Application User Guide for Floor Type Detection of Robotic Vacuums

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1 INTRODUCTION

This guide will explain the hardware and software setup of the floor type detection for robotic vacuum applications. Using a Chirp sensor module, the floor type detection setup can distinguish between a hard and soft floor surface such as a hardwood floor and carpet. Using the GUI, real-time numerical data can be recorded and viewed in plot form. Using automatic parameter settings, a demo of hard and soft floor detection can be demonstrated with proper mounting, the evaluation kit setup and inputting the floor distance. For a more refined demonstration, custom parameter settings can be used.

1.1 SCOPE

- Review the floor type detection demo hardware and software setup
- Run the floor type detection application (Robofloor) GUI
- Understand how to set the floor height and proper mounting
- Tune parameters and data output
- Basic understanding of the GUI detection output
- Debug hardware and software setup issues

1.2 REFERENCE DOCUMENTATION

Table 1-1. Reference Documentation

Type	TDK/ Chirp Reference Document	
	Document Number: Name	**Section**
CH101 Module	AN-000259: CH101 Design Guide AN-000231: EV_MOD_CH101 User Guide AN-000260: CH101 Module with 45° FoV & Particle Ingress Filter DS-000388: CH101 Datasheet	1
Hardware	AN-000158: CH101 Mechanical Integration Guide PB-000110: DK-CH101 Product Brief	2
Software	AN-000180: CH101 & CH201 Smart Sonic Eval Kit AN-000154: SmartSonic Hello Chirp Application Hands-on Exercise AN-000175: SonicLib Programmers Guide AN-000176: SmartSonic Robo-Floor Example User's Guide	2-3

1.3 REQUIRED HARDWARE AND SOFTWARE

The hardware list may differ if a different type of module is used. Use the latest or desired software (s/w) package along with the proper hardware and firmware (f/w).

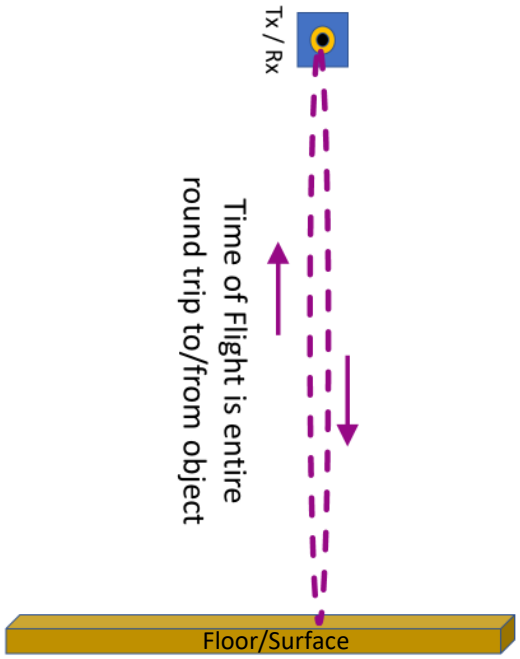
1. Hardware
    - DK-CH101 - Evaluation Kit
    - Micro-USB cable
    - CH101 Chirp sensor module
    - Cable FFC 8POS
2. Software
    - RoboFloor_vX.X.X.exe (provided s/w package)
    - Atmel Studio 7 – if f/w flash needed

1.4 THEORY

Please refer to AN-000259 CH101 Design Guide for detailed module and module integration information.

The CH101 sensor, a single pulse-echo sensor, is an ultrasonic transceiver that can transmit and receive ultrasound signals. These sensors measure the round-trip time that it takes for sound to be transmitted and returned to determine the distance. This is also known as the Time of Flight (ToF). The image below shows an example of the how the sensor detects a signal, in this case a floor surface. Using the data received, the floor type can be distinguished by the strength of the return signal. For a more in-depth explanation of ultrasonic sensing and hardware, refer to the reference documentation section.

Figure 1-1. Single-Sensor Pulse-Echo



2 HARDWARE SETUP

2.1 SMARTSONIC (DK-CH101) PREPARATION

Before using the demo, the DK-CH101 SmartSonic needs to be flashed with the proper f/w. Download and unpack the latest or desired f/w release package. This step can be skipped if the DK-CH101 is known to have the correct f/w. Below is the list of available f/w package/s available. The X in the file name is the version number. The latest file should be provided.

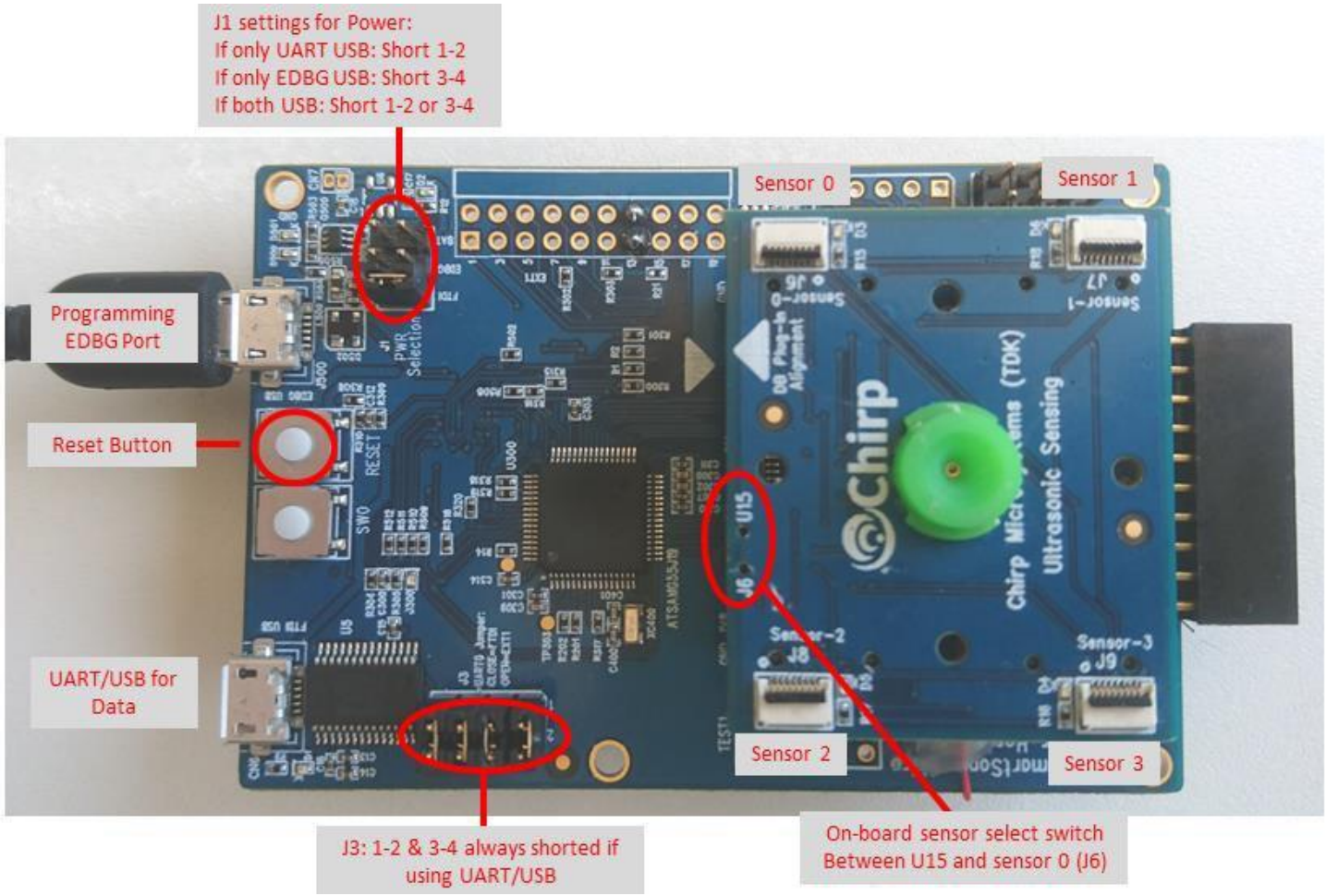
Table 2-1. Available f/w for Standalone Demo

Description	FW
Floor Type GUI logger	Gui-demo-smartsonic-robofloor-logger_X.XX.X.hex

2.1.1 DK-x01 SmartSonic and Daughterboard Hardware

The DK-x01 SmartSonic hardware out-of-box is shown below. Note that the horn on the daughter board may differ from the picture. Refer to the reference documentation for more information.

