AN-000424 Module Test for ICU-X0201 Application Notes

InvenSense, a TDK Group Company
1745 Technology Drive, San Jose, CA 95110 U.S.A
+1(408) 988–7339
invensense.tdk.com

Document Number: AN-000424
Revision: 1.0
Date: 08/17/2023

Table of Contents

InvenSense, a TDK Group Company
1745 Technology Drive, San Jose, CA 95110 U.S.A
+1(408) 988–7339
invensense.tdk.com

Document Number: AN-000424
Revision: 1.0
Date: 08/17/2023

1 INTRODUCTION

The module test is a tool developed to test the module builds of the Ultrasonic Time-of-Flight (ToF) sensor product line and for engineering development purposes. It is an autonomous test that checks the functionality and performance of ToF sensors. Its test methods include the following features:

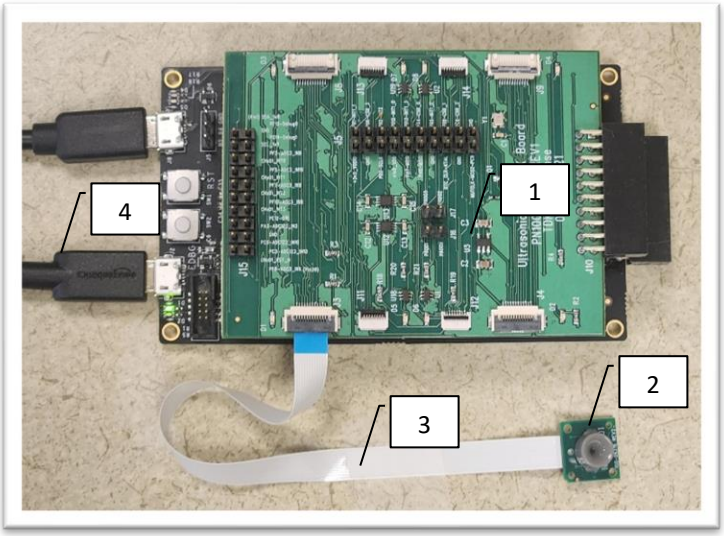
- Checks sensor functionality after the assembly process
- Checks and displays sensor performance data against product specifications and criteria.
- Records sensors data log for traceability and data analysis
- Distinguish different types of failures for binning.

2 HARDWARE REQUIREMENTS AND SET UP

2.1 HARDWARE REQUIREMENTS

The list below shows the hardware required to establish the connection and set the fixture for testing.

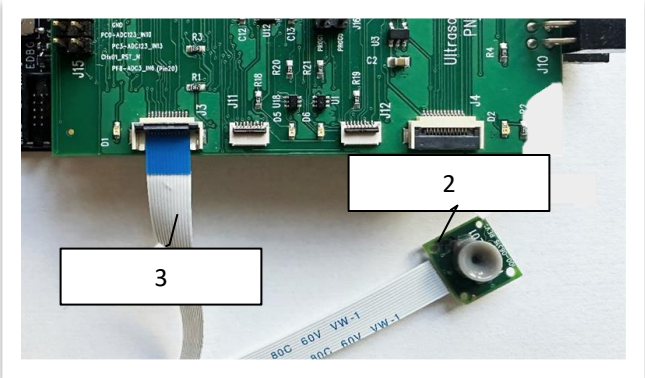
1. A programmed development kit - DK-x0201 (Host)
2. ICU-x0201 sensor module(s) - EV_MOD_ICU-20201-00-01 (example module)
3. Flat Flex cable(s) (FFC)
4. Micro USB -Type A USB cable
5. Fixture



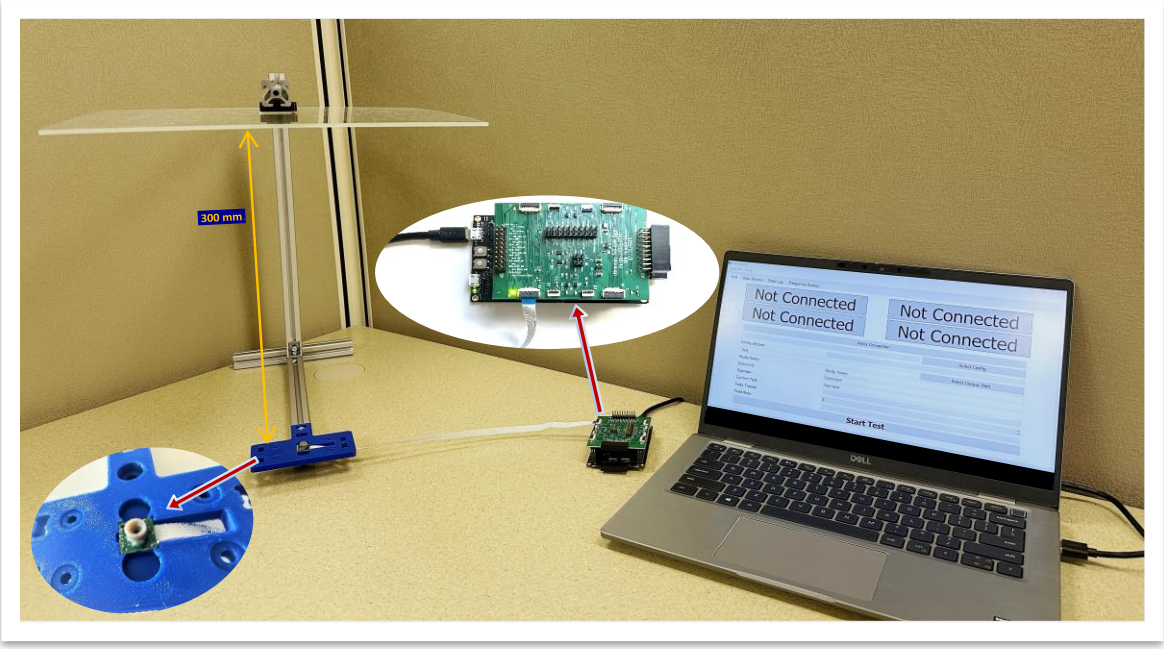
2.2 SET-UP CONNECTIONS

To run the ICU-x0201 evaluation kit and the module test platform, connect the device under test (DUT) to the FTDI connector on the DK-x0201 via the USB cable to the PC. This section shows assembly instruction connecting hardware together.

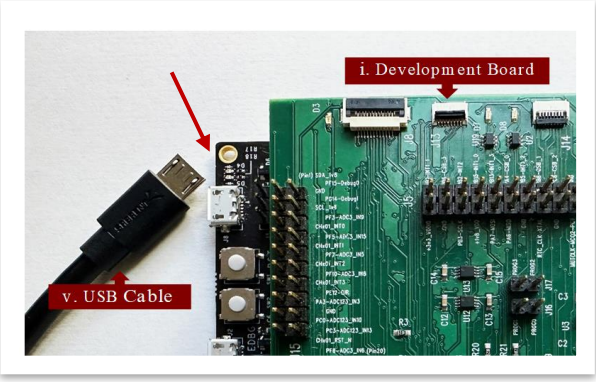
1. Plug in one end of the FFC into one of the connectors on the daughter board and other end to the connector on the ICU-x0201 module.



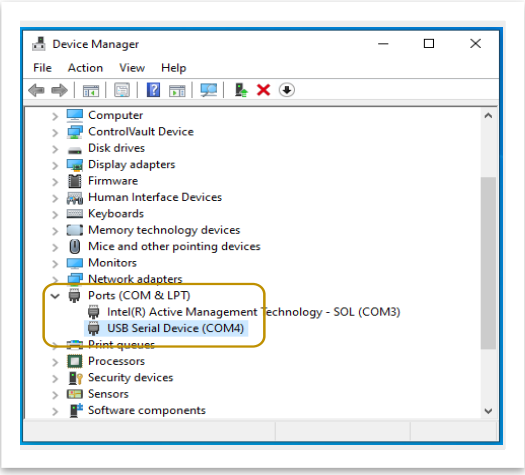
2. Up to 4 sensors can be attached to the connectors on the daughter board using the flat flex cable. Place the unit flat on the module holder, adjust the target to be approximately 300 mm from the sensor. Keep the surrounding area of the fixture clear to avoid any possible interferences. The image below shows the physical connections to run the Module Test software.



3. Plug the Micro USB connector to J8 of the Development board while the other end of the cable should be connected to host PC.



4. Go to the *Device Manager* and verify that the USB is detected. Confirm the COM port number for the development board in the *Ports (COM & LPT)* drop down list. You should be able to see the connected COM port as shown below:



3 SOFTWARE REQUIREMENTS AND SET UP

This section elaborates the software and hardware requirements to set up and run the module testing for ICU-x0201 sensor(s).

3.1 SOFTWARE REQUIREMENTS

i. ShastaMT v 1.6.2 or later version.
ii. Window 10 or later

3.2 SOFTWARE INSTALLATION

This section shows how to extract and install the software upon download from repository.

