Standard Operating Procedure **SOP186**

Title: The use and maintenance of the SensAND instrument

Location: CBE H34, T208B and S3 Laboratories

1. PURPOSE

The intent of this SOP is to describe the safe use and maintenance procedures for the SensAND instrument.

2. SCOPE

This SOP applies to CBE lab users operating the SensAND instrument in CBE H34, Wolfson T208B and S3 3001 laboratories. The SensAND instrument is used for transduction of surface-binding into a recordable electrical signal which is subsequently converted into a mass change data. The procedure describes the process of setting up the SensAND instrument – amplifier assembly, starting and switching off the SensAND instrument, connecting the instrument to a resonator circuit, using the software interface, and calibrating the ADT instrument.

3. RESPONSIBILITES

CBE Laboratory Users

- MUST have received competent instruction before using the SensAND instrument
- Shall be responsible for the proper use and maintenance of the SensAND instrument as outlined in this document. Users must ensure that the working area is kept clean during work and disinfected after the work has been completed
- MUST keep the SensAND instrument in a faultless condition with regard to the electrical safety i.e. ensure PAT testing is in date and ensure that cables are safe, and plug are safe.
- MUST stop using the SensAND instrument as soon as any safety deficiency is detected. Operators MUST inform the Laboratory Manager or designated person

Responsible Person (RP)/Laboratory Manager (LM)

- Shall schedule any service or preventative maintenance requirement with authorized service representatives. This must be coordinated with the Laboratory Manager.
- Ensure that all operators have been given conversant information, instruction, training and supervision in the correct use and maintenance of the microscope.