Figure 2-1. SmartSonic Hardware basics

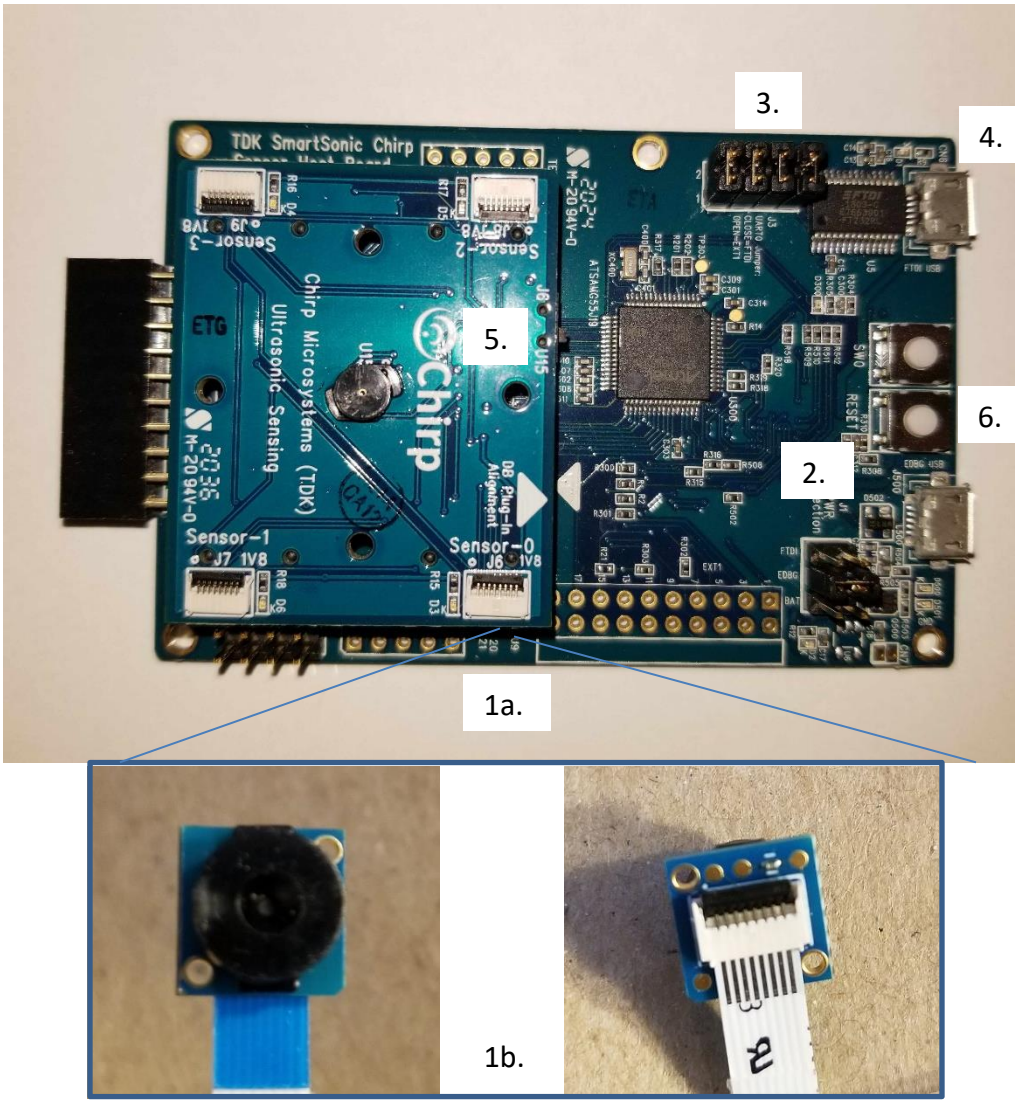


2.1.2 Using SmartSonic Module Sensor

Setup instructions are below:

1. Connect one end of the 8POS FFC cable to the Sensor-0 connector and the other into the CH101 module sensor. Check flex orientation to prevent flex cable hitting other components.
    a) Sensor-0 – J6
    b) CH101 - Note: Horn/Housing may differ from picture
2. Move jumper to FTDI slot after board has been programmed
3. Connect all J3 jumpers
4. Connect USB cable from PC to FTDI-USB connector
5. Toggle the switch from U15 to J6 (Sensor-0) - Note: U15 will use sensor on SmartSonic daughterboard
6. Reset the board when changing any connections

Figure 2-2. SmartSonic Connections

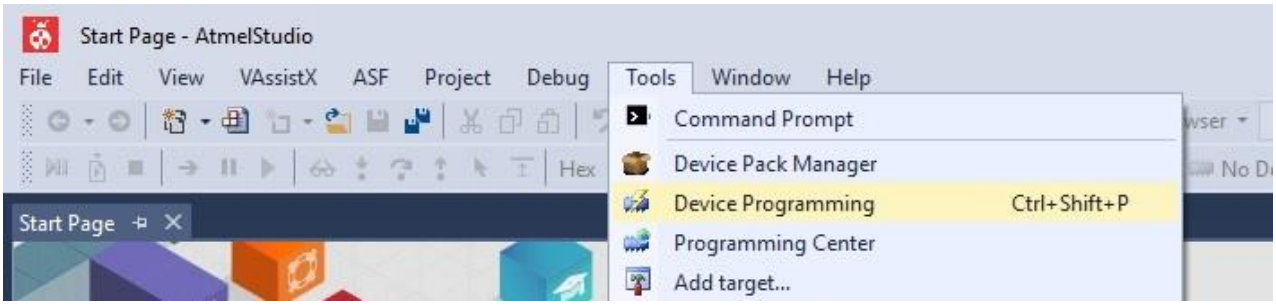


2.1.3 Flash SmartSonic FW

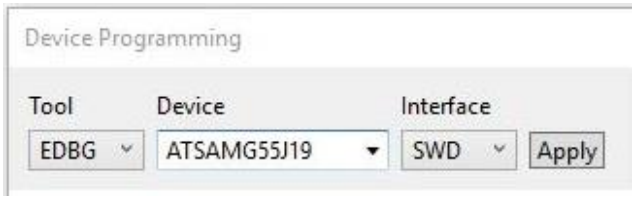
If the SmartSonic has the correct FW, this section can be skipped.

Flash setup instructions:

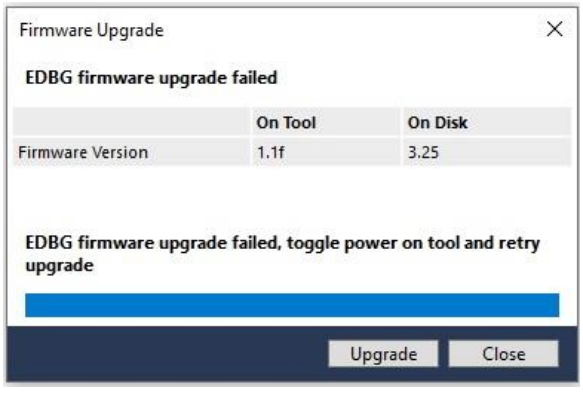
1. Connect the SmartSonic board to your PC:
    - Plug Micro-USB into the EDBG-USB
    - Move jumper to EDBG (middle)
2. Open Atmel Studio 7 application or use command prompt:
    - Download Atmel Studio from their website, if needed.
    - Link: https://www.microchip.com/mplab/avr-support/atmel-studio-7
3. Pull down the Tools menu: “Tools> Device Programming” for programmer SW.



4. Select the settings below and hit ‘Apply’.



5. Upgrade MCU firmware, if necessary. Older SmartSonic boards will need firmware upgrade.



6. In the Memories section, browse for the hex/elf file from the desktop. The file will be in the packaged exe folder or you can specify a desired file.

7. Hit 'Program' button.

8. There will be a Verify Flash completion. If flash procedure has an error, reset the SmartSonic board, then check the setup again from the start of this section.

2.2 CH101 CHIRP SENSOR MODULE MOUNTING

Please refer to AN-000259 CH101 Design Guide for detailed module and module integration information.

