TECHNISCHE UNIVERSITÄT
CHEMNITZ

Department of Electrical Engineering and Information Technology

Chair of Measurement and Sensor Technology

Project Documentation

„Project Lab Embedded Systems“

Group: 07

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Project: Measurement circuit for Nanocomposite Capacitive Pressure Sensor
Date: 2018-08-14

List of Contents

1. Objective

To investigate the ADuCM350 evaluation board and measure Impedance of the board. To design the DUT (Design Under Test) using standard resistance and capacitance. Measure the DUT in the Agilent setup. Measure the DUT using the ADuCM350 evaluation board. Compare the evaluation board's measurement value with Agilent setup values and data sheet for frequency ranges. ADuCM350 is used in impedance spectroscopy.

2. Member Responsibilities

Member	Role
Prashanth Rao Koluvailu	Resonant frequency calculations and Hardware interfacing. Studying the fix for handshake error.
Arunodhayan Sampathkumar	Software installations and data acquiring from evaluation board. Studying the fix for handshake error.
Deepak Narayan Gadde	Hardware interfacing of evaluation board with PC and DUT soldering Studying the fix for handshake error.

Each of the team Members have contributed equally towards the working on Hardware and Software of the Analog Front end board (AFE4300).

- Acquire the evaluation board ADUCM350 to measure the unknown impedances
- Gather the DUT's and the Sensor whose impedance has to be measured
- Measured the impedances for the DUT's using the Agilent and tabulate the values
- Determine the unknown impedances using the evaluation board
- Compare the results between the Agilent and ADUCM350
- Justify the range where ADUCM350 is better than other evaluation boards

3. Introduction

3.1 Impedance Spectroscopy:

Impedance Spectroscopy is used to determine the transfer function of linear Electrical System. In Brief, it is used to define methods to measure the material properties and geometrical compositions of a sample by measuring the device's impedances at different frequencies over a certain predefined range of operation. The measured impedance allows us to determine the component and their arrangement in system.

The information obtained about the real and imaginary part of the impedance for different frequencies can be used for the determination of different sizes which cannot be directly measured. The outcome of Impedance Spectroscopy is generally articulated graphically in a Bode Plot and/or Nyquist Plot. By observing the nature of plots, characteristic behaviour of the Device Under Test (DUT) can be determined. Hence, to find out the composition of a DUT in terms of components, Impedance Spectroscopy is used.

Impedance (Def.) denoted by Z, is an expression of the opposition that an electronic component, circuit, or system offers to alternating and/or direct electric current. Impedance is a vector (two-dimensional)quantity consisting of two independent scalar (one-dimensional) phenomena: Resistance and Reactance.

$$Z = R + j\,X$$

Here,
R is the Real part of the impedance, which is called **Resistance**.
X is the Imaginary part of the impedance, which is called **Reactance**.

3.2 Agilent:

The Agilent Setup is a standard Impedance measurement device which is used to measure the impedances of different components, equipment, and devices under test as per SI standards. The frequency sweep range of this device is 40 Hz to 110 MHz. This setup can also be used to obtain various plots like Nyquist, Bode etc. In this Project, we use this setup to calibrate our DUTs and the given Standard Sensor.

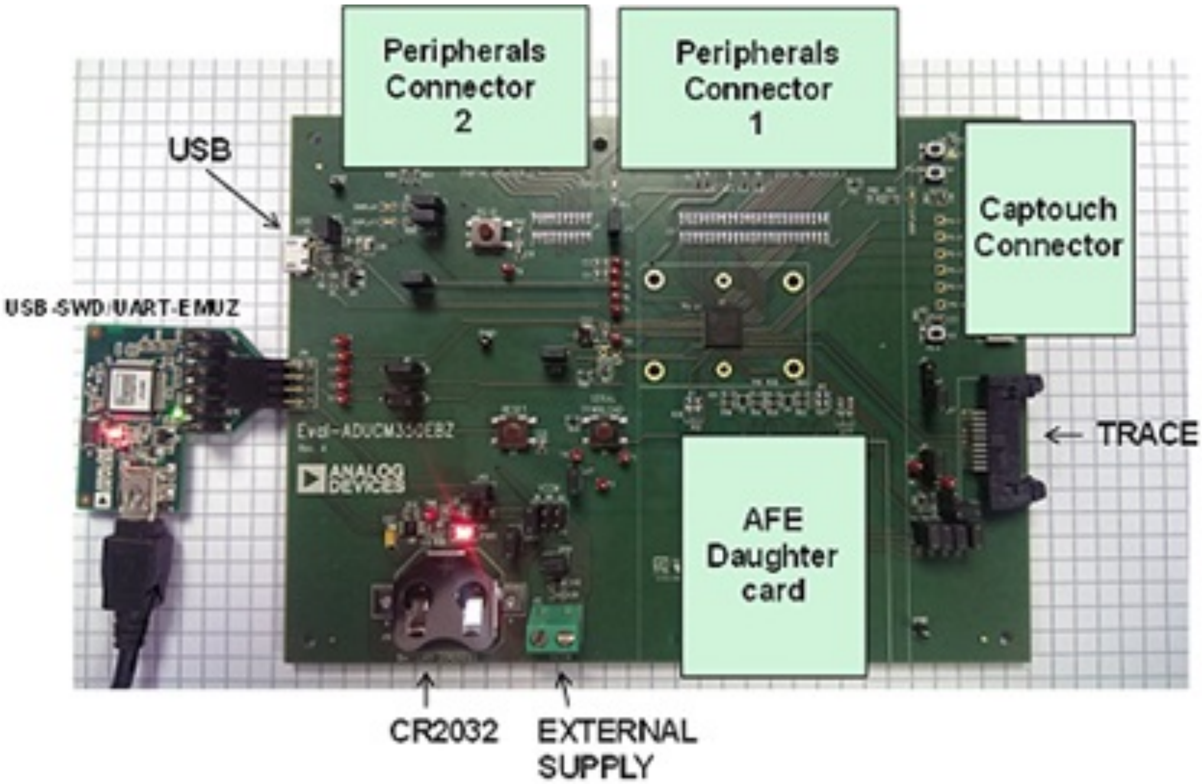
3.3 ADuCM350:

The ADuCM350 is a complete, coin cell powered, high precision, meter-on-chip for portable device applications for applications such as point-of-care diagnostics and body-worn devices for monitoring vital signs. The ADuCM350 is designed for high precision amperometric, voltametric, and impedometric measurement capabilities.

The ADuCM350 analog front end (AFE) features a 16-bit, precision, 160 kSPS analog-to-digital converter (ADC); 0.17% precision voltage reference; 12-bit, no missing codes digital-to-analog converter (DAC); and a reconfigurable ultralow leakage switch matrix. The ADuCM350 also includes an ARM® Cortex-M3-based processor, memory, and all I/O connectivity to support portable meters with display, USB communication, and active sensors. The ADuCM350 is available in a 120-lead, 8 mm × 8 mm CSP_BGA and operates from −40°C to +85°C.

To support extremely low dynamic and hibernate power management, the ADuCM350 provides a collection of power modes and features, such as dynamic and software-controlled clock gating and power gating.

The AFE is connected to the ARM Cortex-M3 via an advanced high performance bus (AHB) slave interface on the advanced microcontroller bus architecture (AMBA) matrix, as well as direct memory access (DMA) and interrupt connections.



Features:

- 16 MHz ARM Cortex-M3 processor
- 384 kB of embedded flash memory
- 32 kB system SRAM
- 16 kB EEPROM
- Integrated full speed USB 2.0 controller and PHY
- Power management unit (PMU)
- Multilayer advanced microcontroller bus architecture (AMBA) bus matrix
- Central direct memory access (DMA) controller
- I2S and beeper interfaces
- LCD controller functions
- Serial peripheral interface (SPI), I2C, and UART peripheral interfaces
- A real-time clock (RTC)
- An analog front-end (AFE) controller
- General-purpose, wake-up, and watchdog timers
- Programmable general-purpose inputs/outputs (GPIOs)
- A power-on reset (POR) feature and power supply monitor (PSM)
- A discrete Fourier transform (DFT) engine

- Receive filters
- Six-button CapTouch® interface
- 12-bit digital-to-analog converter (DAC)
- Temperature sensor
- Instrumentation amplifier control loop
- 16-bit analog-to-digital converter

Analog Front End:

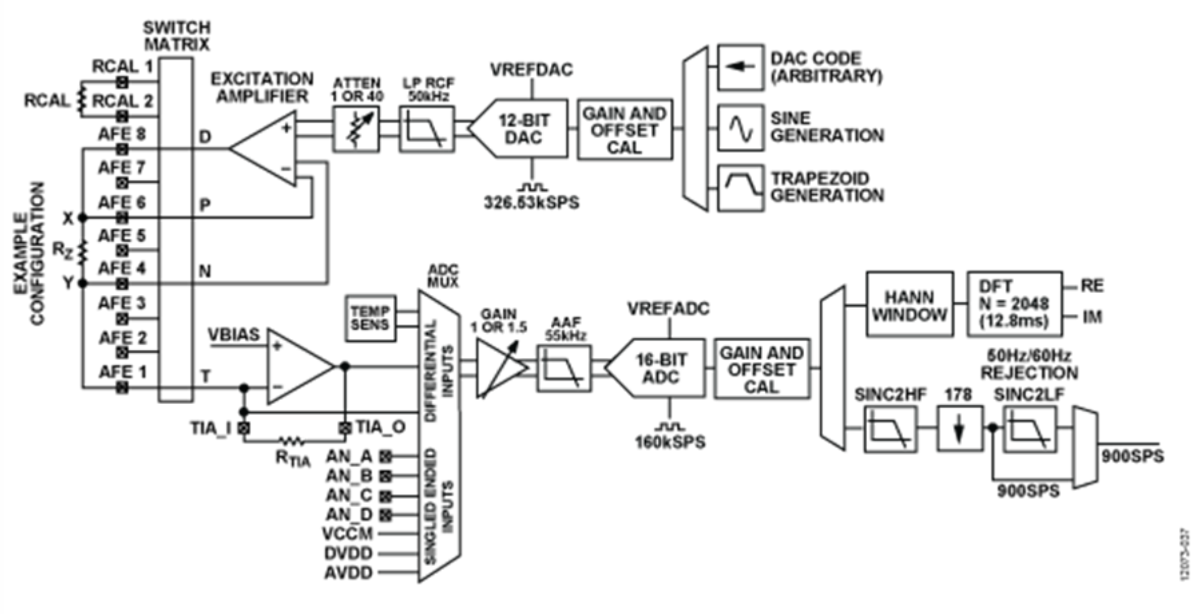


Fig: AFE System Block Diagram

Impedance Measurement:

Table 1: Range of Accuracy and Precision

Parameter	Max.	Unit	Test Conditions
Accuracy:			
i. Magnitude	0.33	%	Std. Deviation as a % of Z
ii. Phase	0.17	Degree	Std. Deviation of Z
Precision:			
i. Magnitude	0.17	%	Std. Deviation as a % of Z
ii. Phase	0.08	Degree	Std. Deviation of Z

Working Range:

This board is best suited for measuring impedance over a wide range of frequencies.
Min freq: 80 Hz to a Max freq: 75 kHz approx.

Impedance Measurement Method:

- 2 wire method
- 4 wire method

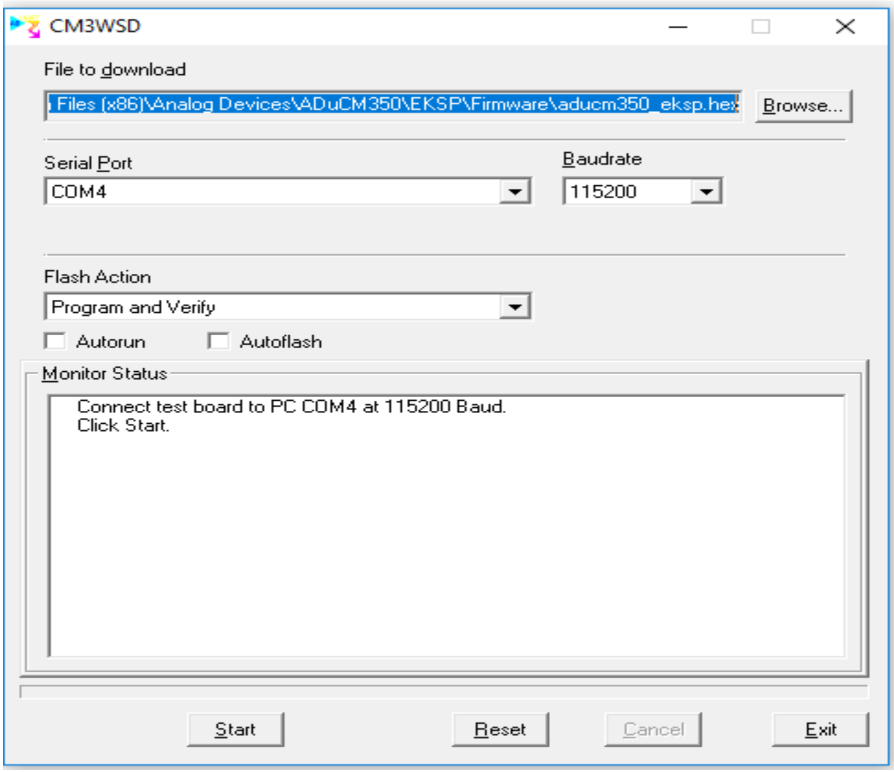
4. Software Description

- IAR Embedded Workbench for ARM (EWARM) cortex (minimum version: 7.10.01)
- Segger J link driver (for Eval-ADuCM350EBZ Rev.B motherboards using analog devices UART-EMUZ emulator board)
- ADuCM350 Software Development Kit (SDK)
- ADuCM350 EKSP (GUI PC software & firmware)

  (***Note***: *It is important that the software be installed in the order above.*)