4. EQUIPMENT AND MATERIALS

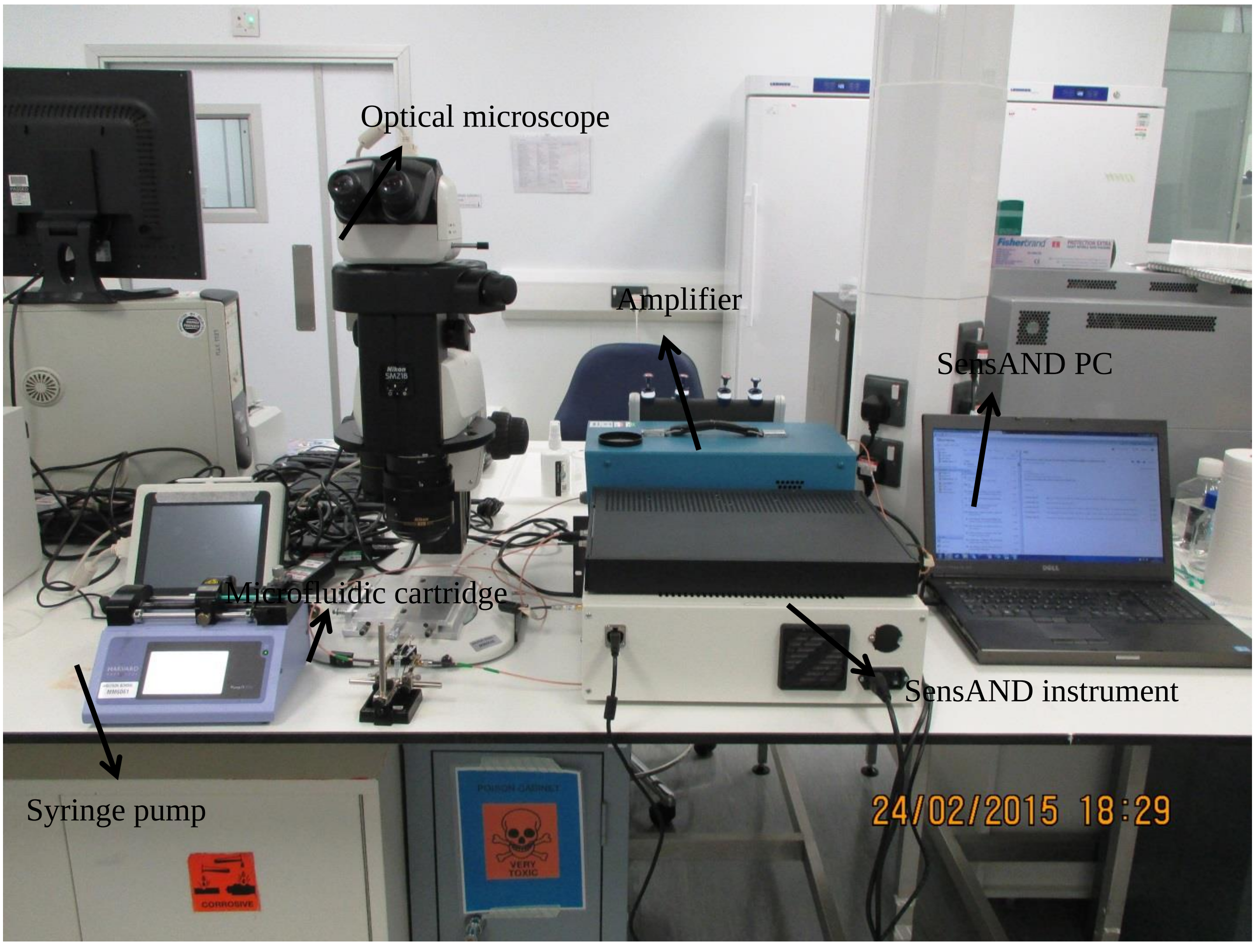

Fig 1: Snapshot of SensAND instrument along with its accessories

List of equipment related to the SensAND analytical setup:

Set- up for:

Microbiology lab

Peristaltic pump
HPLC pump
SensAND instrument (two pieces)
PC (+ keyboard + mouse + computer screen)
Syringe pump
Nikon SMZ 18 stereoscope
MUX Microfluidic Flow Switch Distributor LVF-3536
QCR heaters (separate units for 5MHz and 14.3 MHz crystals)
Microfluidic cartridge with QCR holder

Chemistry lab

SensAND instrument (two pieces)
PC (+ keyboard + mouse + computer screen)
Digital storage oscilloscope
Potentiostat PalmSens3
Electrochemical cell with QCR holder

List of abbreviations:

QCR – quartz crystal resonator
PCB – printed circuit board
AC – alternated current
DC – direct current

Complete analytical setup:

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Microbiology lab setup:

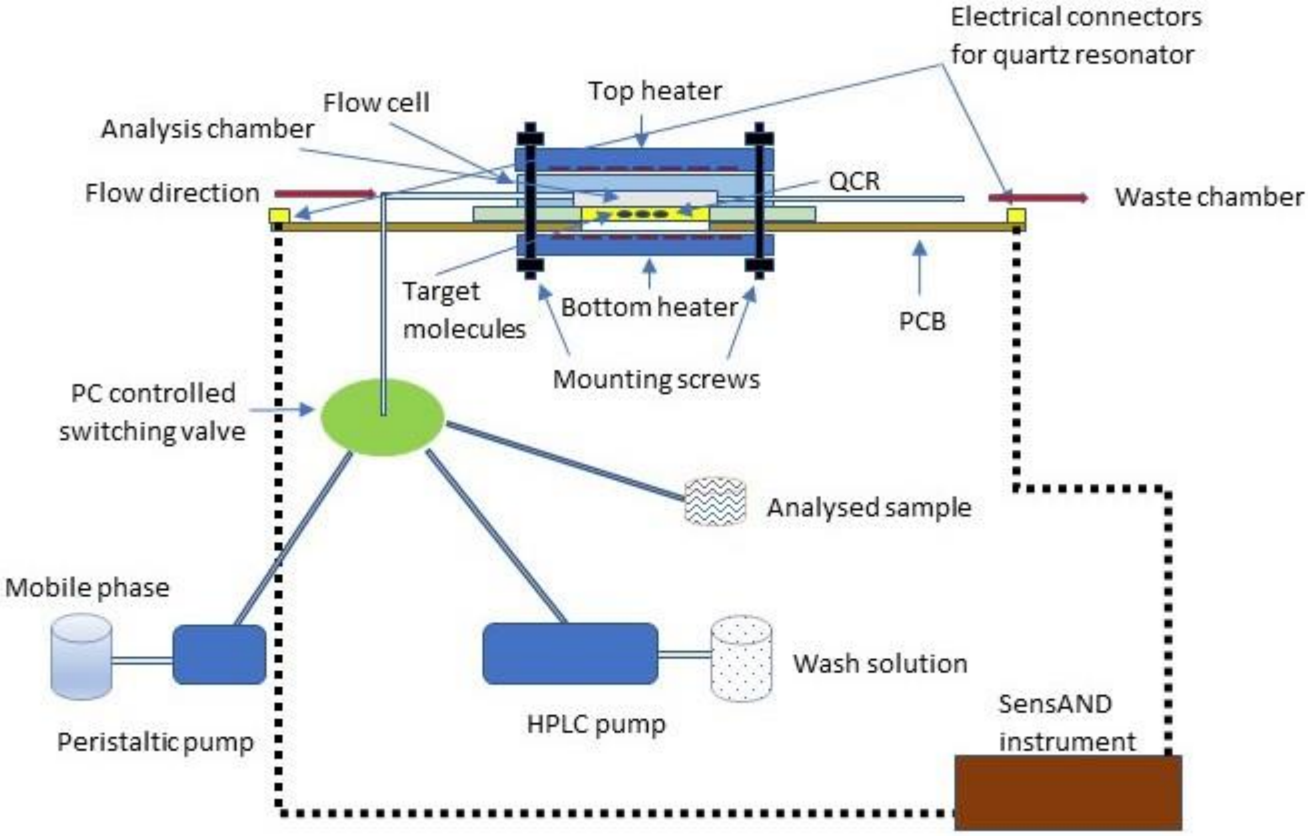

Fig 2. Operational diagram of the SensAND analytical setup for the microbiology lab. System has the capacity to inject up to 10 different solutions into the microfluidic cartridge. Flow rate can be controlled from 5 µL/min to 10 mL/min.

Figure 3. Picture of MUX distributor valve (Darwin Microfluidics, France).

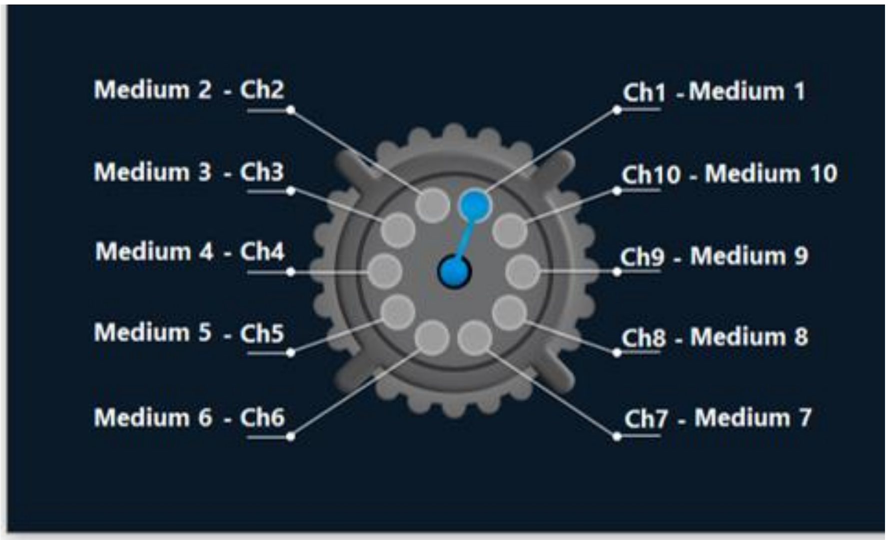

Figure 4. Operational diagram of the distributor valve. Central position is the outlet (i.e. provides the flow to the microfluidic cell) while peripheral positions are assigned to mobile phase, cleaning solutions and analysed sample.