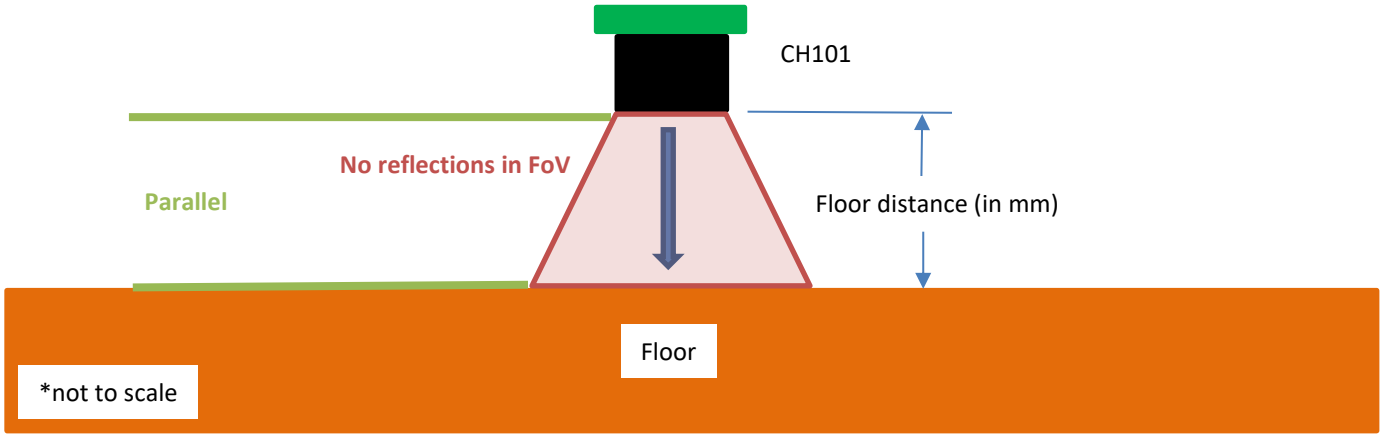
For the module to detect floor types, it must be mounted correctly. It is important to meet all mounting requirements and follow mounting suggestions. The mechanical integration guide, listed in the Reference Documentation section, can be reviewed for a deeper dive into the module assembly and further explanation on the requirements listed below.

Requirements:

Mount the CH101 downward to a fixture, cart, or desired apparatus, but ensure that it meets the list of requirements below:

- No reflecting objects in the FoV (below sensor and floor surface)
- Parallel to floor surface (no tilt angle – for best detection)
- Set to desired distance
- Facing downward to the surface
- No force must be applied on the sensor and horn/housing when mounting

Figure 2-3. CH101 mounting requirements



3 GUI

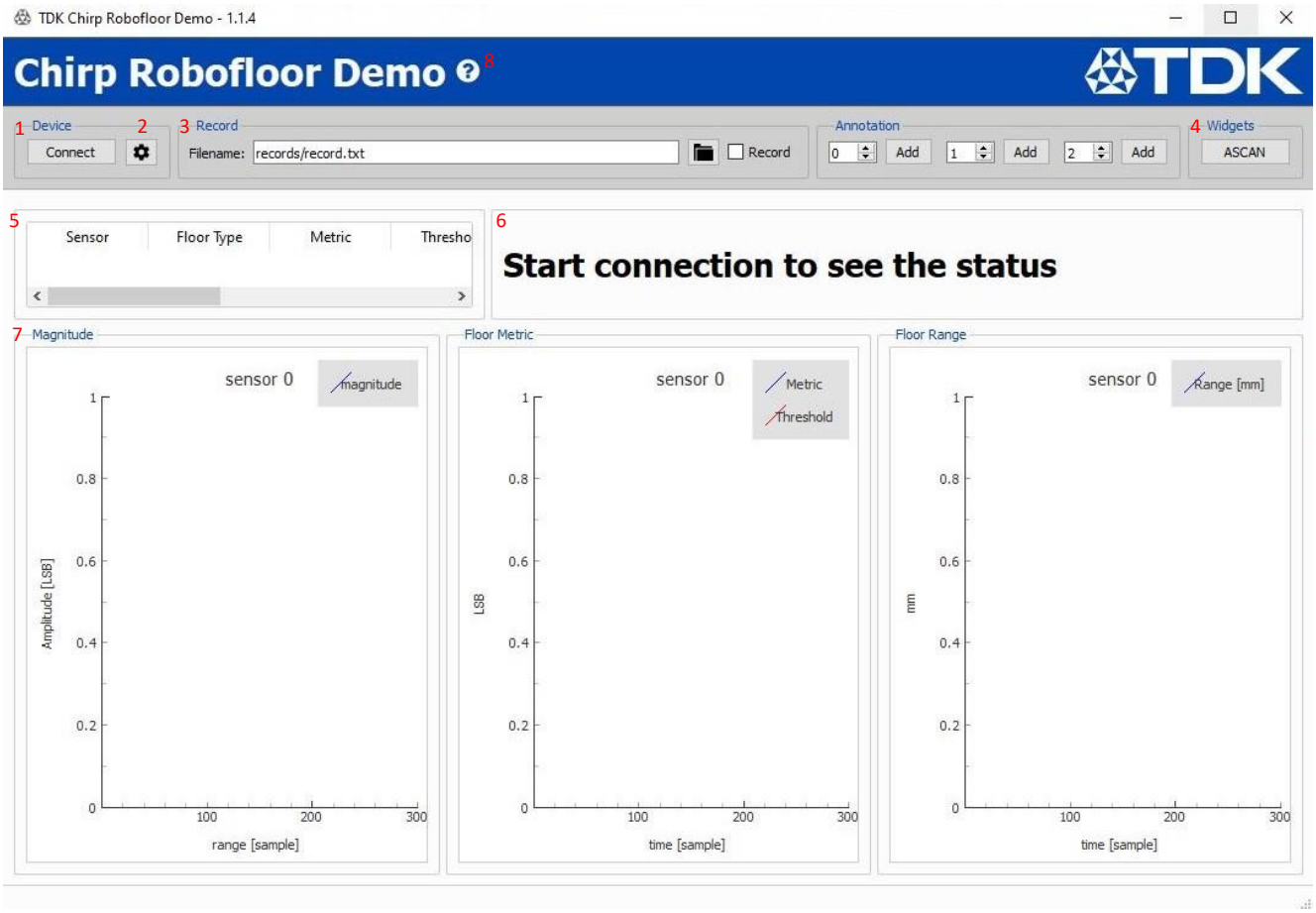
The GUI is used to display real-time plots and output numerical values of its scans.

3.1 LAUNCH GUI

1. Plug in the USB from the Smartsonic to the computer.
2. Open the unpacked folder, 'Gui-demo-robofloor-X.X.X'. Ensure proper firmware is flashed on SmartSonic.
3. Launch 'floor_demo.exe'.
4. Hit 'Connect' and the detection will start.

3.2 GUI FIELDS AND WIDGETS

Figure 3-1. Robo Floor GUI Interface



1. **Connect:** Establish connection. Starts real-time sensing and data stream.
2. **Settings:** Input settings. See *Section 3.3*.
3. **Record:** Record the raw data anytime by checking the 'Record' box. The "record.txt" can be changed to a desired name.

- Records are saved in the GUI records directory folder:
  - Input data settings used for record: \Gui-Demo-robofloor-x.x.x\records
  - Output raw data of record: \Gui-Demo-robofloor-x.x.x\records\algo\floortype_emd

Figure 3-2. Sample Data File

timestamp (µs)	sensor_tx_id	sensor_rx_id	metric	threshold	floor_type	range	range_amplitude	range_status	<reserved>
184699536	ChDataType	0	0	236	281	0	24	1705	1	0
184739536	ChDataType	0	0	233	281	0	22	1620	1	0
184779535	ChDataType	0	0	260	281	0	25	1726	1	0
184819534	ChDataType	0	0	301	227	1	28	1562	1	0
184859533	ChDataType	0	0	298	227	1	47	298	1	0
184899532	ChDataType	0	0	335	227	1	29	1588	1	0

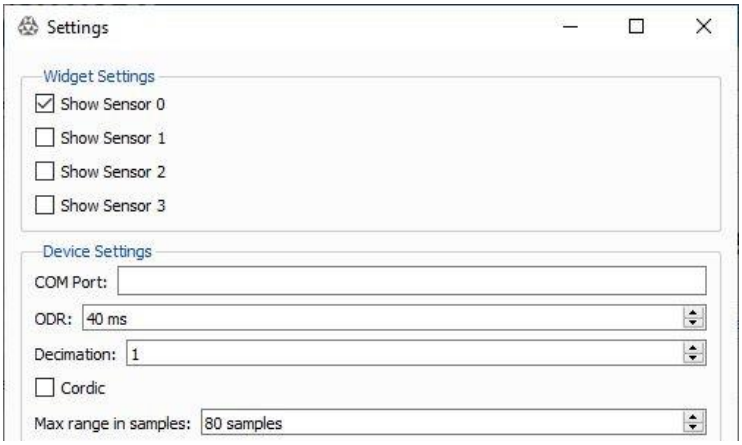
4. **ASCAN:** Grayscale amplitude scan. See *Section 3.4*.
5. **Sensor Table:** Table showing real-time numerical value outputs
6. **Display:** Status display. Shows Sensor and detected floor type.
7. **Plots:** Real-time magnitude, floor metric, and floor range. See *Section 3.4*.
8. **Help (?):** For more information on the GUI features (recording, plots, algo configurations, etc), click the (?) and 'Open documentation' dropdown.