1. Download the ShastaMT v x.x, where x signifies the version of the software and the number changes with every release. After the download is complete right click on the zipped folder, click on *Extract All*

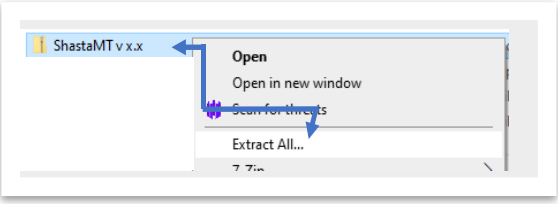
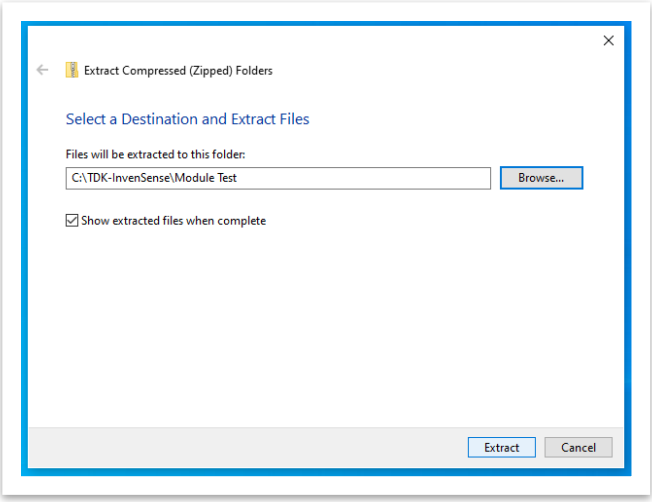
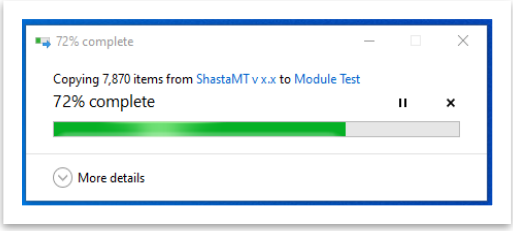


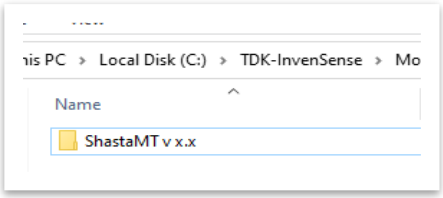
Figure 3-1. Picture

2. Choose file extraction location. Then, click on *Extract.*

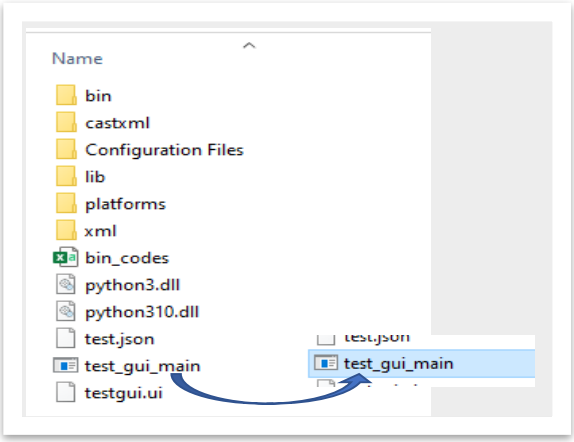




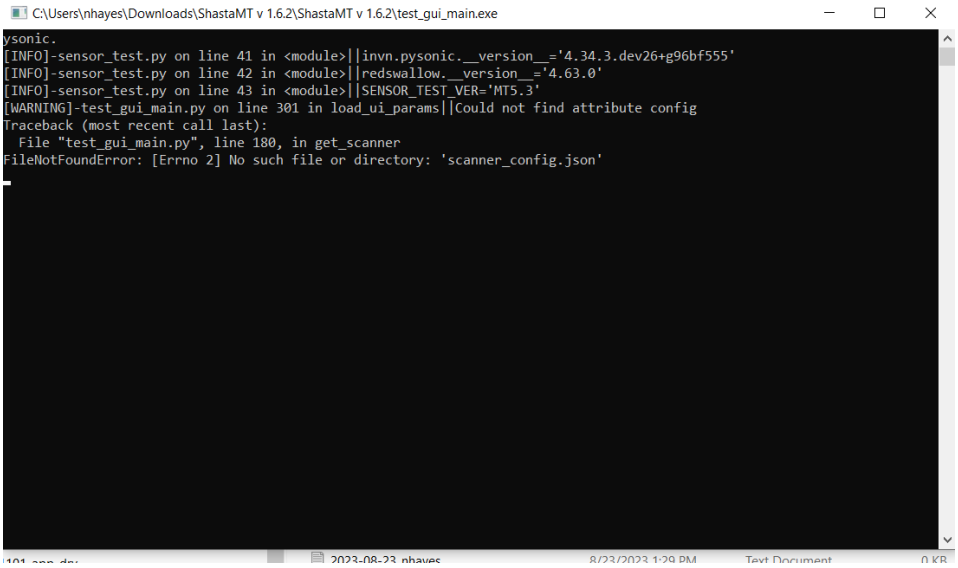
3. Once the extraction is completed, go to the extracted folder. Double click on file name: ShastaMT v x.x



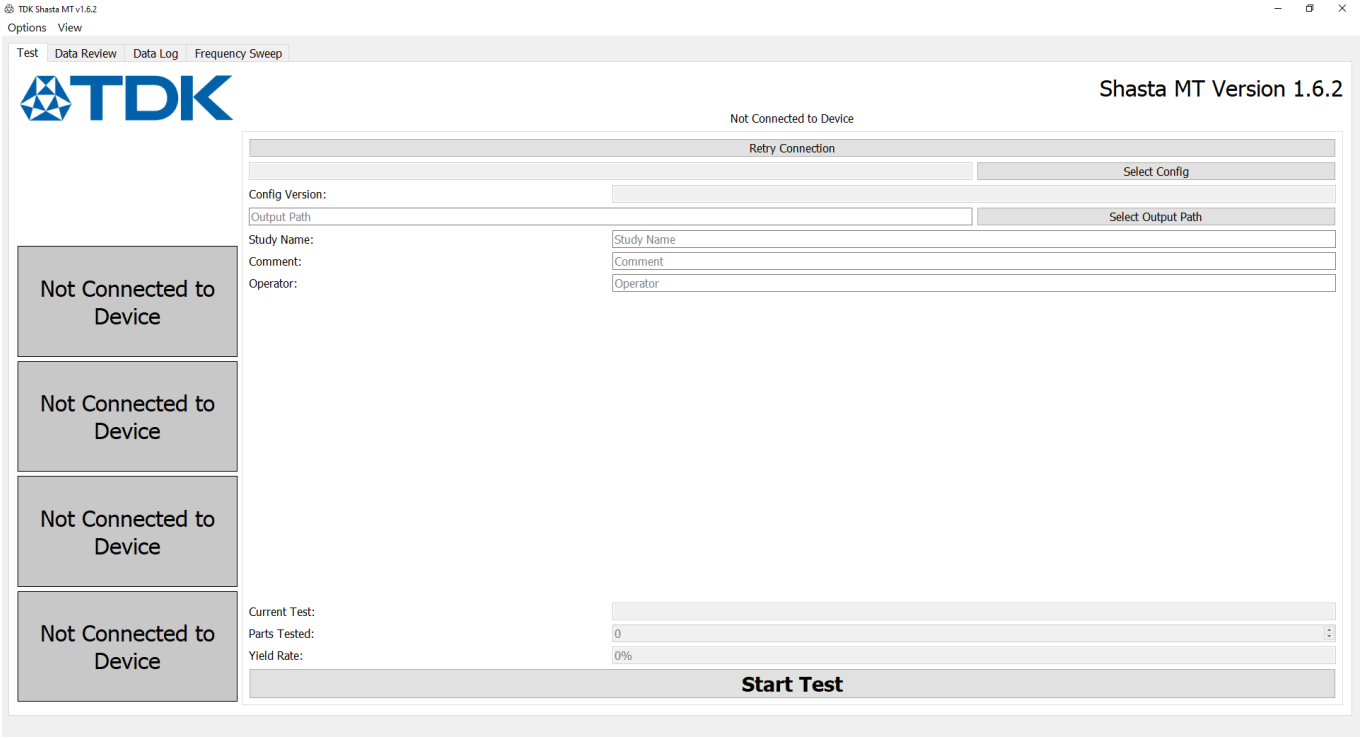
4. You will see the list below. Click *test_gui.main* to launch the GUI application



5. An initializing window will pop up while the software is loading.



6. The main GUI application will appear when software is done loading. Main GUI will look like the image below:



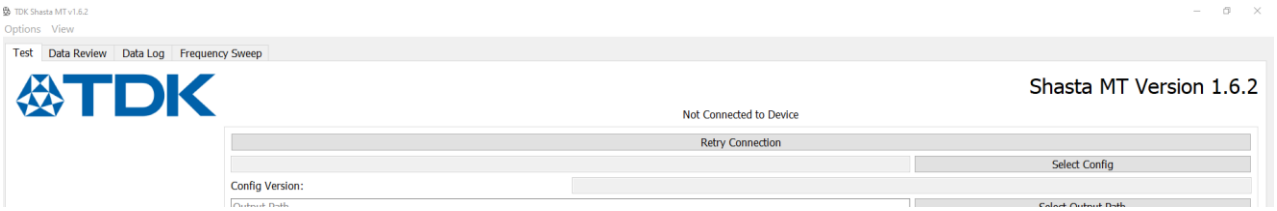
3.3 TEST EXECUTION

This section shows procedures to execute the GUI for the evaluation of sensor modules. ***Note: the EVK kit must be programmed before you can use ShastaMT v 1.6.2.***