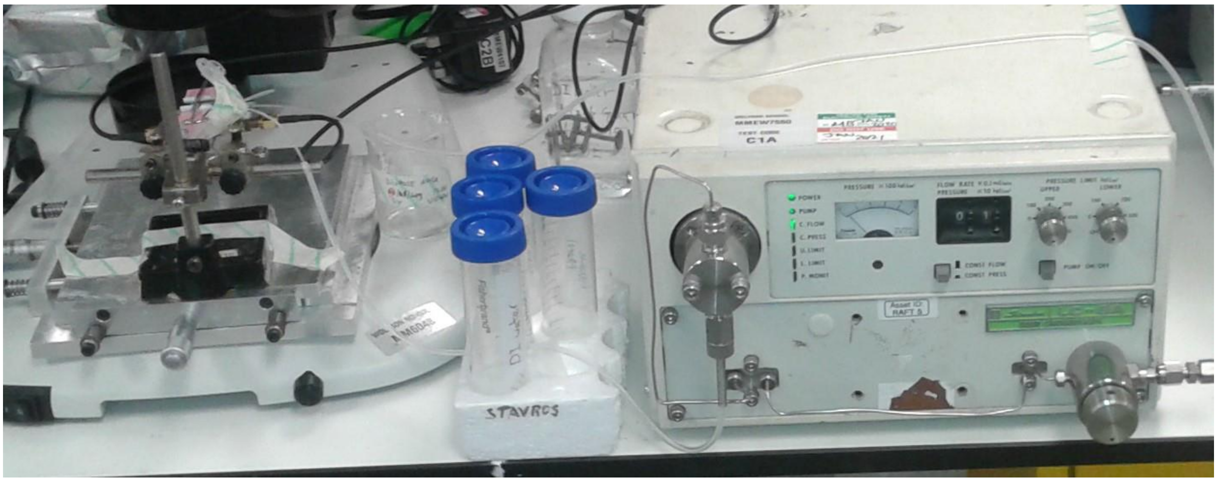

Figure 5**.** Picture of HPLC pump connected to the microfluidic cartrigde. An HPLC pump is to be used in conjunction with peristaltic pump (not shown).

Chemistry lab setup:

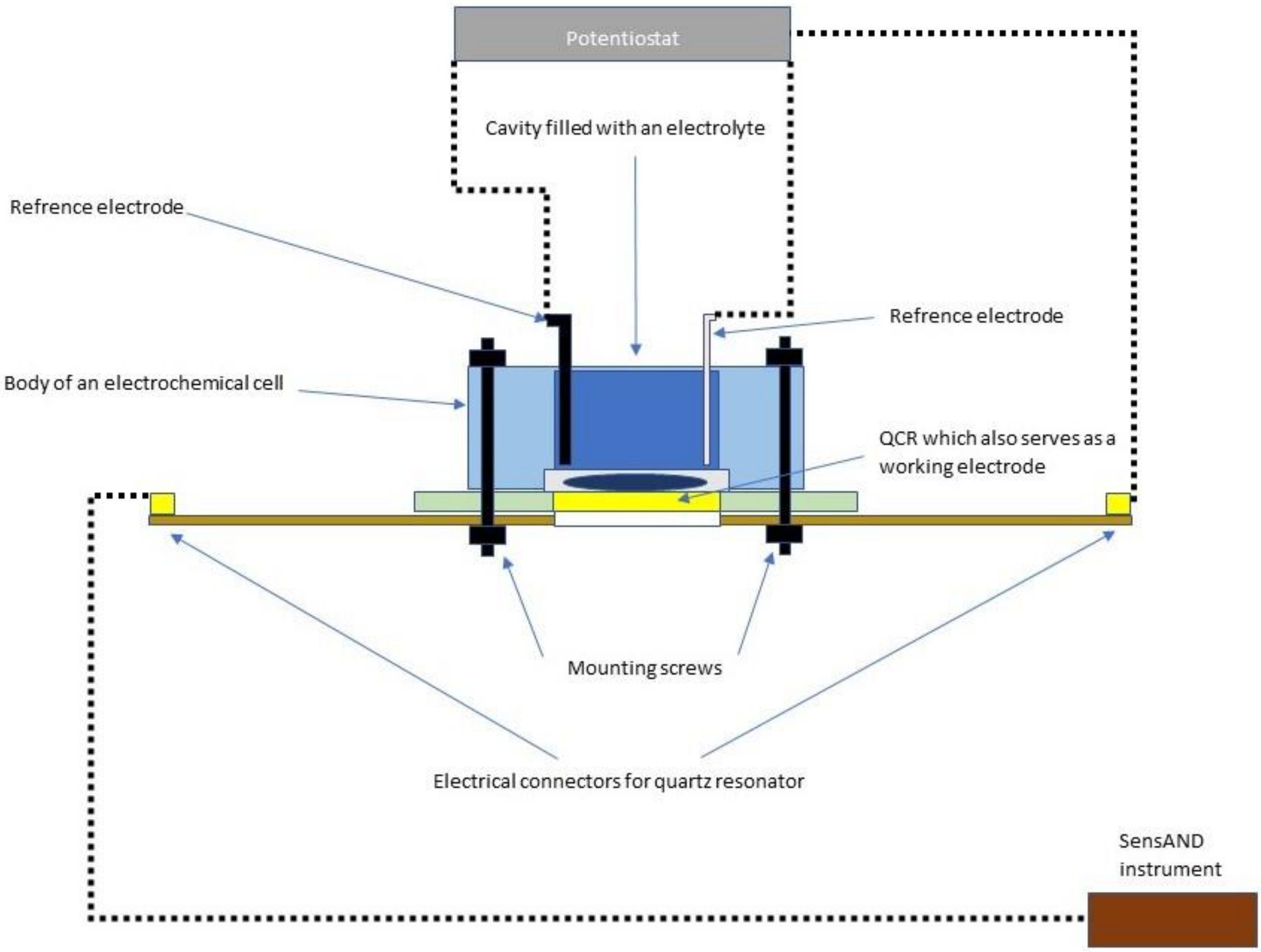

Fig 6. Operational diagram of the SensAND analytical setup for the chemistry lab. Note that only one side of the QCR is connected to the SensAND instrument.