3.3 SETTINGS AND TUNING

The GUI is used to display real-time plots and output numerical values of its scans with automatic (auto) or custom (tuned) parameters/configuration. The auto parameters are set from validation data collected from different surface types and only the floor distance needs to be inputted to output floor metrics. For more refined tuning parameters for custom setups, additional custom parameters are needed. These custom parameter values can be used to set the API functions and input into the MCU.

3.3.1 Settings: Widget & Device Settings

Figure 3-3. Settings: Widget & Device



Widget and Device Setting Description:

- **Widget Settings**
  - **Show Sensor i:** Show plots of sensor number i (where i = sensor 0, 1, 2, and 3); Supports up to 4 sensors.

- Note: ODR needs to be increased when connecting additional sensors as it requires more data bandwidth.

- **Device Settings**
  - **COM Port:** Specify com port in case multiple hardware boards are connected.
  - **ODR:** Time interval to periodically trigger the sensor. Reducing ODR increases the data bandwidth requirement to transfer data from sensor to host.
  - **Decimation:** Decimate IQ data or magnitude streamed from the sensor.
  - **Max range in sample:** Number of IQ samples to acquire.

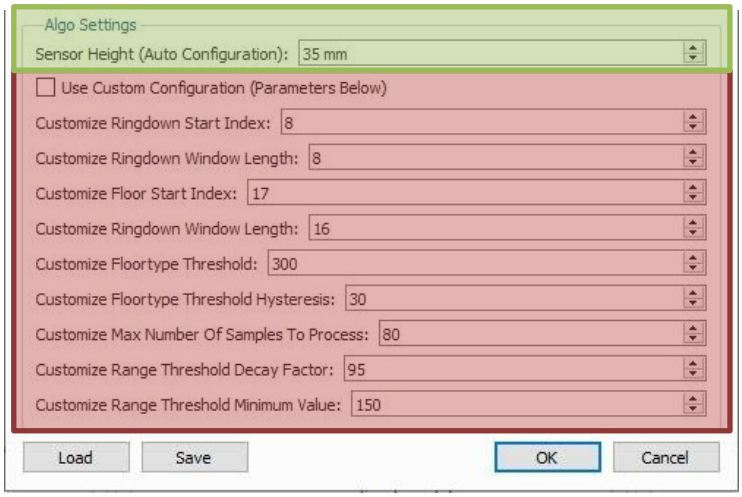
3.3.2 Settings: Sensor height from floor (Auto Configurations)

To use auto configurations set from validation data collected from different surface types, only the floor height value needs to be inputted. All mounting requirements need to be met and the floor distance needs to be known. For setting custom parameters and refining the tuning parameters, see *Section 3.3.3*.

Steps:

1. Mount the module to the desired location with the horn/housing facing downward to the floor surface. The sensor must be facing the floor surface with no tilt or reflective surroundings. For more information on module mounting, refer to *Section 2.2*.
2. In the unpacked folder (RoboFloor_vX.X.X.exe) and in the GUI folder, open 'Gui-demo-robofloor-x.x.x'.
3. Click the settings icon ( ) to input settings.
4. For auto-configuration, only edit the "Sensor Height" value in the settings between 2.5-6cm (25-60mm). This is the distance from the acoustic horn/housing bottom surface to the surface.
   a. The default is set to 35mm. All custom parameters are disregarded (in red).
   b. The 'Sensor Height' value corresponds to the height that the CH101 sensor is set on the hardware relative to the surface.
   c. Settings can be saved to a .json file. This will be saved in the GUI folder. Loading the file will overwrite the current settings to the saved .json file. The .json file can be opened in a notepad or text application to modify the parameters.

Figure 3-4. Settings: Floor Height



5. Hit 'OK' to save settings for current run. Then click 'Connect' to display real-time outputs.

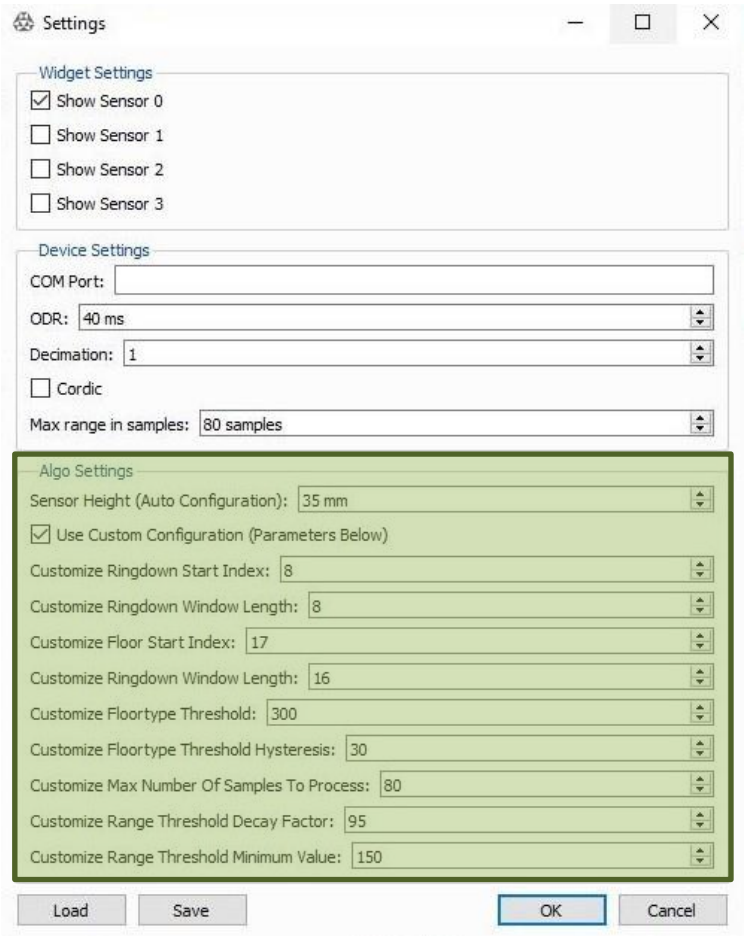
3.3.3 Settings: Tuning with Custom Parameters

To tune for custom apparatus, floor types, or different setups, custom parameters need to be used

Steps:

1. Mount the module to the desired location with the horn/housing facing downward to the floor surface. The sensor must be facing the floor surface with no tilt or reflective surroundings. For more information on module mounting, refer to *Section 2.2*.
2. In the unpacked folder (RoboFloor_vX.X.X.exe) and in the GUI folder, open 'Gui-demo-robofloor-x.x.x'.
3. Click the settings icon ( ) to input settings.
4. To use custom parameters, the "Use Customer Configuration (Parameters Below)" must be checked. Edit values for each setting (see Algo Setting Descriptions below). Load or save settings using the buttons. This will load or save a .json file from the GUI folder.