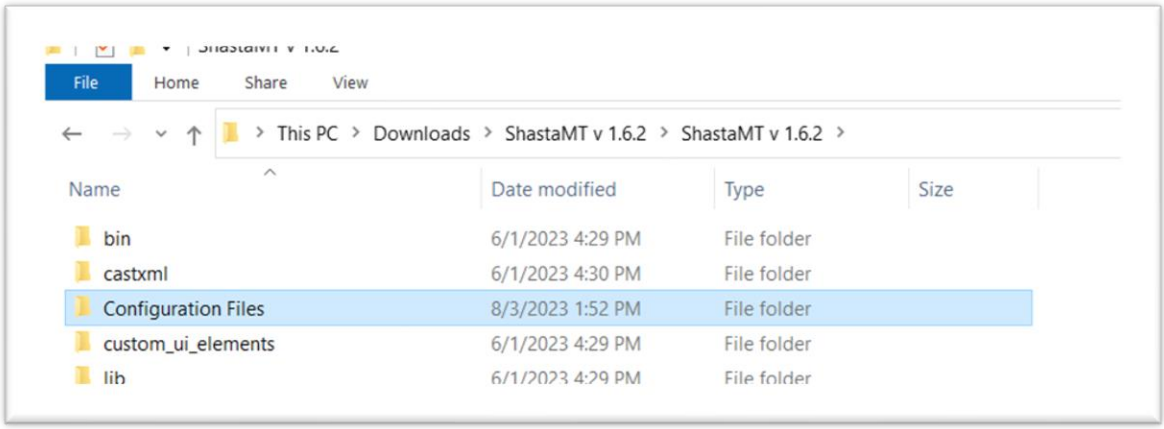
3.3.1 Connection

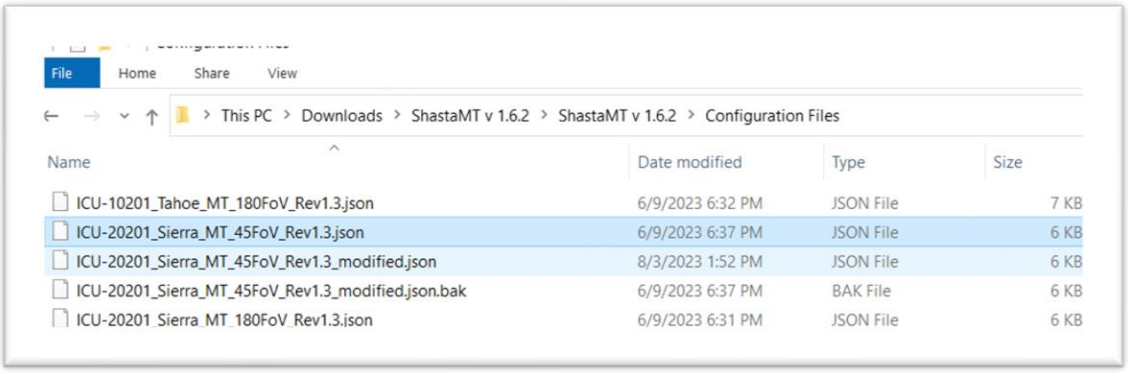
Connect the DUT to the test computer and let the GUI self-detect the hardware. Follow the steps below to start test:

1. The test tab is the main window of the test, and it should appear at the start of the software.
2. Click on *Retry Connection* button to connect DUT with COM port.

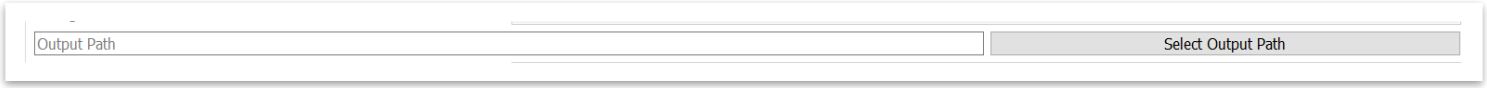


3. The test configuration file will also be loaded in this step. A pop-up window will appear prompting for a configuration file. Select *Configuration Files* folder then select the configuration intended for testing.

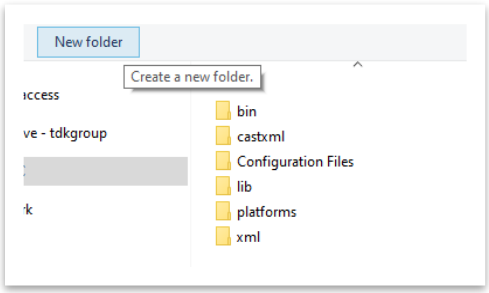


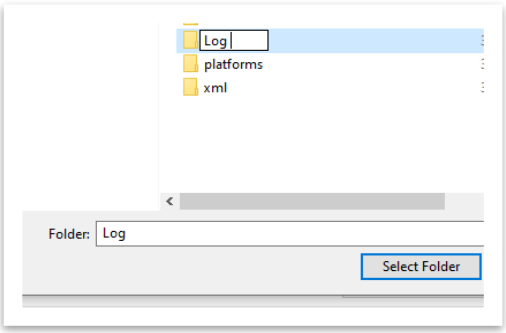


4. Log files automatically will go to folder “Log” under the main SW directory. If a different location is desired, in section *Config Version: Click* on *Select Output Path* set the log file path for each test run. Note: This step should only be done one time at the start of the test.



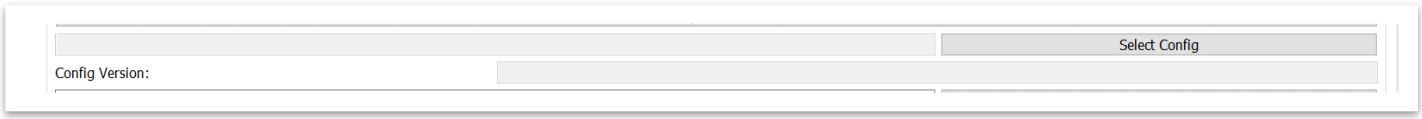
   a. Create a folder at the destination of our choice for test results log to be automatically updated within the same site for each test run



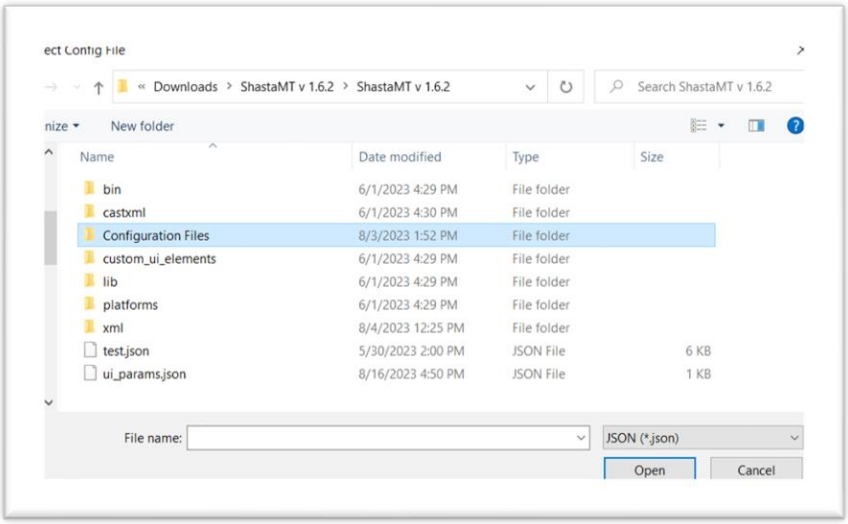


b. Click Select Folder, output path will set up successfully.

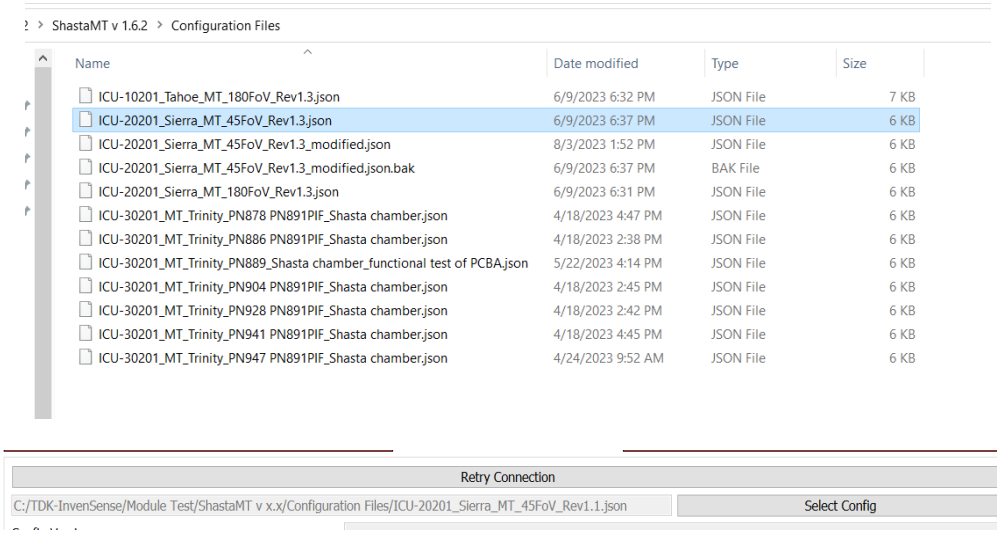
5. To change the configuration file, select the configuration file in accordance with product family by clicking on *Select Config* button. This configuration provides test and operation parameters to the test software.