5. PROCEDURE

Microbiology lab

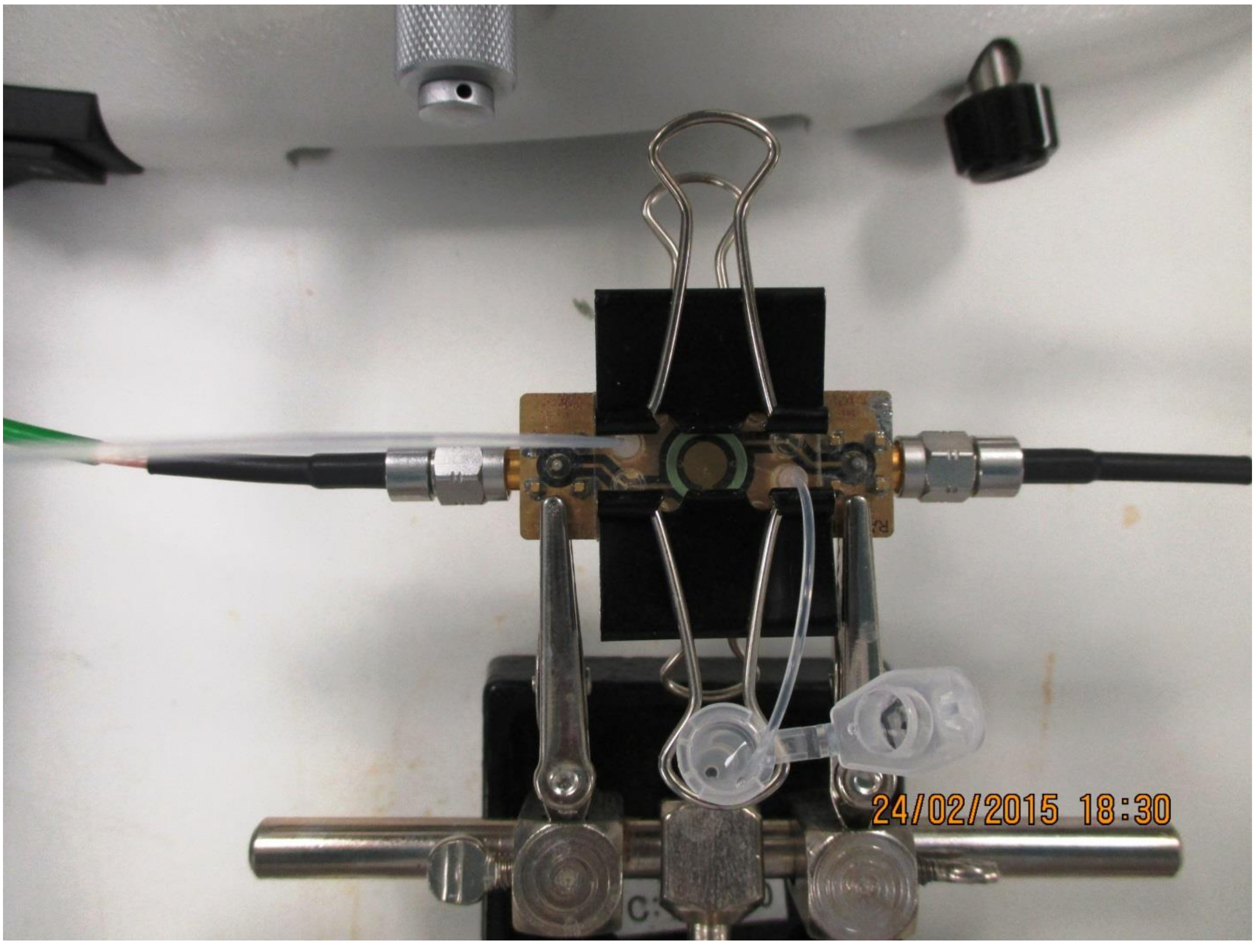

Fig 7: Detailed view of the microfluidic cartridge along with PCB (containing QCR holder)

Steps for setting up of SensAND-amplifier assembly:

- Connect RF Power from Amplifier pin on SensAND to Output pin on Amplifier with SMA cable
- Screw Attenuator to RF Test Signal to Amplifier Input pin on ADT
- Connect Attenuator to Input pin on Amplifier with SMA cable
- Connect Pc Interface plug on SensAND to USB port on PC with USB type B cable
  Connect the holder with the cartridge to Cartridge pins on ADT with SMA cable

Notes: Screwing of SMA connection must be done gently

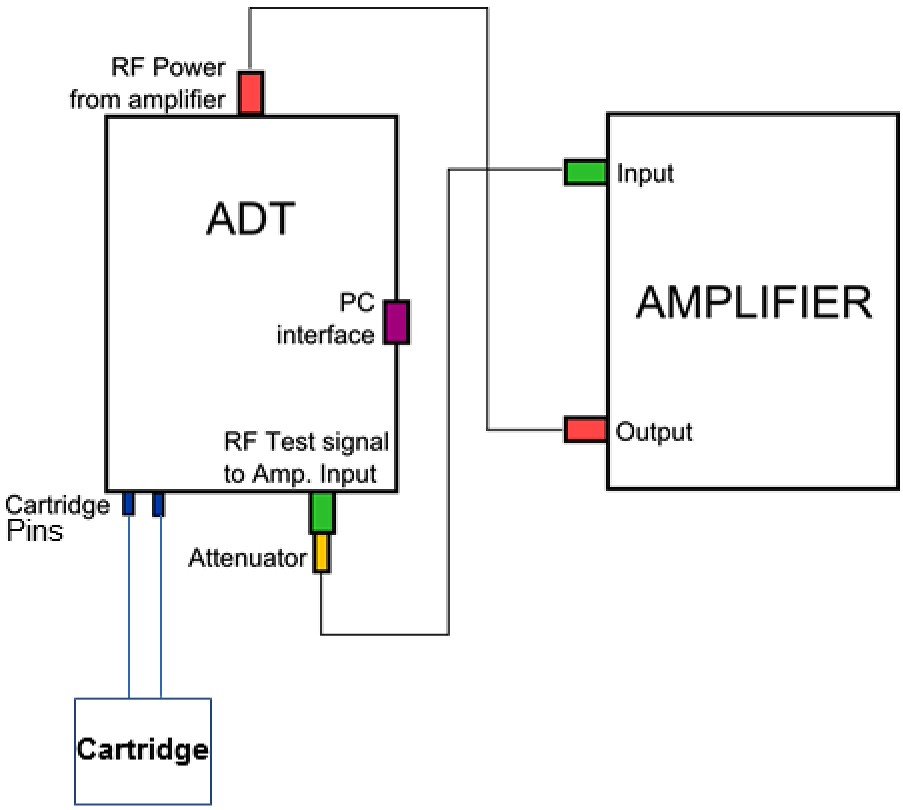

Fig 8: Schematic of SensAND-amplifier assembly set up for the experiments in microbiological mode

Steps to start the SensAND instrument:

Connect SensAND to PC dedicated for SensAND instrument
Switch on SensAND
Wait for 15 sec
Switch on Amplifier
Wait for 15 sec
Launch SensAND control software icon located on SensAND PC

Steps to switch off the SensAND/ADT instrument:

Close SensAND control software
Switch off Amplifier
Switch off SensAND

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Chemistry lab

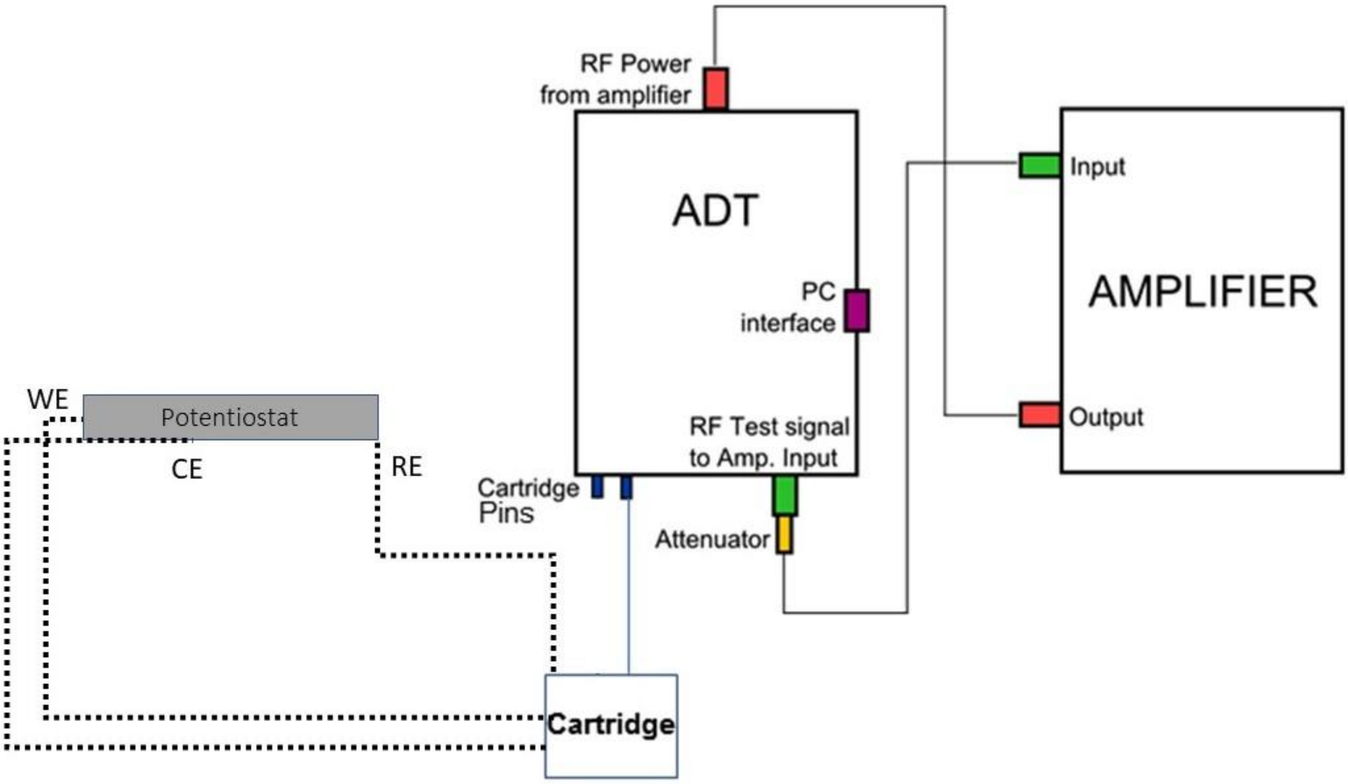


Fig 9: Schematic of SensAND-amplifier assembly set up for the experiments in electrochemical mode

Procedure for the electrochemical mode is very similar to the one in microbiological mode there is however one important difference in experimental set – up, namely in electrochemical mode the AC potential from the SensAND instrument is applied only to the bottom face of the QCR (i.e. the side that faces the air). This is done to avoid the interference on DC signals applied and collected by the potentiostat to the upper face of the QCR (i.e. the side that faces the analyzed solution).

Electrochemical reactions are setup and controlled by PalmSense 3 potentiostat which in turn is controlled by PS Trace 5.7 software. Potentiostat is connected to the electrodes in the electrochemical cell by means of labelled cables and crocodile clips. In order to collect matching sets of data electrochemical experiments have to be started at the same time as the acoustic ones.