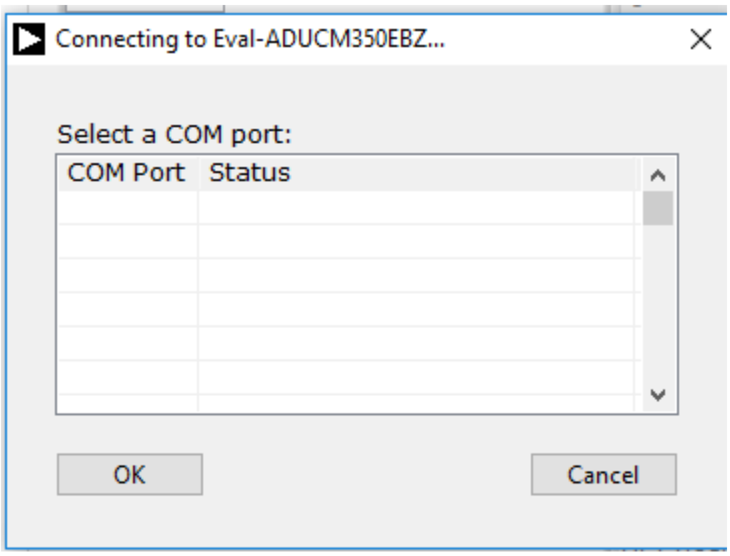
Step 1:

- Once the software is downloaded, install the software in the order given in software setup. Now connect the emulator board to the target pc using USB cable, open the device manager in ports you will see JLink CDC UART port
- Launch the CM3WSD serial downloader tool. This can be found in C:\Analog Devices\ADuCM350BBCZ\Eval-ADUCM350EBZ\tools\SerialDownloader.
- Open the CM3WSD click the browse option and navigate it to C:\Program Files (x86)\Analog Devices\ADuCM350\EKSP\Firmware you will get a hex file .
- Set the baud rate to 115200
- Select the Program and verify flash action and connect the emulator board to the mother board before clicking start.
- The status windows displays “Press Download and Pulse reset on the hardware”. This implies SERIAL DOWNLOAD button (S6) and reset button (S5) before releasing the SERIAL DOWNLOAD button.
- In the CM3WSD click Reset and press reset (S5) in the mother board.



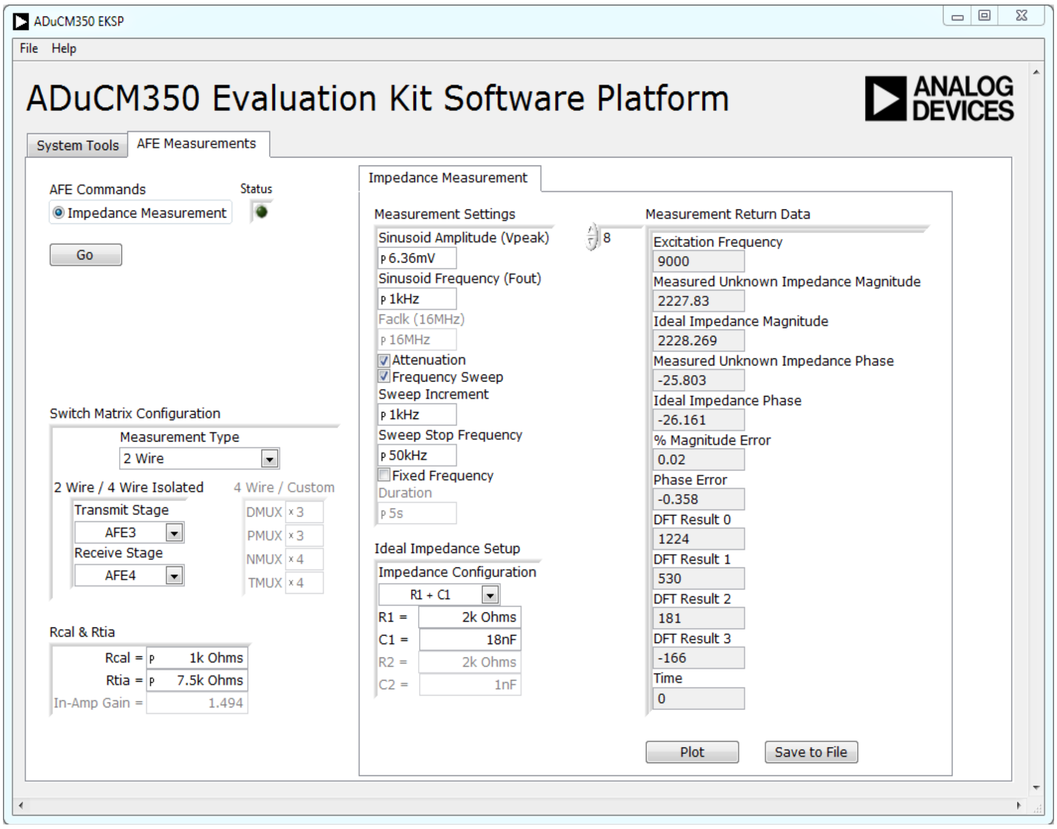
Step 2: Run EKSP GUI software

- Launch the ADuCM350 EKSP GUI Software (C:\Program Files (x86)\Analog Devices\ADuCM350)
- Ensure that UART-EMUZ emulator board is attached with the mother board.
- Ensure that aducm350_eksp.hex has been downloaded to the board at the end of *step1*