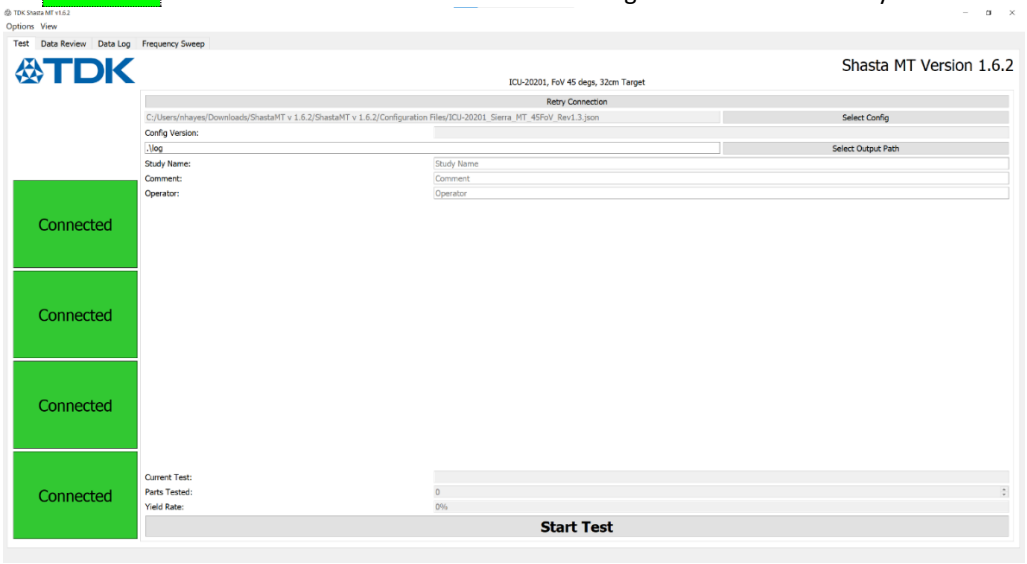
6. In the *Configuration Files* folder, select the appropriate .json file for the DUT.



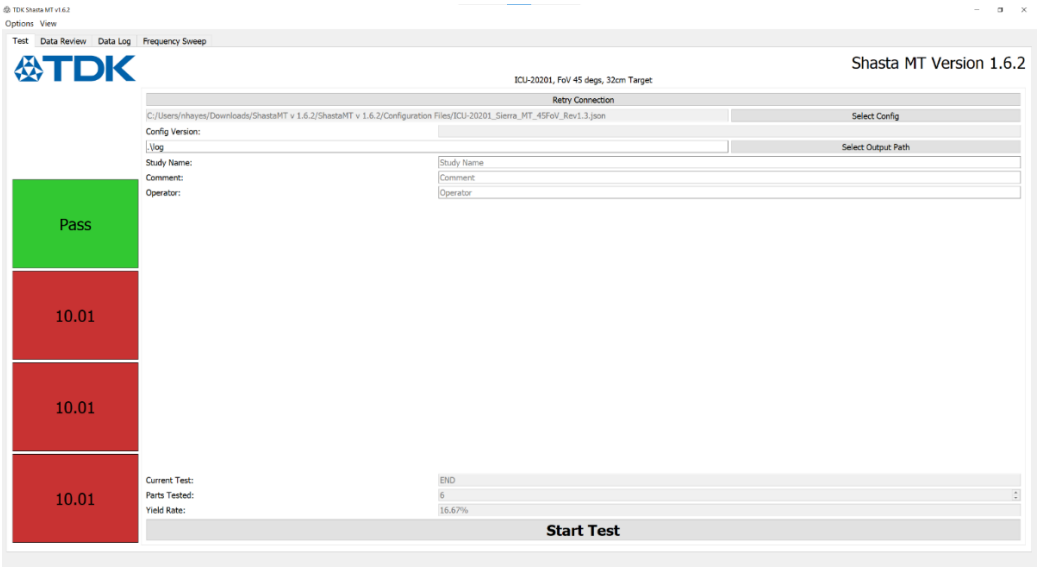
i.e; if testing EV_MOD_ICU-20201-01 that is the module with 45˚ FoV from the ICU-20201 series, choose *ICU-20201_Sierra_MT_45FoV_Rev1.1.json,* then click *Open.*



7. The GUI will show Connected status for each of the four slots once configuration file successfully loaded.



8. Click **START TEST** to start test.



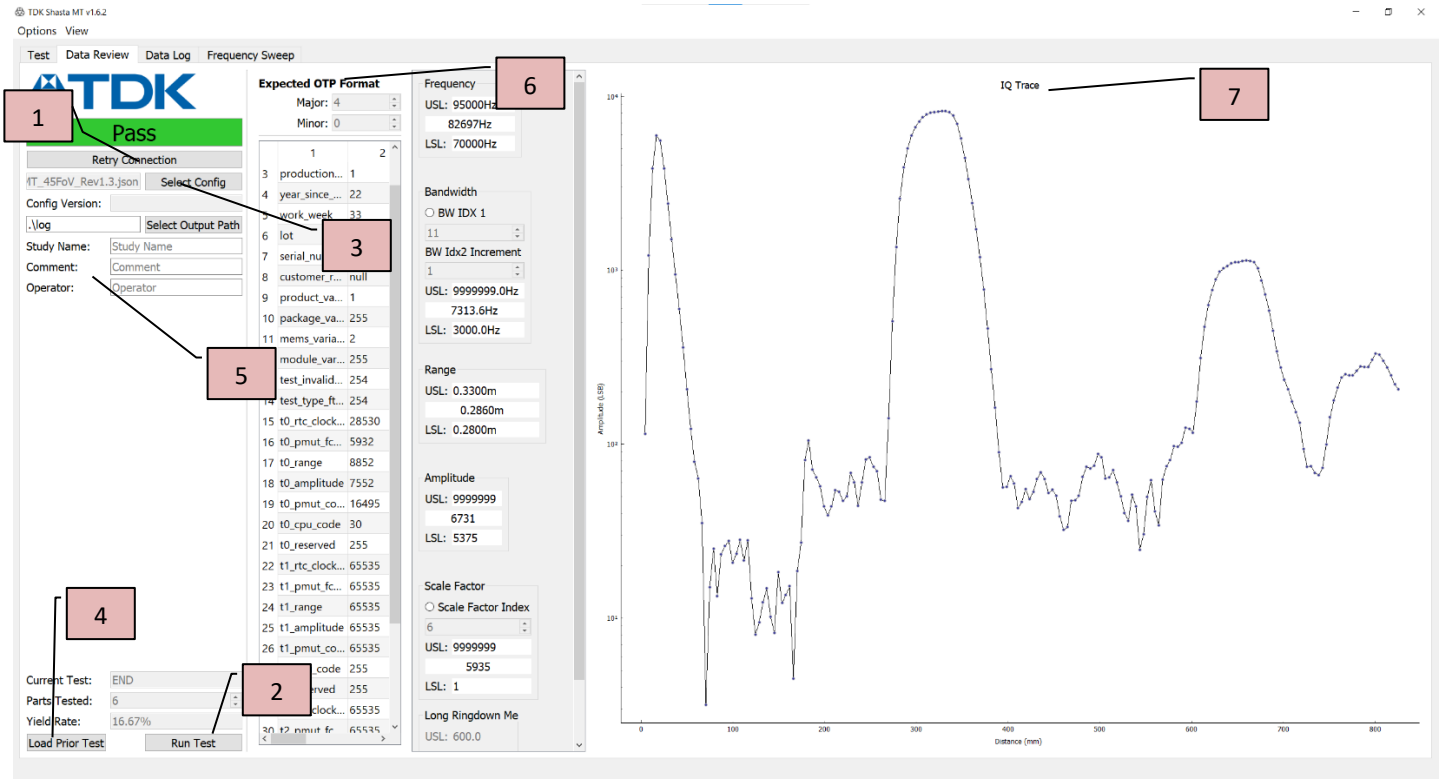
3.4 ENGINEERING/FA TABS

There are three tabs following the main test tab. Each provides functionality and/or information used to validate a module design and to failure analyze (FA) a concern with a supported sensor feature.

3.4.1 Data Review Tab

Data plots are available in *Data Review* tab. The *IQ Trace* tracks down the change of amplitude over time. Users can repeat tests on this tab without returning to *Test* tab.

