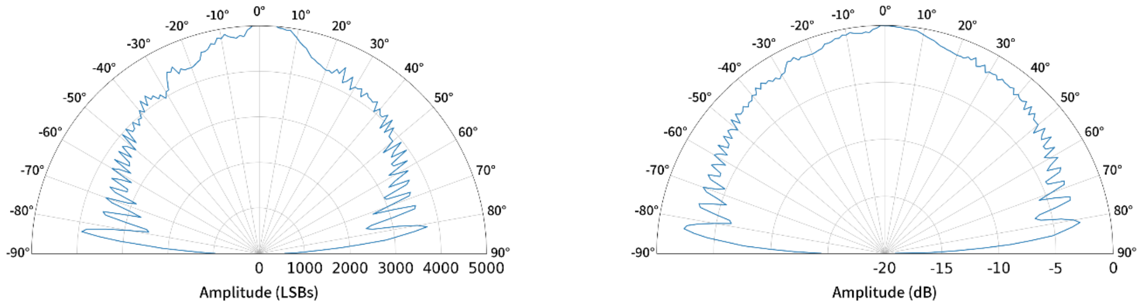
Sensor beam-patterns

The CH-101 sensor on the SmartSonic daughterboard is covered by the same omnidirectional acoustic housing used in the MOD with a 0.7 mm diameter acoustic port and a 5.3 mm outer diameter. Because the surface of the evaluation kit has many edges and protrusions, the ultrasonic beam-pattern of the on-board CH-101 sensor is not truly omnidirectional. To achieve omnidirectional response, Chirp recommends that customers use external MOD-CH101-03-01 omnidirectional sensor modules mounted into an appropriate enclosure. Alternatively, customers may insert the on-board CH-101 sensor into a mounting plate (see the MOD-CH101 datasheet for further information).

Pulse-echo beam-pattern plots of the CH-101 sensor mounted on the SmartSonic daughterboard are shown below. This beam-pattern was measured by placing a 1 m^2 target at a 30 cm distance from the SmartSonic daughterboard and recording the CH-101 ToF amplitude as the sensor is rotated 180°. The plots are shown in both raw LSB units and normalized dB units, where 0 dB corresponds to the peak amplitude (16,000 LSB) recorded on-axis. Note that the beam-pattern consists of a central main-lobe and four side-lobes at ±35° and ±60°. The multi-lobed beam-pattern means that the on-board sensor will give good performance for detecting on-axis targets but may result in poor detection of targets located at angles where the beam-pattern shows small amplitude (e.g. ±20° and ±50°). For comparison, the CH-101 beam pattern when mounted in the recommended 100 mm diameter mounting plate is shown below. When mounted in the recommended plate, the beam-pattern shows a relatively constant amplitude from +80° to -80°, where the pulse-echo amplitude is reduced to half of the maximum amplitude observed on-axis.



Beam pattern measurements of CH-101 SmartSonic daughterboard (raw linear LSB units left, normalized dB right)



Beam pattern measurements of CH-101 module in 100 mm diameter plate (raw linear LSB units left, normalized dB right)

2 REVISION HISTORY

Revision Date	Revision	Description
9/30/2019	1.0	Initial Release

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