Figure 3-5. Settings: Algo Settings

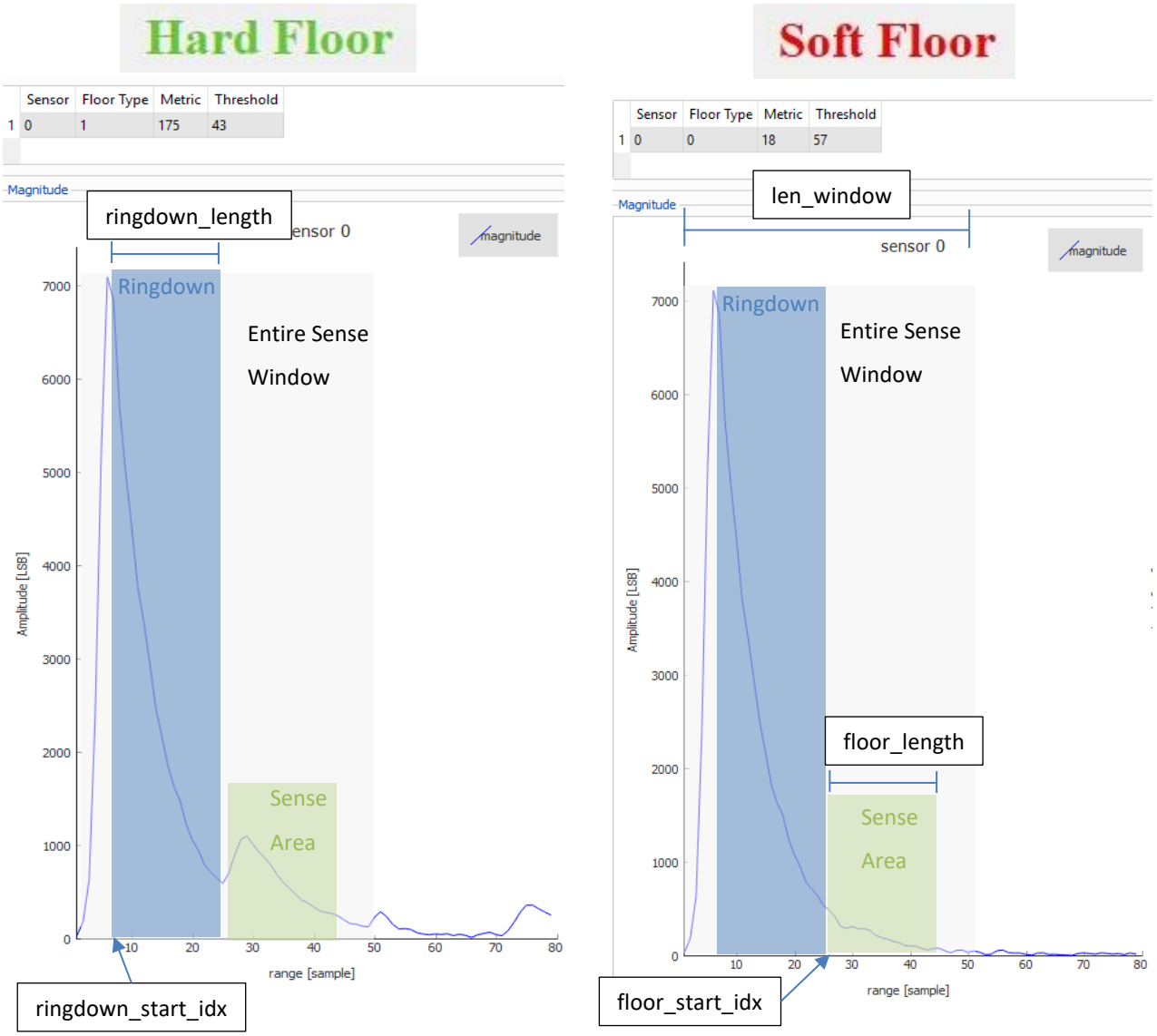


5. Hit 'OK' to save settings for current run. Then click 'Connect' to display real-time outputs.

Algo Setting Descriptions:

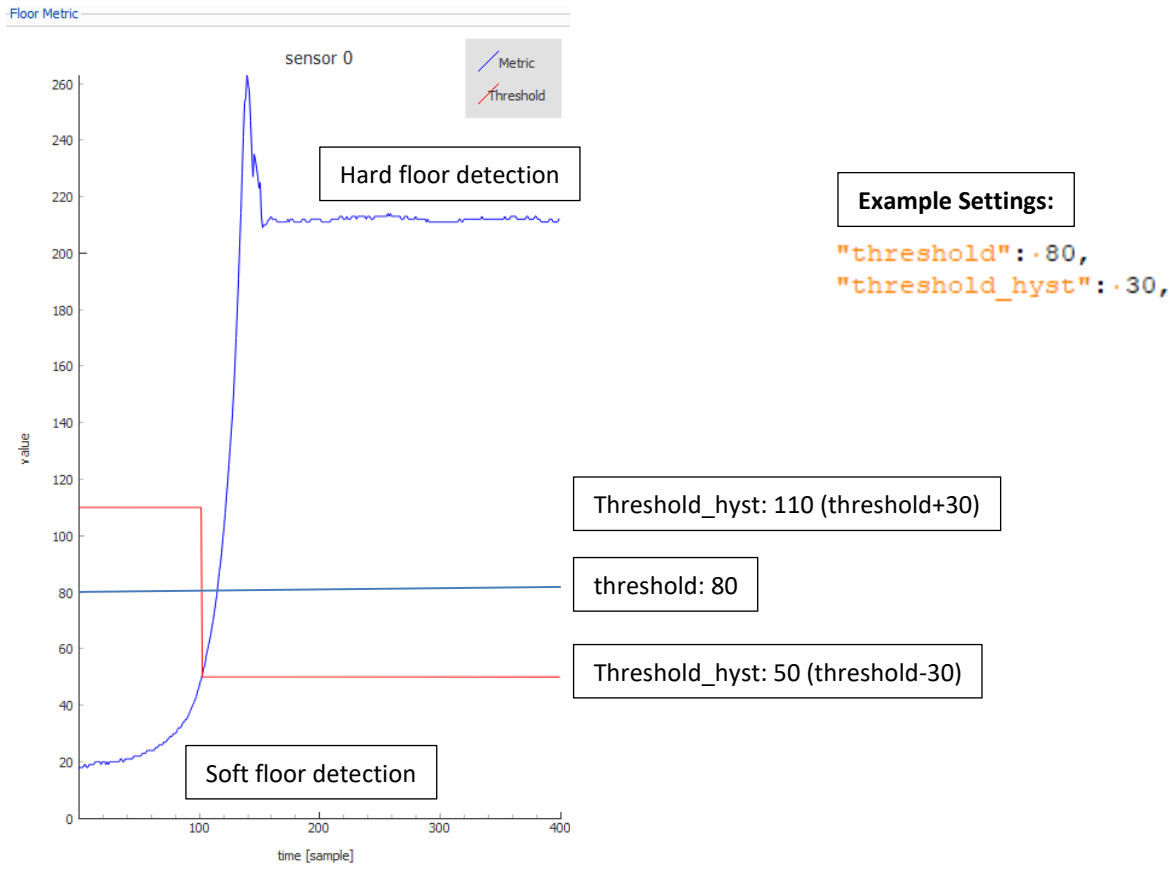
- **Sensor height:** Sets up the library with recommended parameters given a specific sensor height
    - Distance from the horn/housing bottom surface to floor surface. See *Section 2.2* for mounting *Section 3.1* for auto parameters
- **Use custom configuration:** Check this box to enable custom parameters below
- **Customize ringdown start index:** Define the index where ringdown started (typical is 8). Start index of window before floor reflection. Shift this setting to where ringdown begins or to desired starting point.
- **Customize ringdown length:** Define the size of ringdown window (typical ringdown window ends before floor 1st echo)
- **Customize floor start index:** Define the index where floor echo started (depends on floor height). Occurs after ringdown section
- **Customize floor length:** Define the size of floor echo (typical size is 16 samples at decimation = 1).

Figure 3-6. Ringdown and Floor Windows



- **Customize floortype threshold:** Threshold that classify soft vs hard floor types. The threshold should be reduced with higher sensor to floor distance.
- **Customize floortype threshold hysteresis:** Threshold margin to avoid floor type classification toggling when metric transition occurs.
- **Customize max number of samples:** Set the max number of samples to process (typical value should cover the whole floor window).
- **Customize range threshold decay factor:** Decay factor of the threshold [0-100]. Impacts short distance detection. Low values improve detection sensitivity. Higher values reduce false positives.
- **Customize range threshold minimum value:** Lower bound of detection threshold. Impacts far distance detection.

Figure 3-7. Threshold Settings



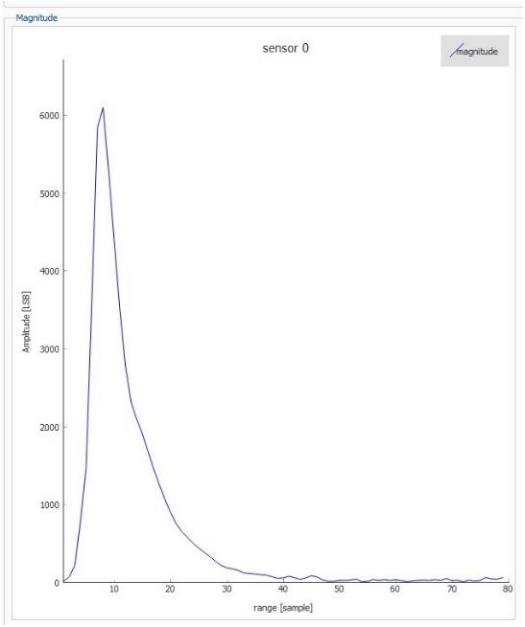
3.4 GUI DISPLAY

The GUI plots are displayed in real time. The section below explains each of the display windows and widgets.