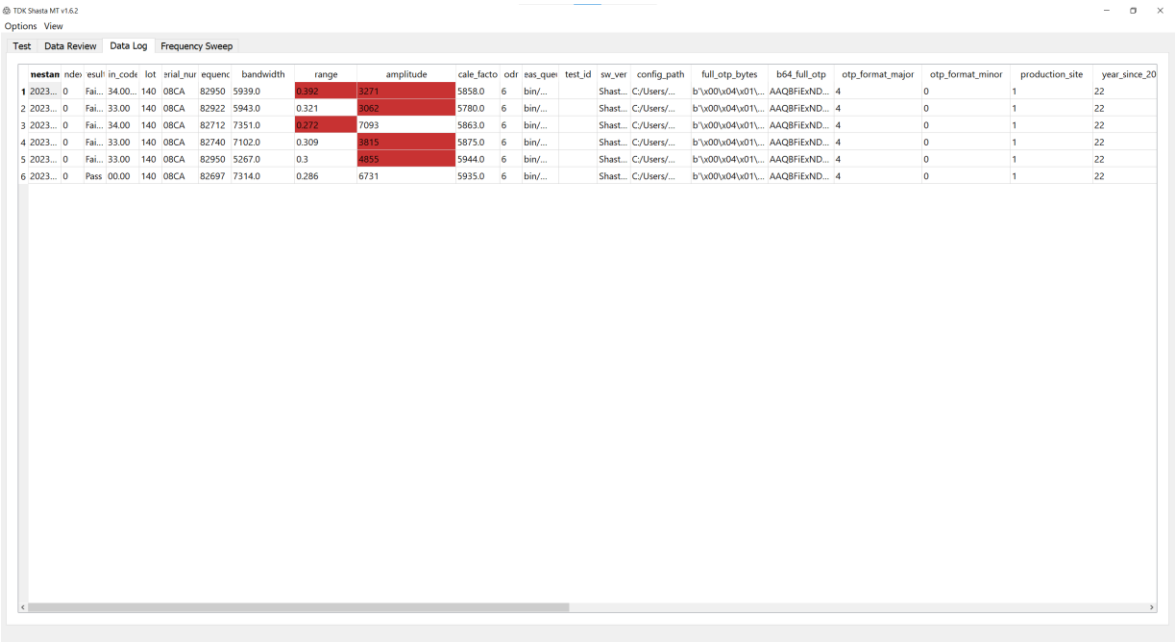
1. If DUT was unplugged or lost connection, click on *Retry Connection* to reconnect the board to GUI.
2. Click on *Run Test* again to repeat test with the same configurations.
3. Users can change different configuration and/or log file path in this section by selecting *Select Config* and Select *Output Path* options respectively. (See section 3.3.1 to set up new paths)
4. Previous test data can be uploaded again through *Load Prior Test*. The column in the middle displays the configuration file limits for tests frequency, bandwidth, range, amplitude, and scale factor.
5. Enter notes to test data in *Study Name, Comments* and *Operator* information for traceability purposes.
6. *Expected OTP Format* indicates the OTP specification version in your sensor. The data in the table is the OTP contents read from the module.
7. *IQ Trace* section, with all parameters displayed, is for failure analysis purposes. User can modify parameters for failure analysis



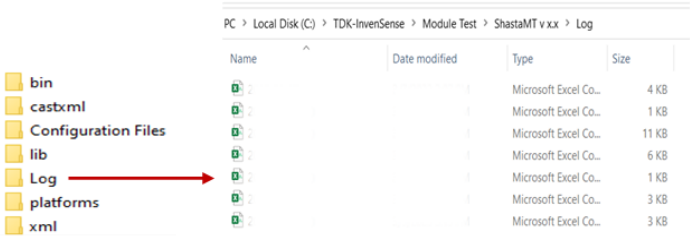
Document Number: AN-000424
Revision: 1.0

3.4.2 Data Log Tab

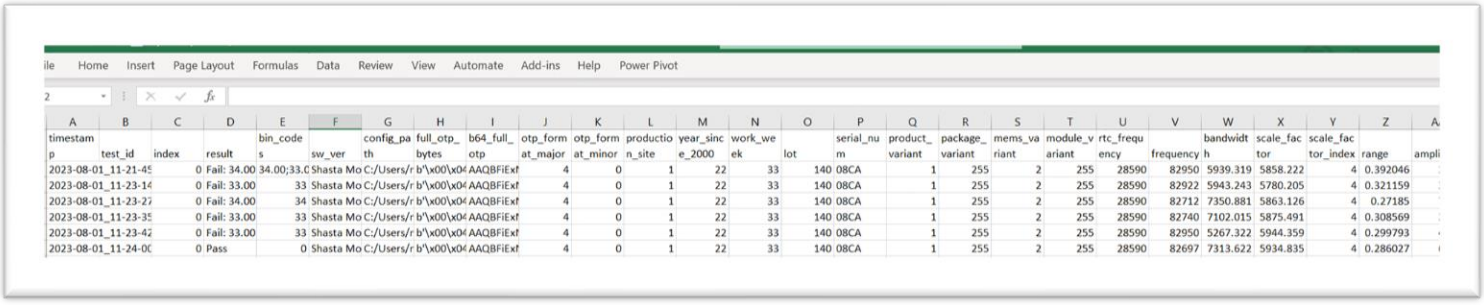
The *Data Log* tab charts the data from each test run. Failures are highlighted in Red.



The data logs are also being collected at the defined output path. The log files can be retrieved at any instance for detailed data analysis by going to the *Log* folder (or other if you named it different), and you will find the list of test results conducted over a period.



Open a log file to review the test results.



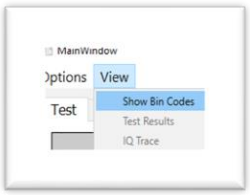
**Note that for multiple tests or retry attempts on the GUI, the data will keep appending to the same log file.

3.4.3 Frequency Sweep Tab

This tab is generally for engineering analysis purposes. Users need to understand the IQ data fundamentals to analyze.

3.5 BIN CODES

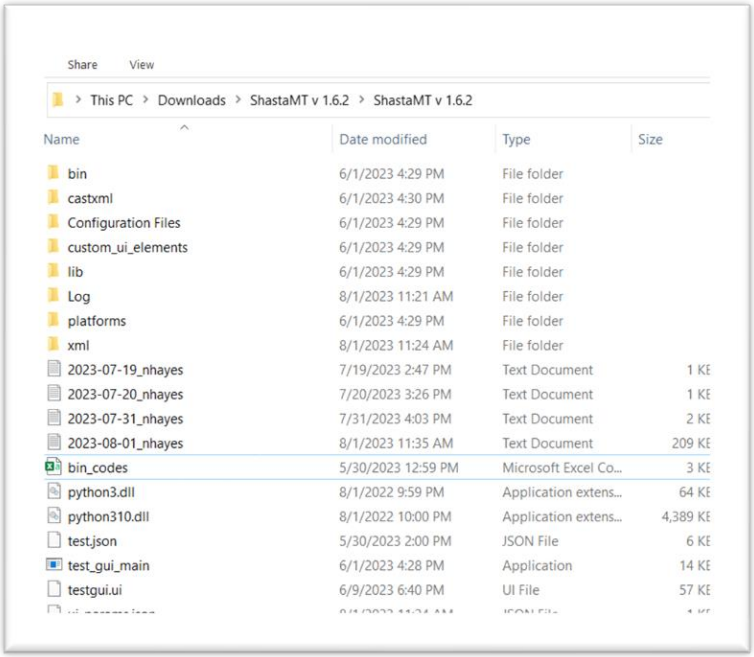
Bin Codes associate a number to module failure modes, to focus the failure analysis. Click *View* in the main toolbar, from the drop-down menu choose *Show Bin Codes*.



A pop-up window appears when “Show Bin Codes” is selected, consisting of a list of bin codes and the corresponding reason for the failure.

	Bin Code	Failure Reason
1	00.00-09.99	Pass
2	01.xx	Frequency Bin
3	02.xx	Bandwidth Bin
4	03.xx	Amplitude Bin
5	04.xx	Range Bin
6	05.xx	Scale Factor Bin
96	29.12	Minimum ...
97	30.00-39.99	MEMS
98	31.00	Frequency
99	32.00	Bandwidth
100	33.00	Amplitude
101	34.00	Range
102	35.00	Scale Factor