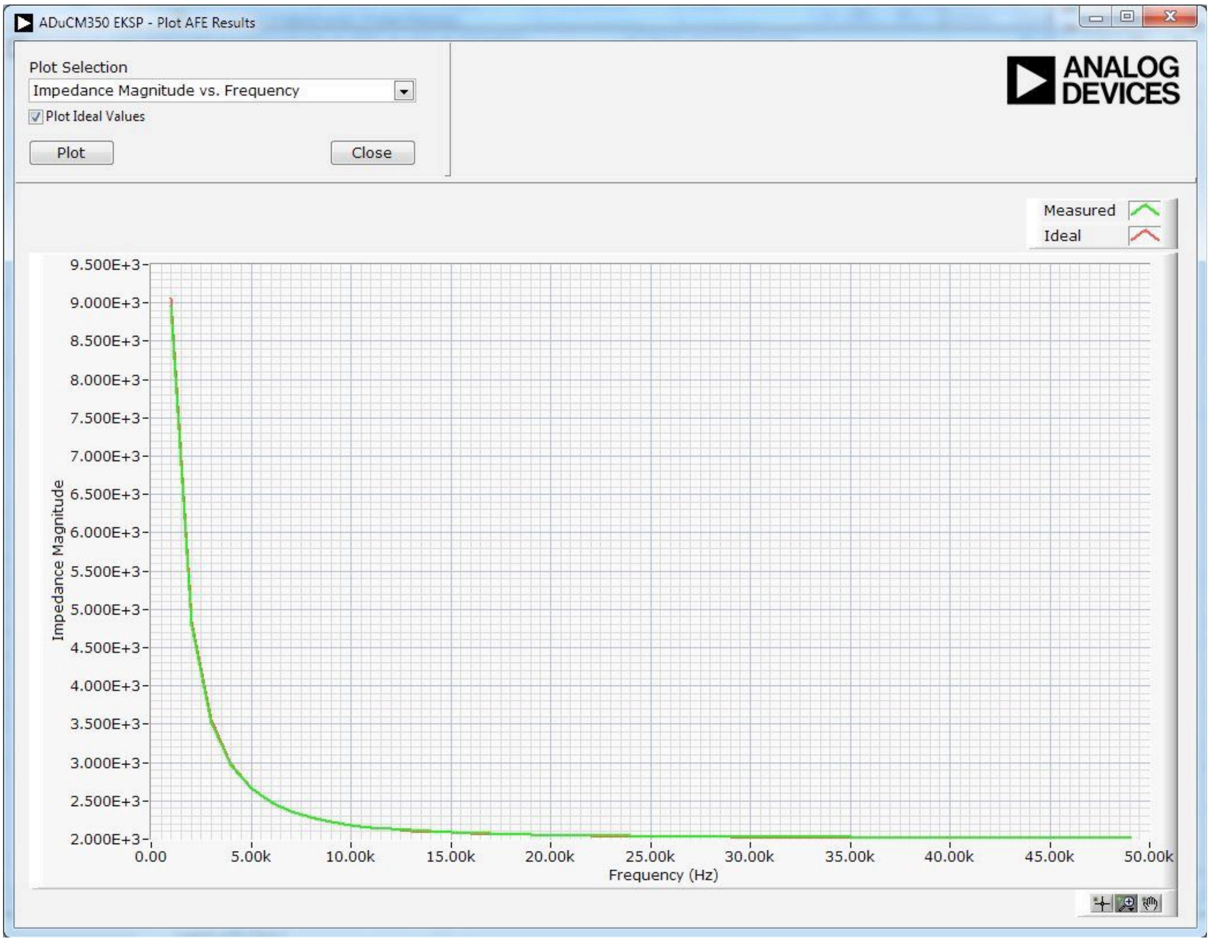


In the above image the com port will be displayed.

Step 3: Perform the evaluation



- By default the ADuCM350 EKSP software has been configured to a particular frequency.
- Select the type of measurement (Here the measurement is 2 wire measurement).
- In the ideal impedance setup select the type of circuit and enter resistance and capacitance value.
- Press Go.
- The values will be displayed in Measurement Return data.
- Click the plot button, the values will get plotted.
- Click Copy to file option, to get a text file containing the values of unknown impedances with magnitude and phase values which can be used to plot Nyquist.