3.4.1 Real Time Plots

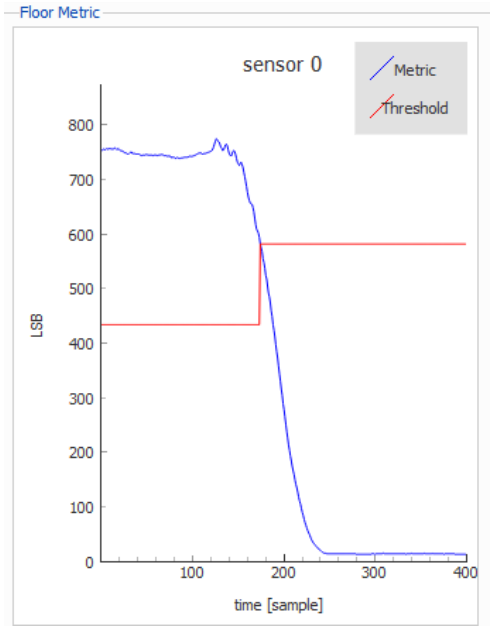
- **Magnitude:** Echoes measured by the sensor
    - Magnitude plot of range vs amplitude for the sensor

Figure 3-8. Plot: Magnitude



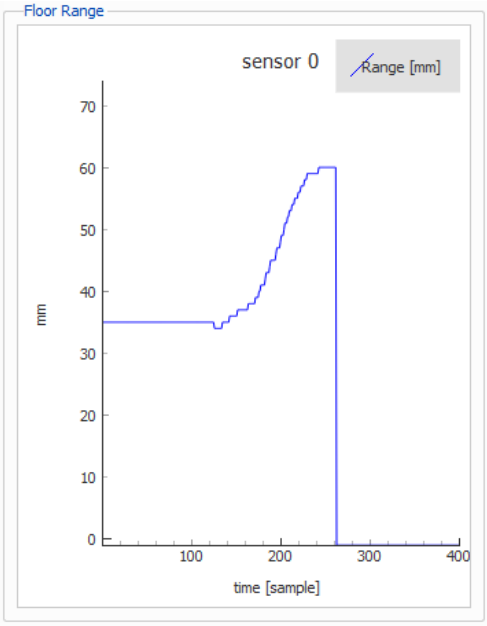
- **Floor Metric:** Decision metric to distinguish between a soft and hard floor
    - Plot of floor metric in LSB over time for the sensor

Figure 3-9. Plot: Floor Metric



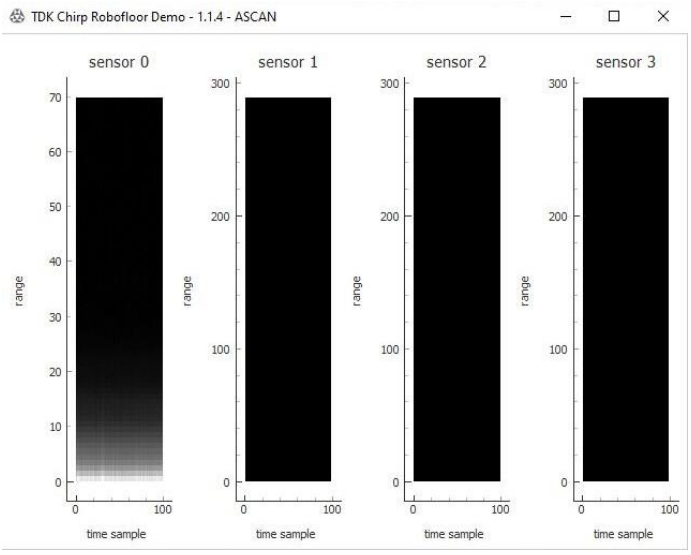
- **Floor Range:** Distance between floor and sensor
    - Plot of distance to floor over time for the sensor

Figure 3-10. Plot: Floor Range



- **ASCAN:** Amplitude scan
    - Bright/white areas in the plot represent high amplitude reflections, while dark areas represent low amplitude reflections

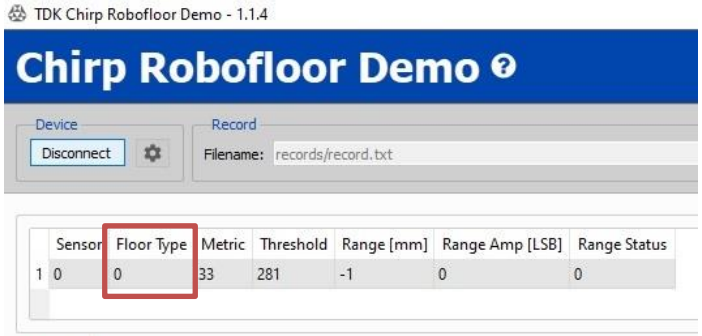
Figure 3-11. Ascan



3.4.2 Floor Type Detection

After inputting the proper settings, the GUI will output the detected type of surface. Moving the sensor over a 'Soft Floor,' such as a carpet, will output a 0, while moving over a 'Hard Floor,' such as a hardwood floor, will output a 1.

- **Soft Floor Detection:**
    - Floor Type of 0 and a metric below the detection threshold will display a 'Soft Floor' along with its numerical output values



    - Example of Floor Metric plot for 'Soft Floor' (below the threshold)

Figure 3-12. Example of a "Soft Floor" output plot. (Real-time plot at time 0 being current value)

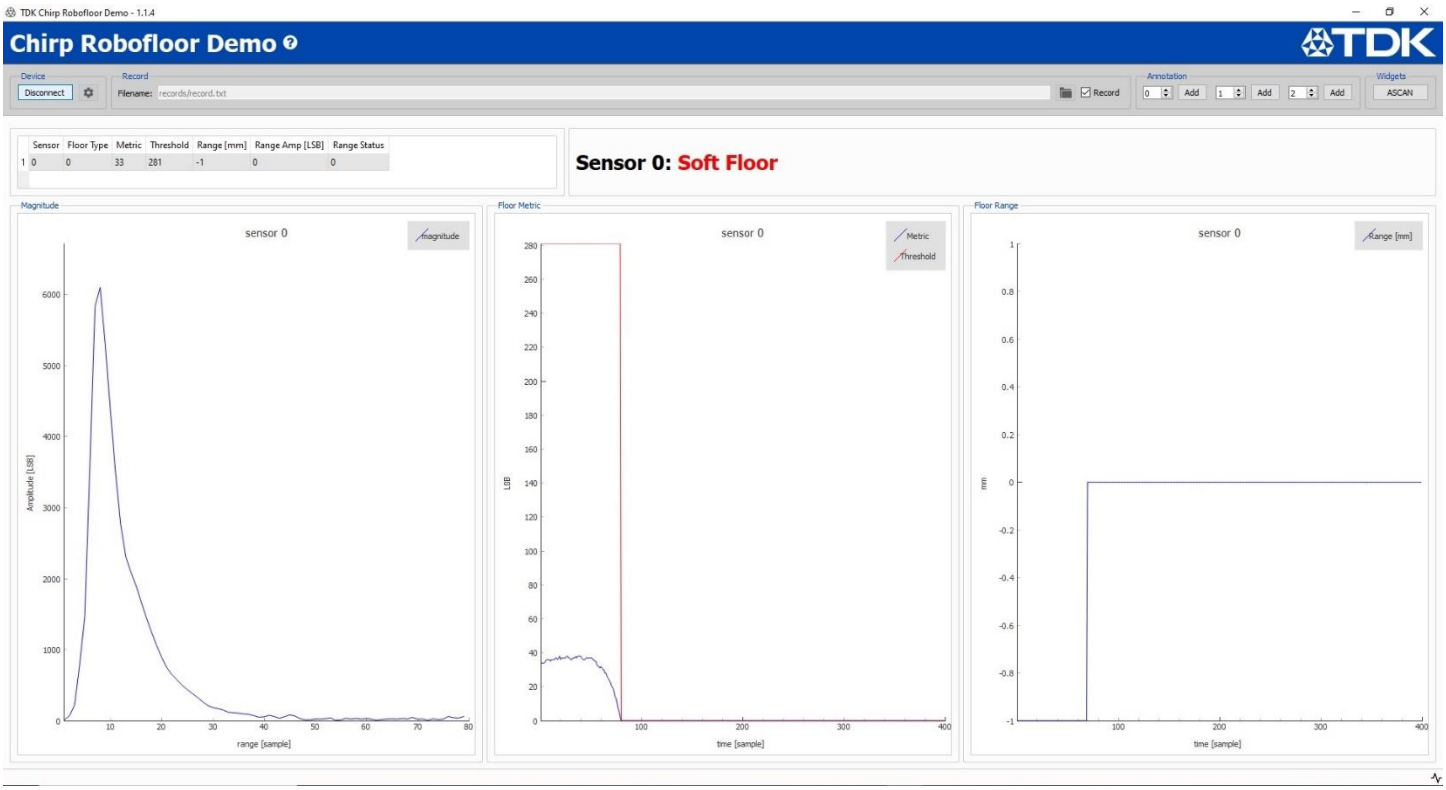
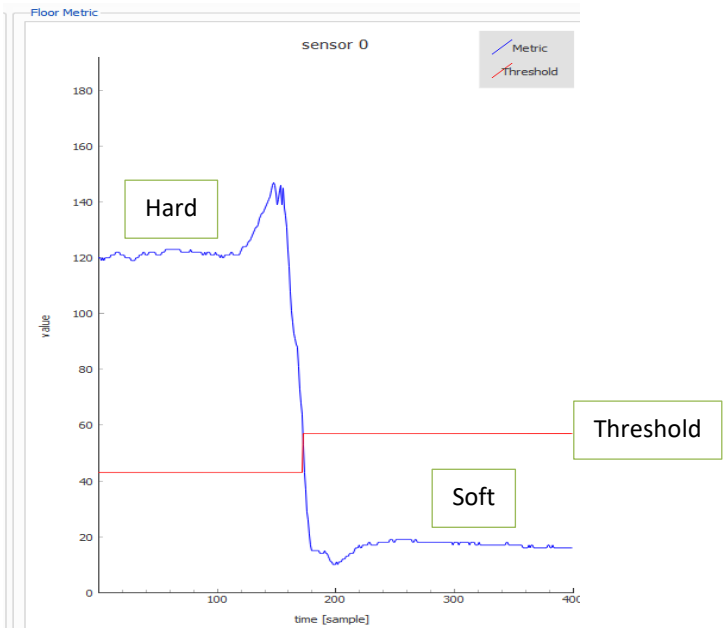
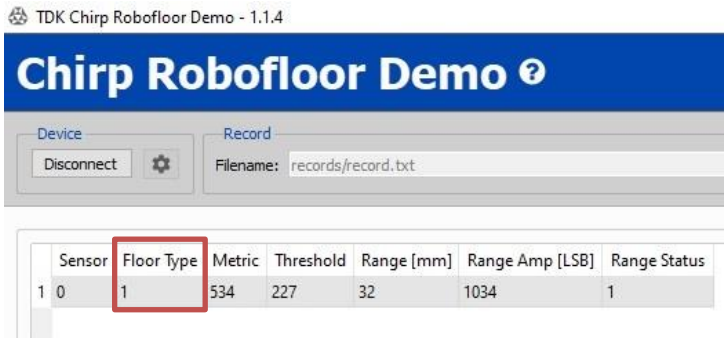