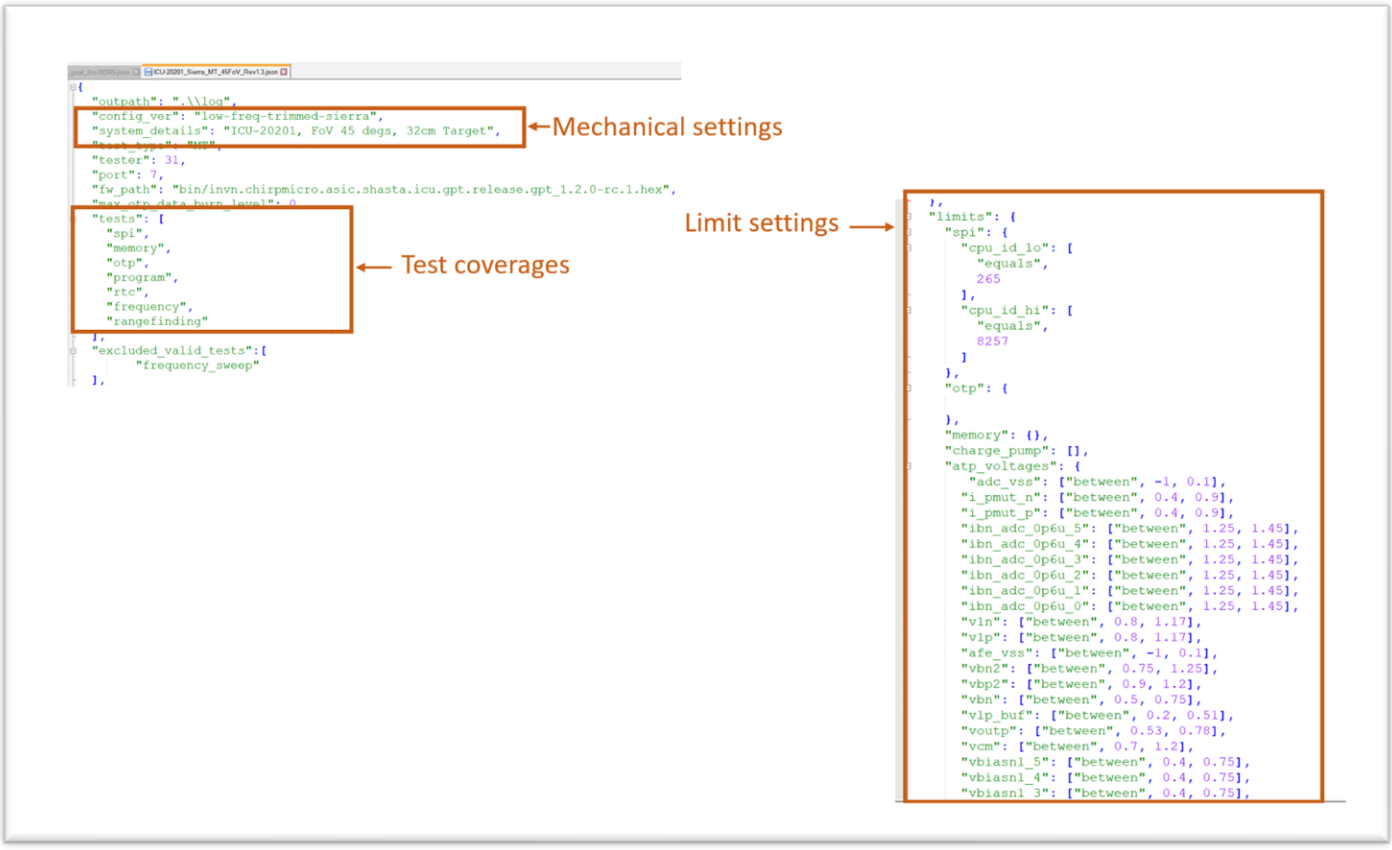
A complete list of bin codes and descriptions are in the same file directory as the MT software. One can access it in windows explorer like shown below or refer to Appendix.



4 CONFIGURATION FILES

The module test application discovers, programs, and configures up to 4 sensors connected to a SmartSonic evaluation board. The application programs each sensor and subsequently performs a subset of the checks. Once the test is initiated by clicking *Start Test* on the GUI application, the sensor is triggered and performs ultrasonic measurements, the results are captured. The collected data is compared against standard test limits defined in the configuration file, e.g.

Below is an example of parameters and limits in the configuration file. "`config_ver`" is used to define the type of test configuration and is logged in the results file. The "`system_details`" shown at the top of any configuration file will indicate the required mechanical components for operating the test and displayed on the front panel of the MT SW to clearly show the operator what's being tested.



Optionally, any of the standard test limits can be modified to different values. A corresponding Pass or Fail indication will display on the GUI once the configuration file is updated. The "`tests`" section in the configuration file shows the test coverage in the selected configuration file.

4.1 MODIFY RANGE FINDING PARAMETER

The default limits are listed in the configuration file as shown here. Limits are listed in brackets [], in purple color font in the example below. These values are changeable after engineering evaluation.

```
"rangefinding": {
  "scale_factor": ["greater_equals",1],
  "range": ["between", 0.28, 0.33],
  "amplitude": ["greater_equals", 5375],
  "bandwidth": ["greater_equals", 3000],
}
```

5 TEST COVERAGE

The following subsection investigates different testing scenarios and results.

Test Names	Test Descriptions
`spi`	Checks that the reported CPU IDs match the expected CPU IDs. This test is setup to run at the low voltage settings of 1.71 volts on Vdd, Avdd and Vddio.
`memory`	hecks the memory test fills the d-mem and p-mem of the ASIC and then reads back the values and compares the readback list to the written list. Two patterns are used by default, 01010101 and 10101010 (or "0xa5", "0x5a" in hex).
`otp`	hecks reads from the one-time programable (OTP) memory.
`program`	Ensures the general programming transducer (GPT)/main firmware is programmable.
`rtc`	Checks the Real Time Clock (RTC) of Asic. A clock pulse sent to ASIC via INT2 line to check whether the RTC is in the expected range of 25 to 35kHz.
`frequency`	Checks the Piezoelectric micromachined ultrasonic transducer's (PMUT) resonant frequency.
`rangefinding`	Checks rangefinding functionality via scale factor, range, amplitude, and bandwidth parameters.

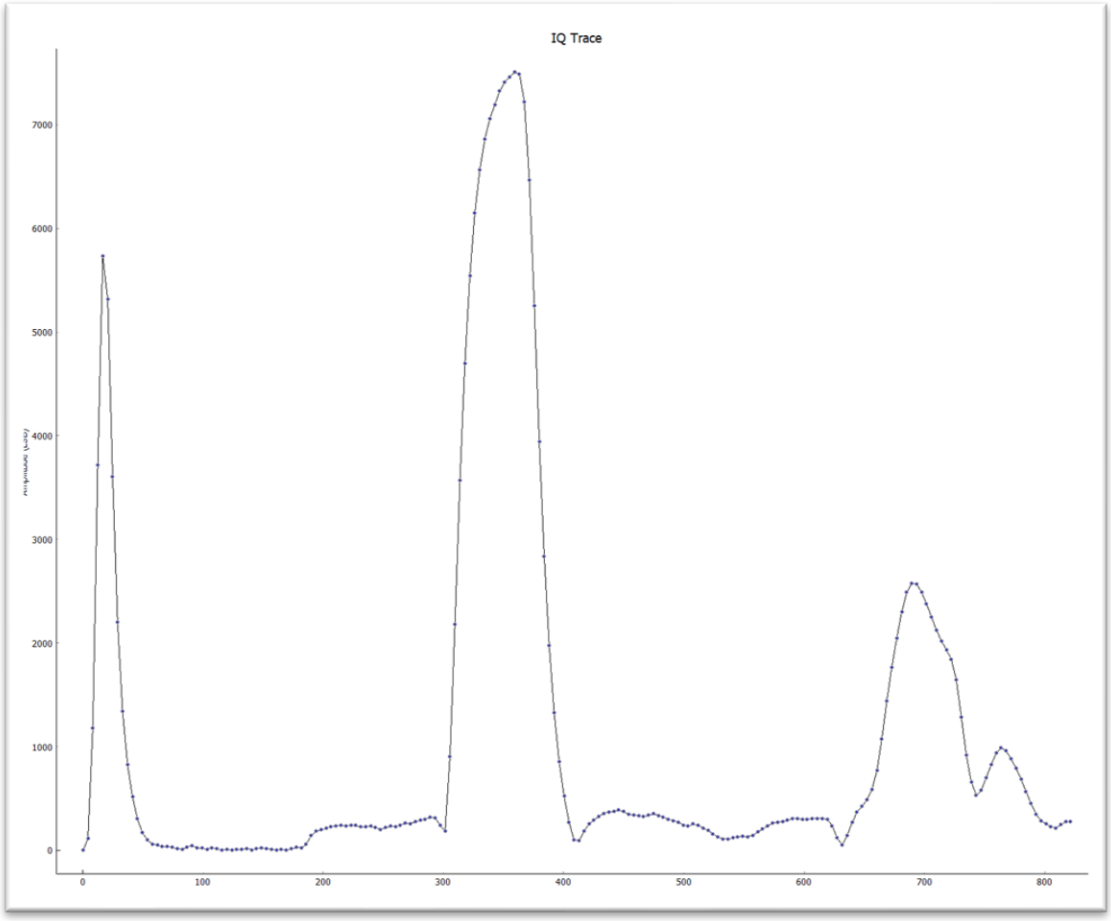
5.1 CASE 1 - A FULLY OPERATIONAL MODULE

A module was evaluated under the setup, the test results collected illustrate the case of a fully functional sensor unit.

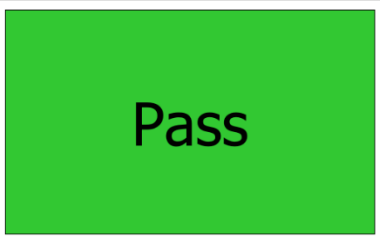
1. *Data Log* tab:

es	lot	serial_num	frequency	bandwidth	range	amplitude	scale_factor	odr	meas_queue	t
	LAQ	b'\xff\x00\x04\xd4'	77903	5462.942324340909	0.2883218954982478	11109	6536.925577058378	6	bin/test_-10dB_gain_10rxSamples-45DegreeHornForMOD-ODR6.json	

2. From the *IQ trace*:



3. Result displayed in the main view:



Conclusion: All measured parameters reported to be within the specified range and limits.