5. Hardware Description

Equipment Needed:

- 1 EVAL-ADuCM350EBZ board
- 1 USB-SW/UART-EMUZ
- 1 ADuCM350 switch mux configuration board (daughter board)
- 1 USB cable

Connecting DUT's for measuring impedance:

- Connect the AFE daughter card to the main board
- Connect the unknown impedance of the DUT/ Sensor to the daughter board using the 2/ 4 wire method
- Once the DUT/ Sensor is connected, use the software to obtain the required plot
- From the plot obtained calculate the impedance (Magnitude and Phase) of the circuit
- Compare the result with value measured using the Agilent
- Also compare the parameters (Accuracy and Precision) with the other boards

6. Applications

- Optimizing the ADuCM350 for 4-Wire, Bio-isolated Impedance Measurement Applications
- Profiling the ADuCM350 Supply Current in an Example Application
- Point-of-care diagnostics
- Body-worn devices for monitoring vital signs
- Amperometric, Voltametric, and Impedometric measurements

7. Experiment Setup

Measuring the unknown impedances of the DUTs with

- ADuCM350
- Agilent Setup

Plotting the Nyquist Plots for both the methods and comparing the same over a wide range of frequencies (1 kHz to 50 kHz in ADuCM350, and 40 Hz-110 MHz in Agilent Setup)

Below is the Tabulation containing the DUT Circuits with their component values and their cut-off frequencies. These DUTs were selected keeping in mind the restrictions of all the three boards regarding the Impedance limit, frequency sweep range, etc. Out of the 6 DUTs designed below few of the DUTs are outside the measurable region of the evaluation board ADuCM350. The main significance of using these DUTs is that most of the DUTs designed are standard impedance measurement circuits whereas DUT 6 alone is a random circuit design.

Table 2: DUTs Used and their configuration

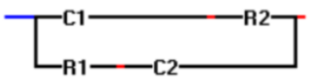
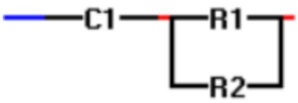
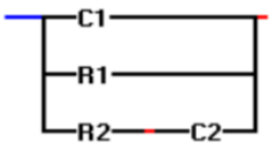
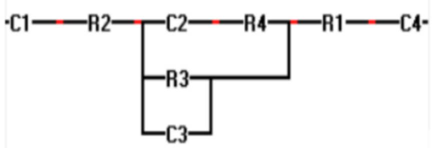
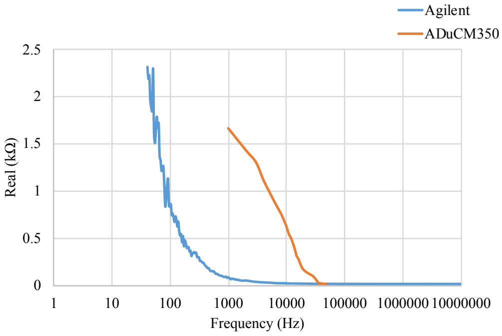
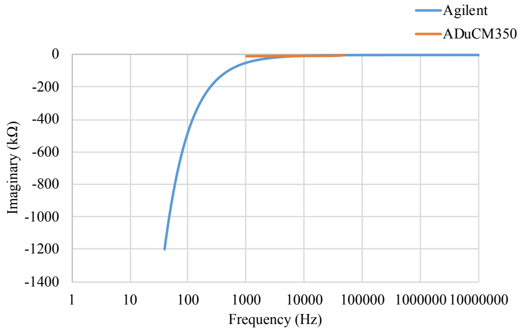
DUT	Image	Component Values	Cut-off Frequency fc (Hz)	Impedance Z (Ω)
1		R1:12 Ω C1: 47 nF	300	11.3 k
2		R1:2.7 kΩ C1: 4.7 nF	16 k	50.9
3		R1:12 Ω C1: 47 nF R2:82 kΩ C2: 68 nF	600	18.8
4		R1:390 kΩ C1: 0.1 µF R2:15 Ω	300	5.3 k
5		R1:68 kΩ C1: 68 nF R2:180 kΩ C2: 47 nF	500	2.34 M
6		R1:270 kΩ R2:15 Ω R3:6.8 KΩ R4:390 kΩ C1: 68 nF C2: 47 nF C3: 0.1 µF C4: 68 nF	1.8 M	270 k

Table 3: Comparison of Nyquist Plots for various DUTs:

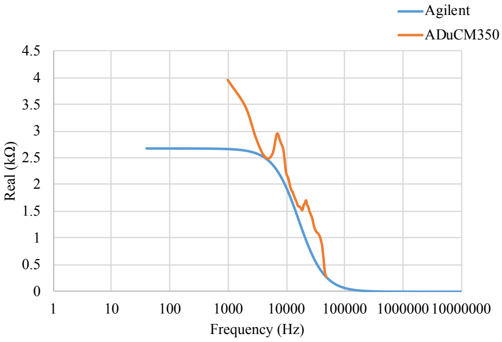
DUT 1
Real Vs Frequency



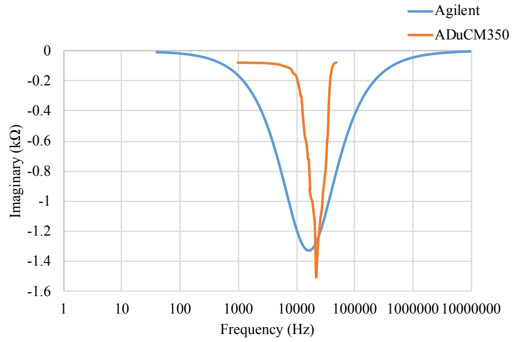
DUT 1
Imaginary Vs Frequency



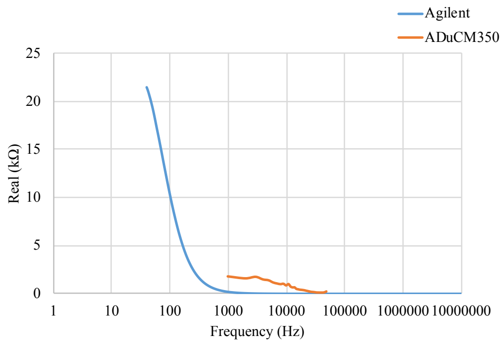
DUT 2
Real Vs Frequency



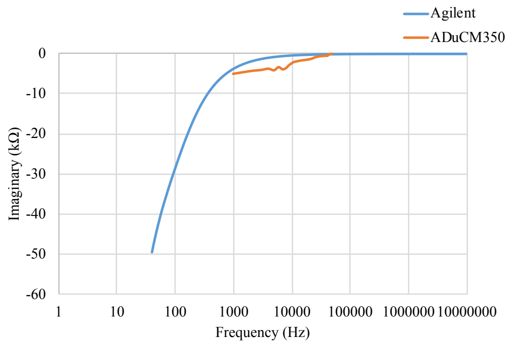
DUT 2
Imaginary Vs Frequency



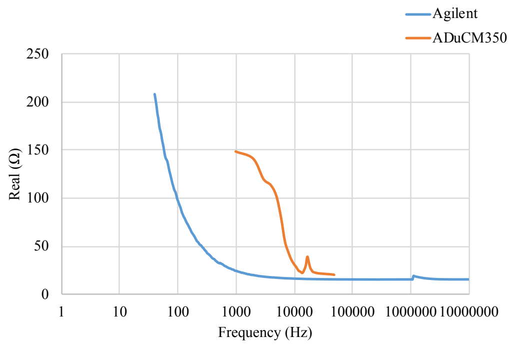
DUT 3
Real Vs Frequency



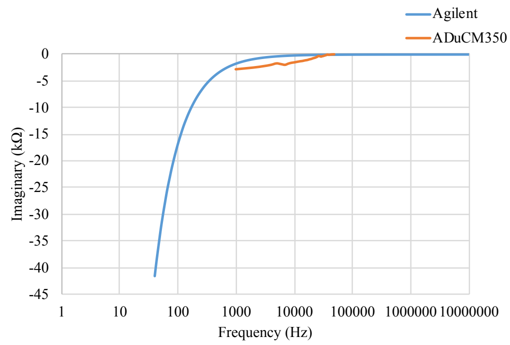
DUT 3
Imaginary Vs Frequency



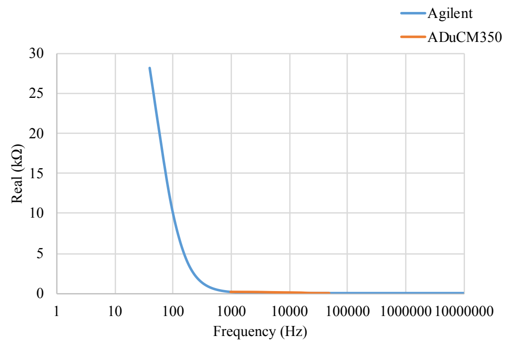
DUT 4
Real Vs Frequency



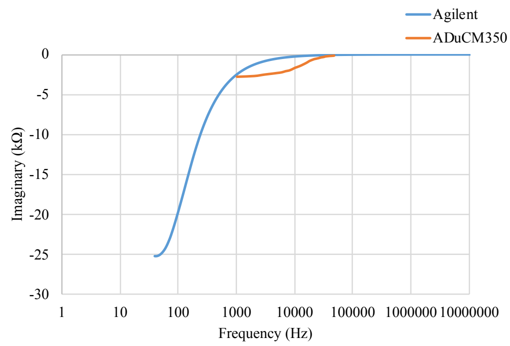
DUT 4
Imaginary Vs Frequency



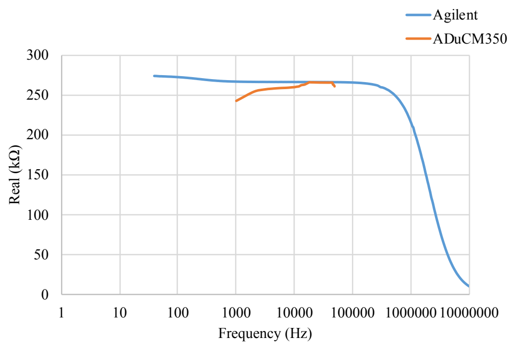
DUT 5
Real Vs Frequency



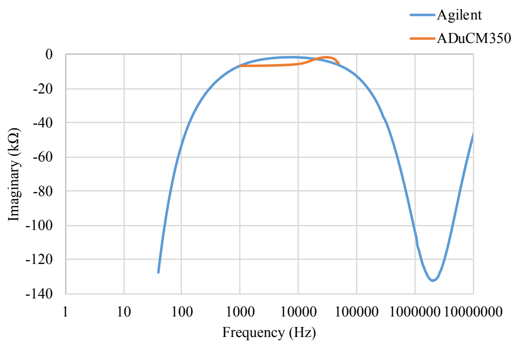
DUT 5
Imaginary Vs Frequency



DUT 6
Real Vs Frequency



DUT 6
Imaginary Vs Frequency



The difference in the values between the Agilent setup plot and the plot of ADuCM350 evaluation board is mainly because of the measurement range of agilent is from 40 Hz to 110 MHz whereas the frequency sweep capability of the ADuCM350 is from 80 Hz to 75 kHz as mentioned in the working range limitations.

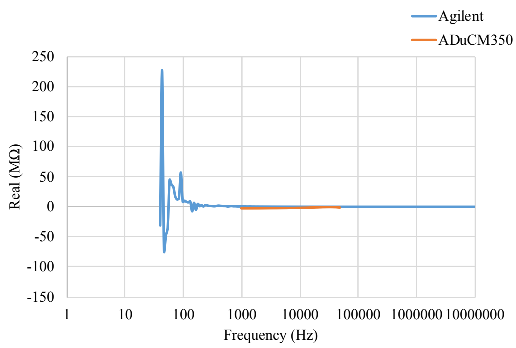
Also we can see that the evaluation board ADuCM350 cannot measure the impedance values properly which is evident from the Nyquist plots of DUTs 2 and 3.

As done for DUTs we perform the comparison between ADuCM350 and Agilent for a standard Nanocomposite Pressure Sensor with different weights applied over the sensor.

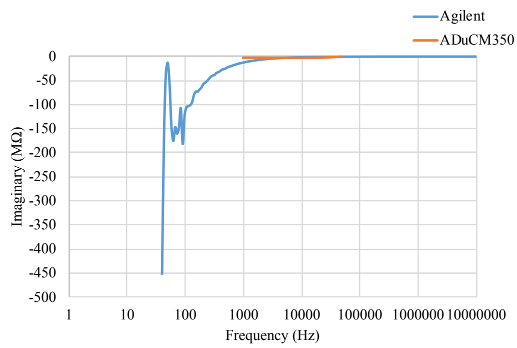
Below is the Tabulation for the same.

Table 4: Comparison of Nyquist Plots for Nanocomposite Pressure Sensor with 200 grams as Load

Real Vs Frequency



Imaginary Vs Frequency