Figure 3-13. Example of a plot of a transition from 'Soft Floor' to 'Hard Floor'. (Real-time plot at time 0 being current value)



- **Hard Floor Detection:**
  - Floor Type of 1 and a metric below the detection threshold will display a 'Hard Floor' along with its numerical output values



  - Floor Metric plot for 'Hard Floor' (above the threshold)

Figure 3-14. Example of a "Hard Floor" output plot. (Real-time plot at time 0 being current value)

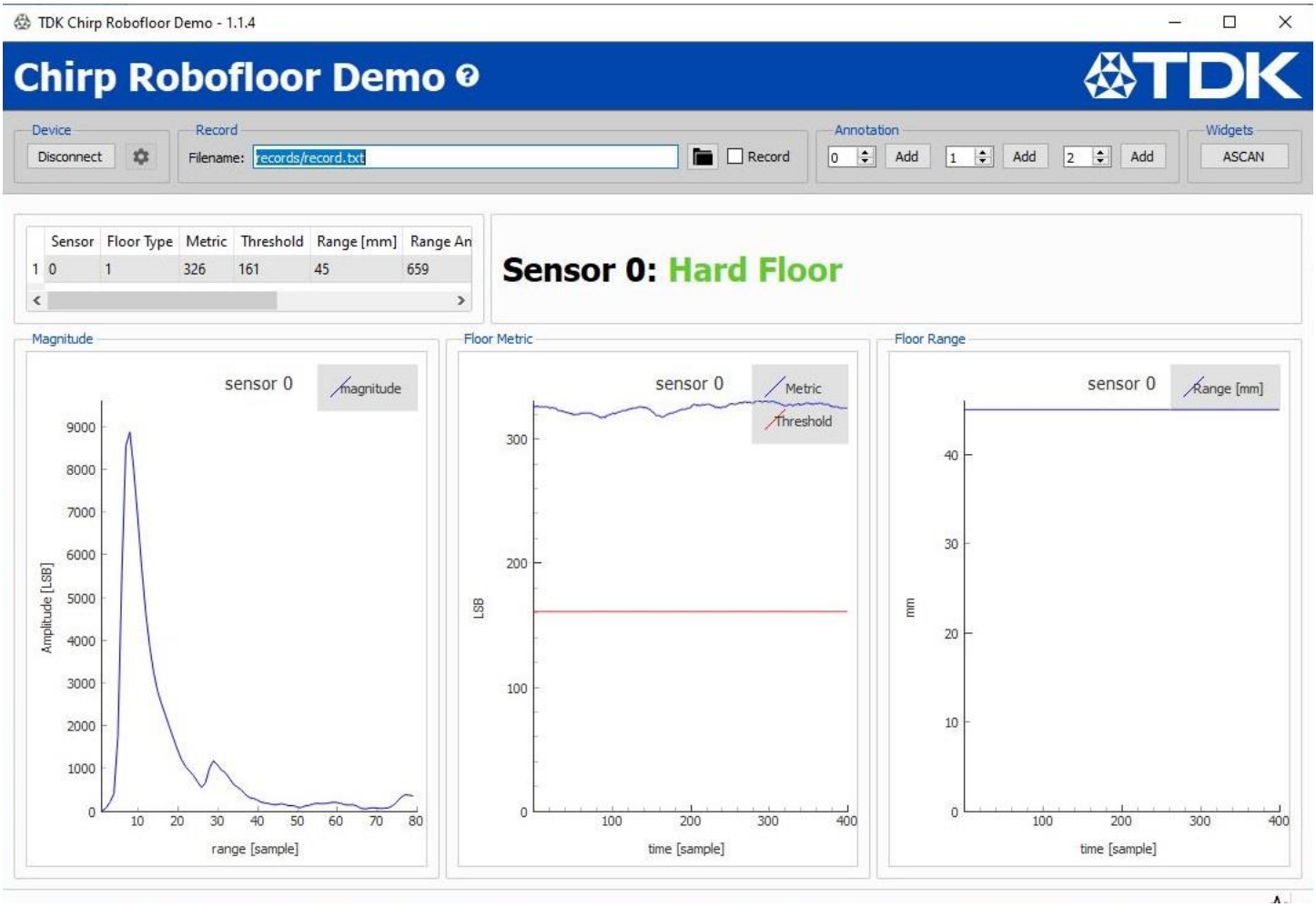
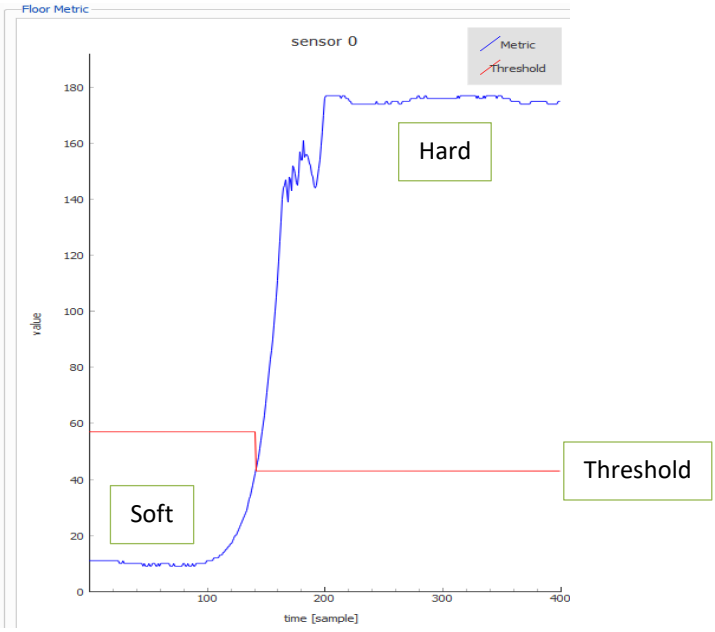


Figure 3-15. Example of a plot of a transition from 'Hard Floor' to 'Soft Floor'. (Real-time plot at time 0 being current value)