5.2 CASE 2 - A MODULE WITH NO HORN

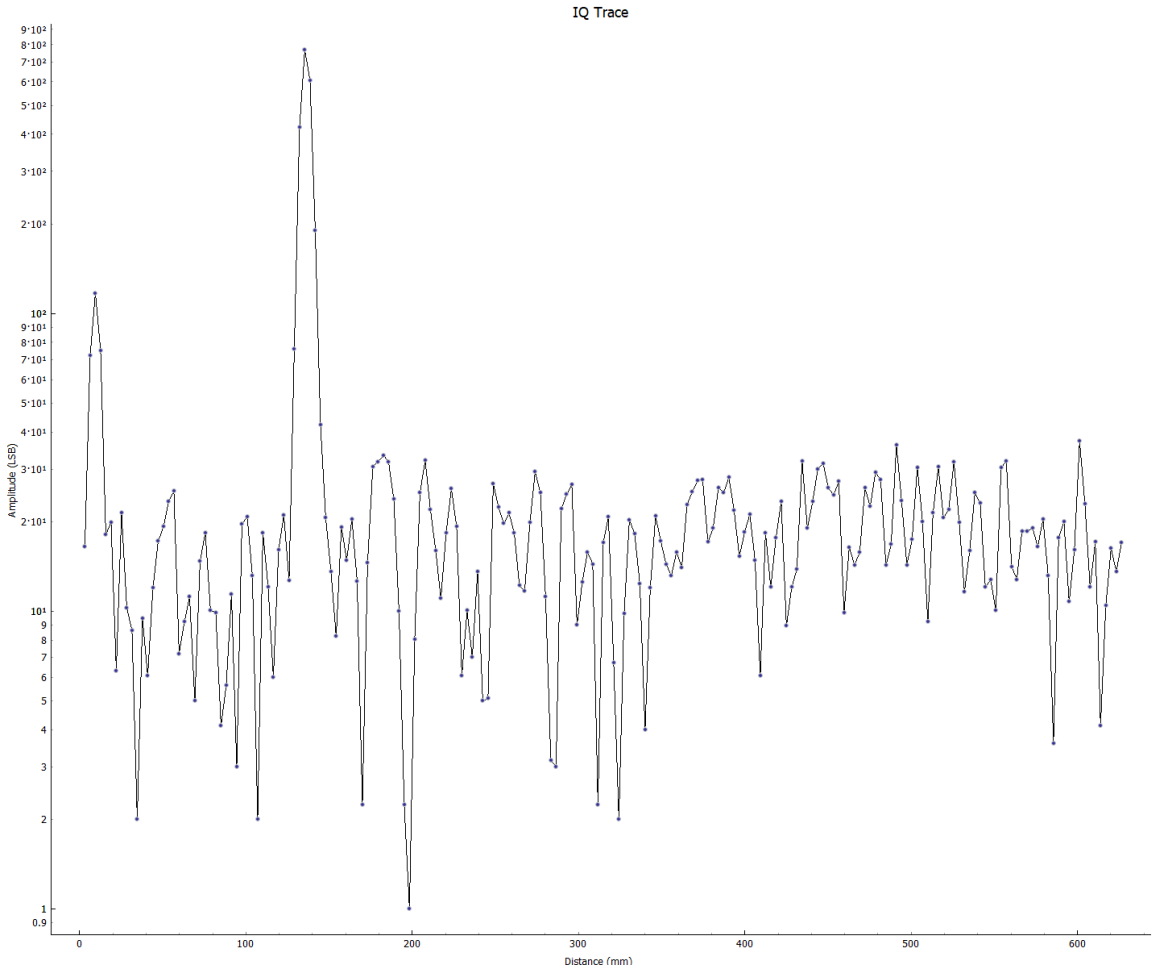
Module evaluated without a horn attached to sensor.

1. *Data Log* tab:

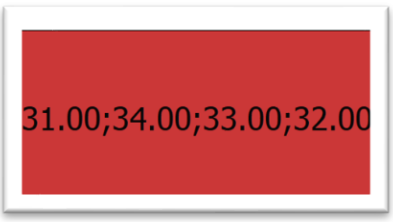
Data Log | Frequency Sweep

result	bin_codes	lot	serial_num	frequency	bandwidth	range	amplitude
Fail: 33.00	33.00	145	02L6	87505	4246.472154912557	0.29034180601863485	3206

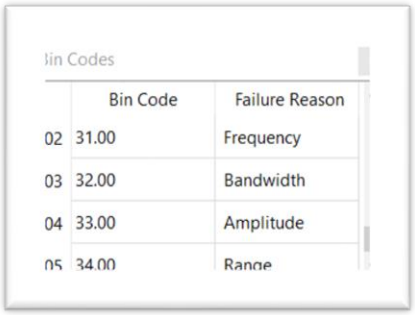
2. From the *IQ trace*:



3. Result displayed in the main view:



Reason of failure:



Conclusion: Failed for the frequency, bandwidth, amplitude, and range.

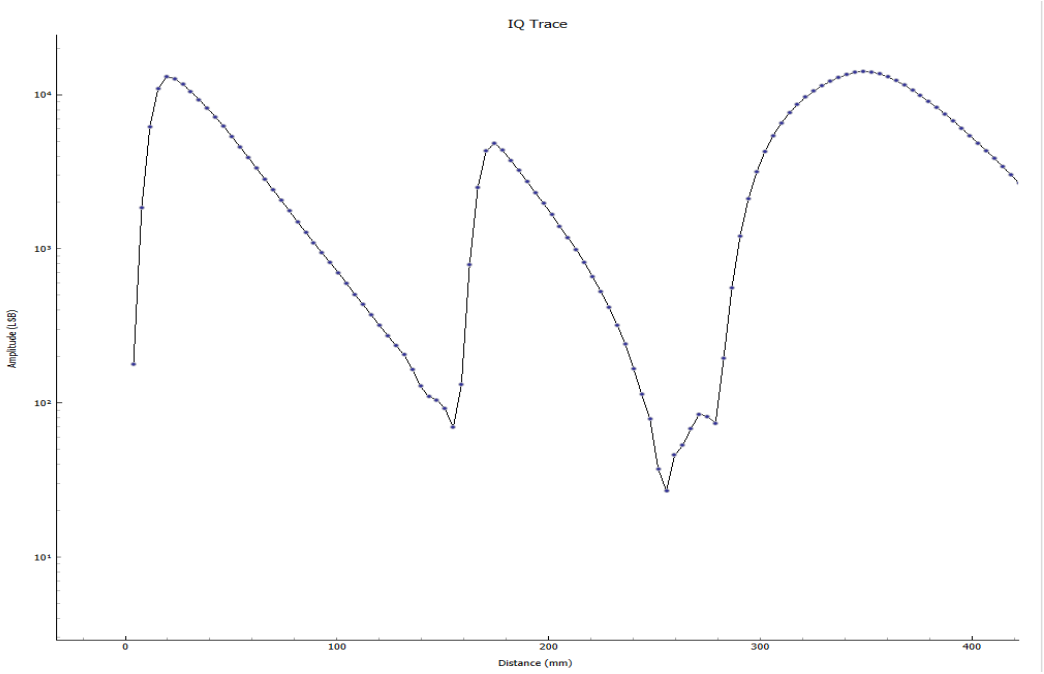
5.3 CASE 3 - A NON-CONCENTRIC MODULE AND HORN

Module with horn that was not aligned with and partially covered the port hole.

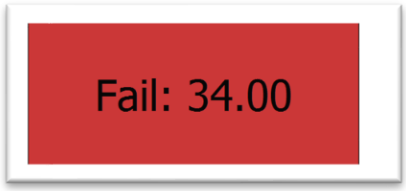
4. On the *Data Log*:

ncy	bandwidth	range	amplitude	s
	1989.2738923875615	0.16621428299406468	3981	1

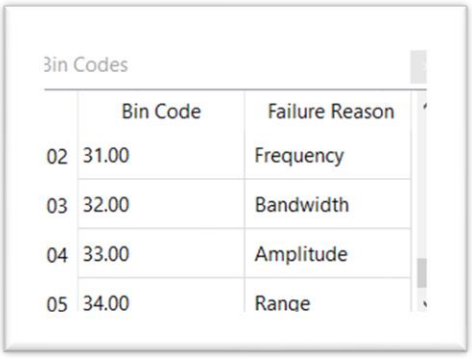
5. From the *IQ trace*:



6. Result displayed in the main view:



7. Reason of failure:



Conclusion: Failed for range, as well as the amplitude.