From the above we can observe that the real and imaginary values against frequency of both Agilent and ADuCM350 evaluation board (for 200 grams) are overlapping for the range between 1kHz and 50 kHz showing that both the set of values are similar to each other. The same sensor can have different set of loads and the data can be tabulated.

8. Conclusion

From the above set of calculations and computations, we can clearly observe that the ADuCM350 finds it difficult to measure the impedances if it is below the Evaluation Board's measurement range (100Ω) As seen the case for DUT 2, DUT 3, and DUT 4.

Also the frequency range is from 80 Hz to 75 kHz, but the Software Development Platform allows us to sweep only from 1 kHz to 50 kHz. If the resonant frequency of the given circuit is greater than the working range of ADuCM350, it will be difficult to measure. As seen in the case of Nanocomposite Impedance measurement graphs of ADuCM350 and Agilent. Also, the software setup for measuring the impedances is a tedious process.

Hence, this Evaluation Board can be used only if the frequency range of operation is small and the impedance to be measured is greater than 100 Ω but less than 1 MΩ.

9. References

- **Impedance Spectroscopy**
  https://www.gamry.com/application-notes/EIS/basics-of-electrochemical-impedance-spectroscopy/

- **Datasheet AduCM350**
  http://www.analog.com/media/en/technical-documentation/user-guides/EVAL-ADuCM350EBZ_UG-668.pdf

- **Downloading the HEX file to ADuCM350**
  https://ez.analog.com/docs/DOC-11121

- **Software Downloads**
  http://www.analog.com/en/products/processors-dsp/microcontrollers/precision-microcontrollers/aducm350.html#product-overview

- **Software Setup**

  https://ez.analog.com/docs/DOC-12779