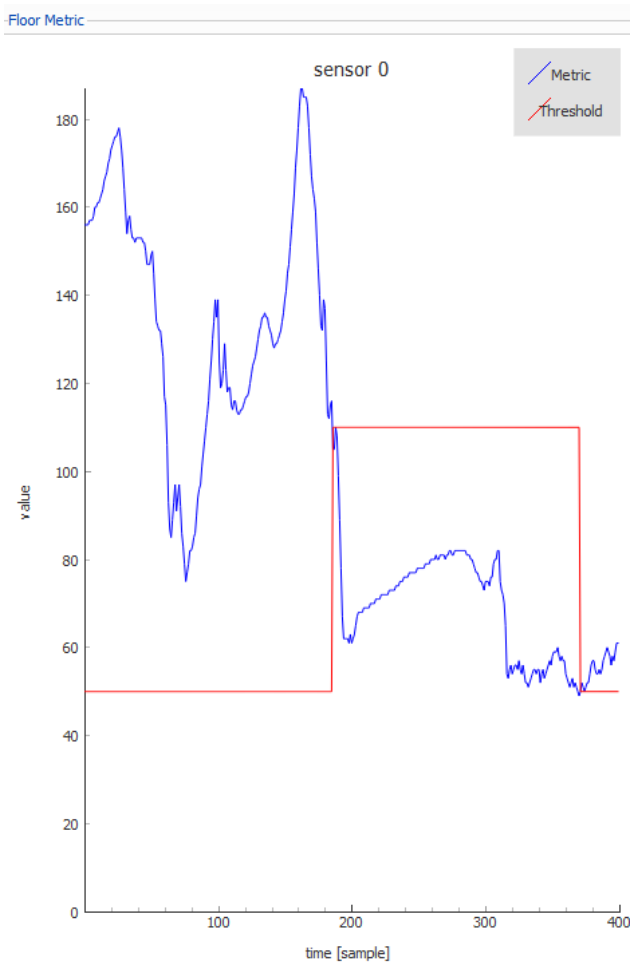


4 APPENDIX

4.1 TROUBLESHOOTING: BAD TUNING

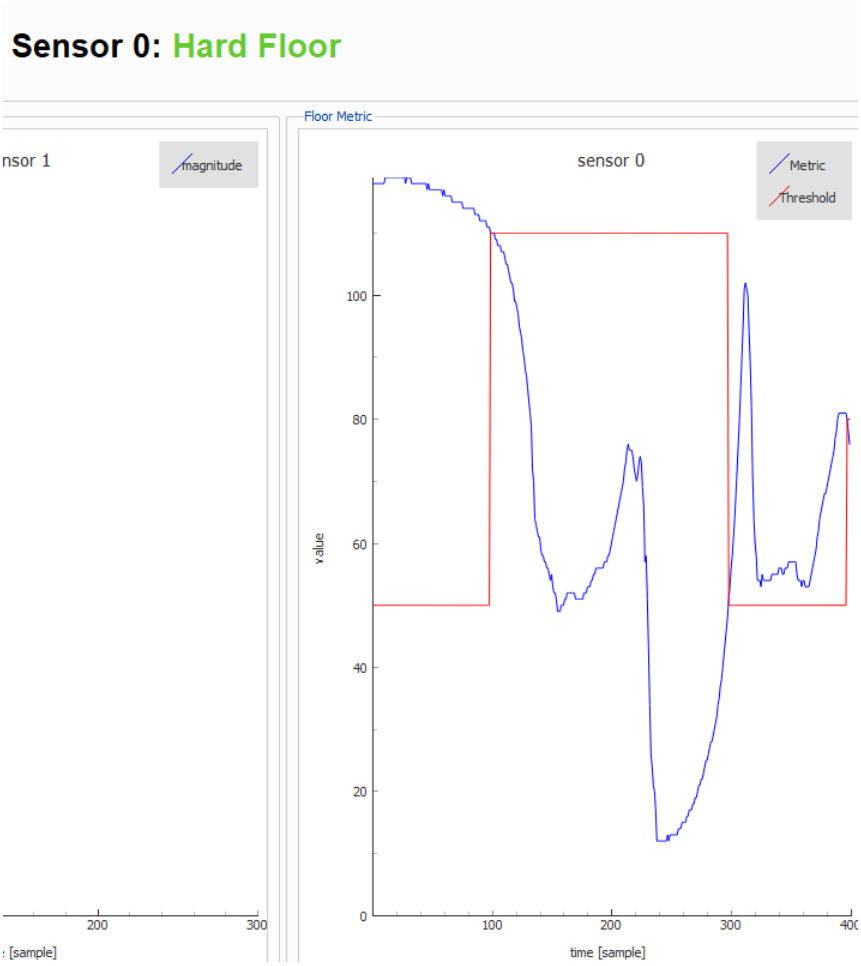
1. Ringdown settings

- Example settings:
  - Sensor Height: 48mm
  - “ringdown_start_idx”: 5
- Issues:
  - Latency affected
  - Bad data in the ringdown phase
  - Hard to distinguish floor type due to threshold limit of bad data
  - Stuck in one floor type



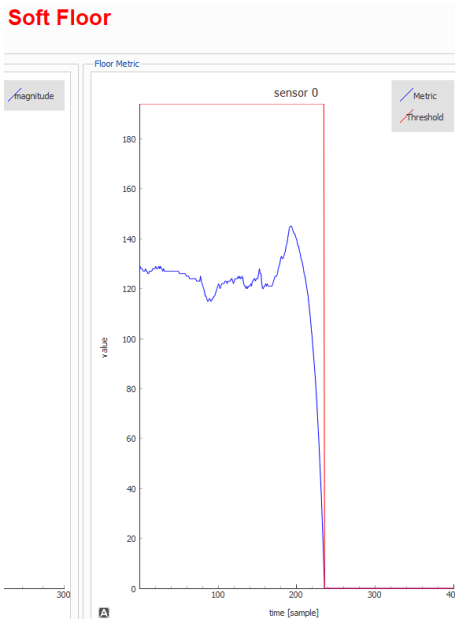
2. Floor Distance settings

- Example settings:
  - Module mounted at 48mm
  - "floor_start_idx": 15
  - Moved from hard to soft then back to hard surface
- Issues:
  - Latency affected
  - Floor detection accuracy (Echo detection)

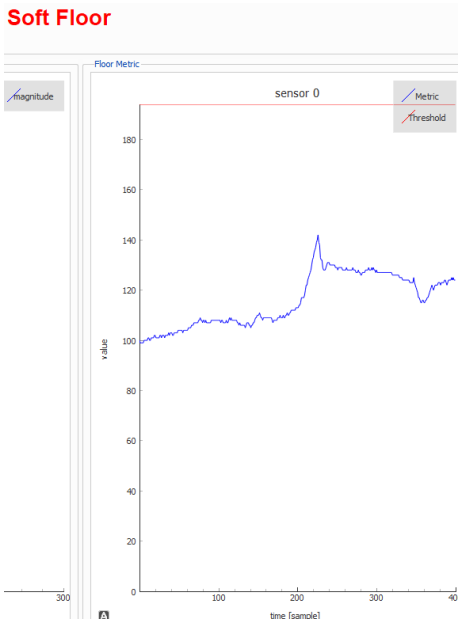


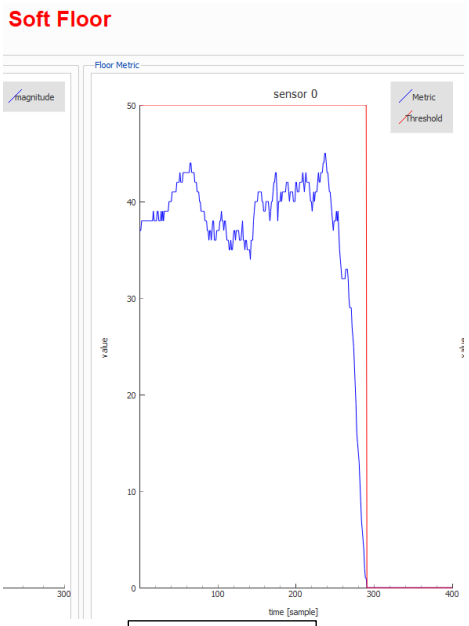
3. Module not set to proper floor distance

- Example settings:
  - "Sensor Height": 25mm and 60mm
  - Module mounted at 48mm
- Issues:
  - Floor detection accuracy
  - Floor type metric
  - Can detect threshold

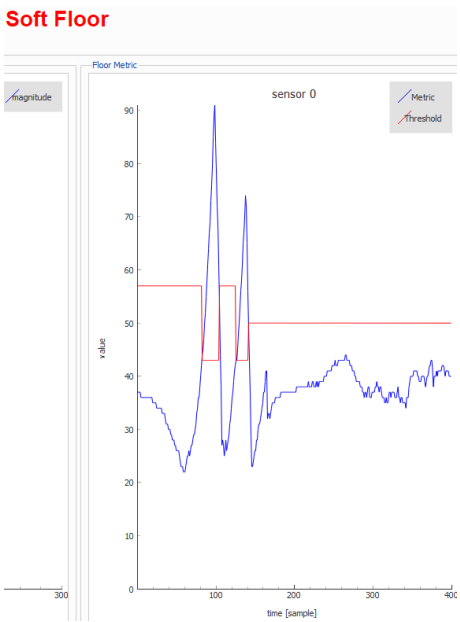


25mm





60mm



On Hard floor

On Soft floor

5 REVISION HISTORY

Revision Date	Revision	Description
09/10/2020	1.0	Initial Release
09/30/2020	1.1	Revised Introduction. Added H/W preparation section. Revised plot explanation.
01/15/2021	1.2	Added mounting req. Added custom tuning parameter explanation. Added Tuning Appendix.
03/04/2022	2.0	Revised document for latest GUI release

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