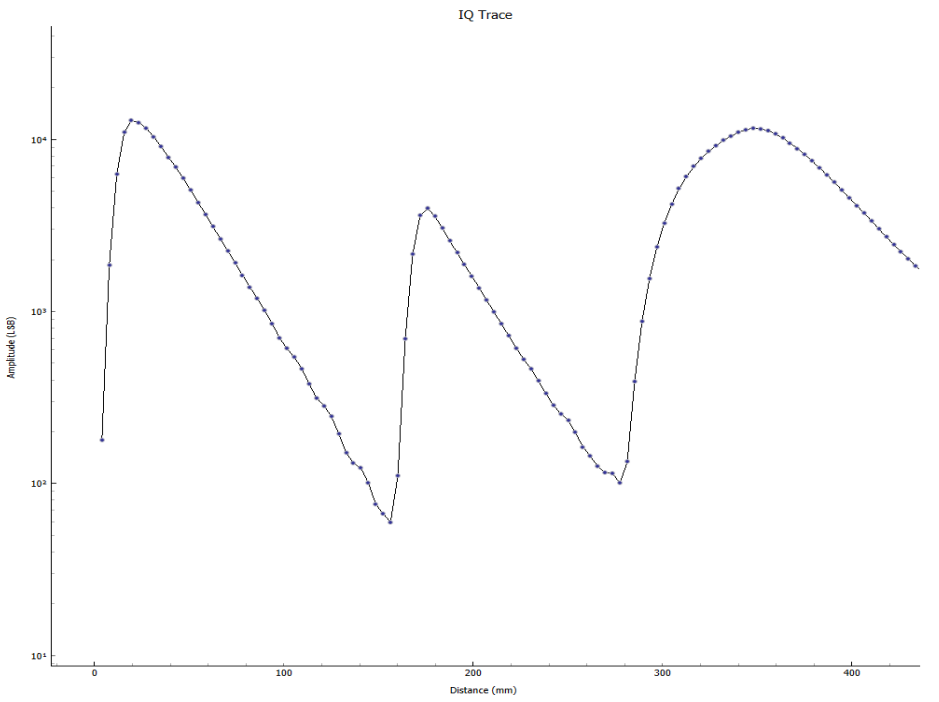
5.4 CASE 4 - A MODULE WITH ANGLED HORN

Module is horn sitting at an angle, not flush with the sensor.

8. On the *Data Log*:

frequency	bandwidth	range	amplitude	
37780	2033.880525821736	0.16733751365700433	3247	1

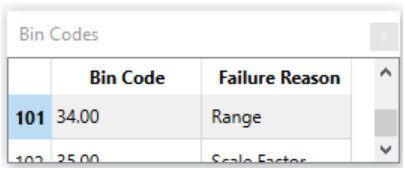
9. From the *IQ trace*:



10. Result displayed in the main view:

Document Number: AN-000424
Revision: 1.0

11. Reason of failure:



Conclusion: Failed for range as well as amplitude.

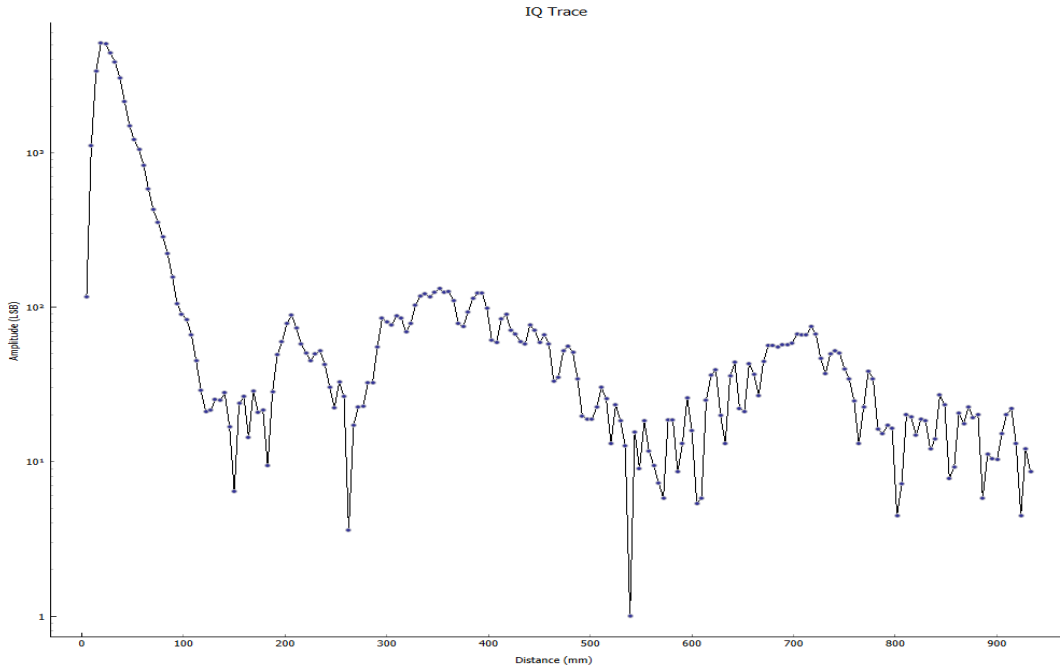
5.5 CASE 5 - A MODULE WITH COVERED HORN

Module with a blocked horn

12. On the *Data Log*:

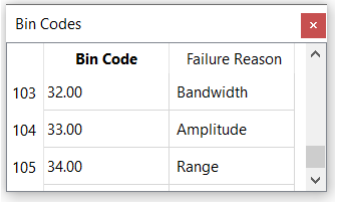
frequency	bandwidth	range	amplitude	scale_factor	odr
73161	1692.4798201722554	-1	-1	5112.2331...	6

13. From the *IQ trace*:



14. Result displayed in the main view:

15. Reason of failure:

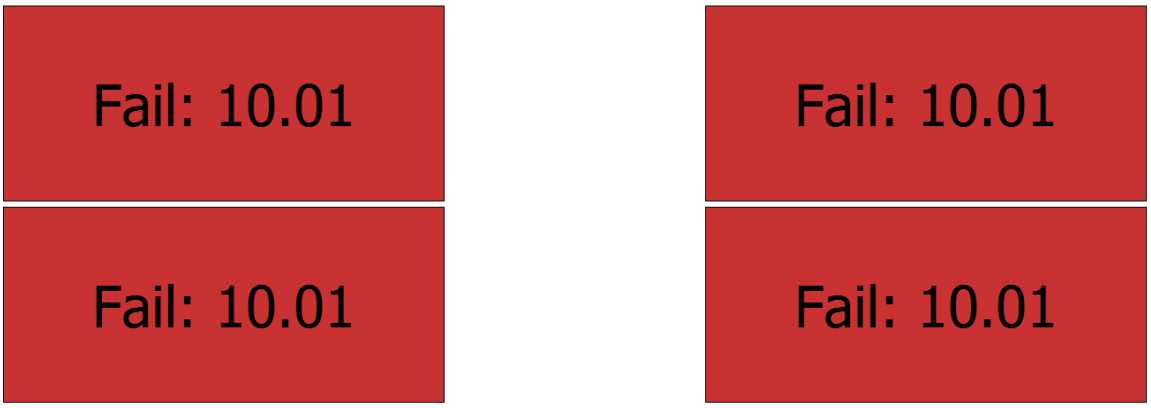


Conclusion: Bandwidth and range failures. Bandwidth is too low, and object not detected within range limits.

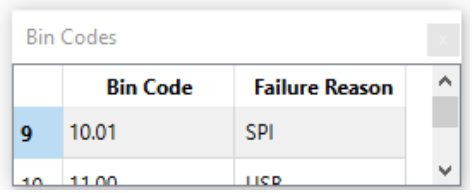
5.6 CASE 6 - NO CONNECTION

Module cannot communicate with the tester.

16. Result displayed in the main view:



17. Reason of failure:



Conclusion: Module incorrectly connected to the development kit. Flex connected in the wrong orientation or at an angle at either the development kit or the module flex connectors.

6 APPENDIX – BIN CODES FOR MODULE TEST ONLY

This list contains only bin codes that are relevant to Module Test SW. The full list covers other production values can be found in the zipped folder with file name: bin_codes.xls

Bin Codes

BIN CODE	FAILURE REASON
00.00-09.99	Pass
01.xx	Frequency Bin
02.xx	Bandwidth Bin
03.xx	Amplitude Bin
04.xx	Range Bin
05.xx	Scale Factor Bin
10.00+	Failure
10.00-19.99	Communication
10.01	SPI
11	USB
12.00-12.99	Timeouts
12.01	SPI Timeout
12.02	OTP Timeout
12.03	Memory Timeout
12.1	Programming Timeout
12.11	RTC Timeout
12.12	Frequency Sweep Timeout
12.13	CMOS Currents Timeout
12.14	Frequency Timeout
12.15	Range finding Timeout
12.17	INT2 Timeout
12.18	External Clocks Timeout

BIN CODE	FAILURE REASON
24	Memory
25.1	OTP Read Failure
25.2	OTP Major Version Not Given
25.21	OTP Minor Version Not Given
27	External Clocks
27.01	RTC Clock
27.02	PMUT CLOCK
28	INT2 Trigger
29	Currents
29.05	Idle Current
29.1	Average Current
29.11	Maximum Current
29.12	Minimum Current
30.00-39.99	MEMS
31	Frequency
32	Bandwidth
33	Amplitude
34	Range
35	Scale Factor

7 REVISION HISTORY

REVISION DATE	REVISION	DESCRIPTION
08/17/2023	1.0	Initial Release