Software interface

Settings panel

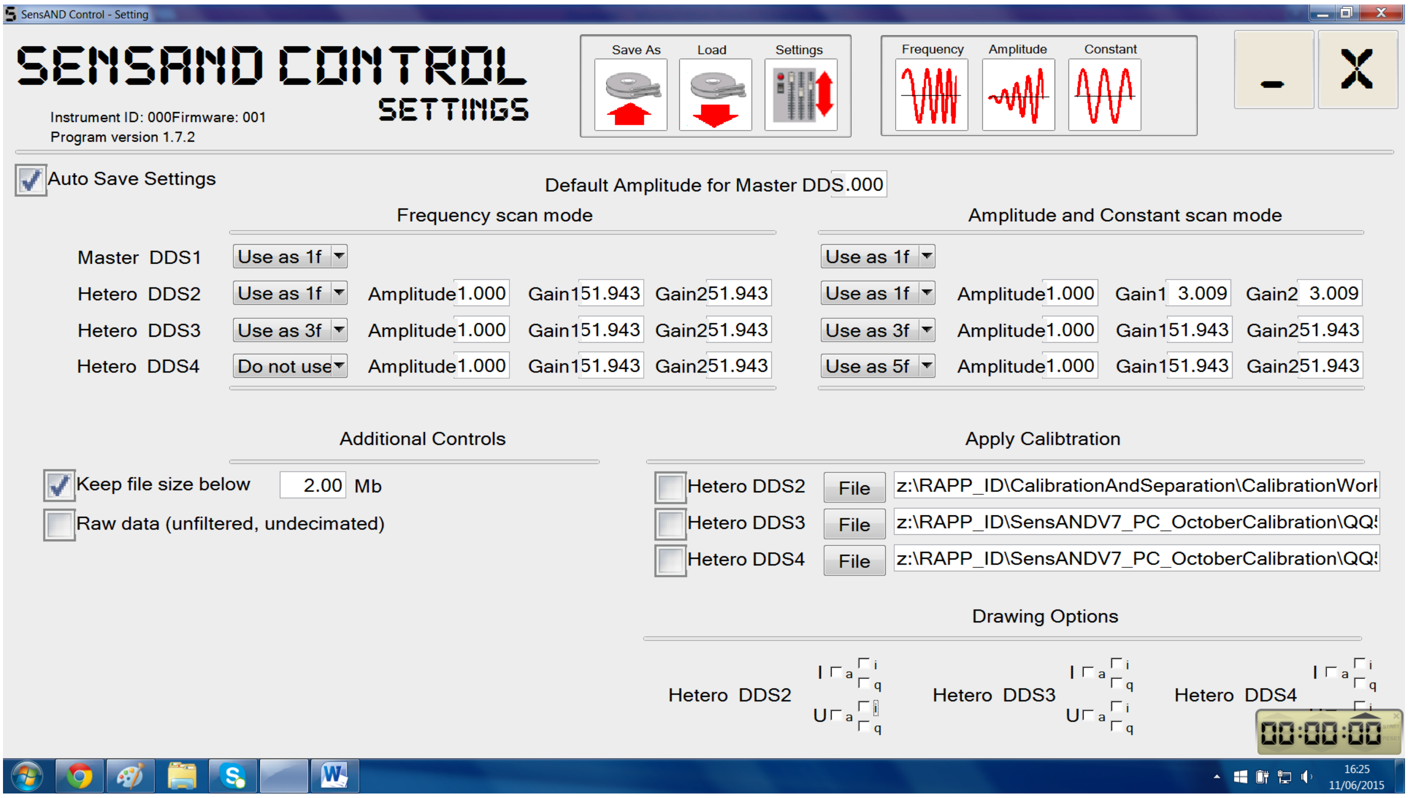


Figure 10: Snapshot of settings panel window

Default amplitude for master DDS: Keep it at 0 always.

Different Scan modes: Frequency, Amplitude and Constant scan modes

Amplitude and gain settings for amplitude and constant scan modes are the same. Thus, we have to apply amplitude and gain settings for frequency and amplitude/constant scan modes separately.

Master DDS1is the generator used to drive the sensor at fundamental frequency or closer to the fundamental frequency (1f)

Hetero DDS2, Hetero DDS3 and Hetero DDS4 are the receivers used for receiving transduced signals at various frequencies namely 1f (fundamental), 3f (3rd harmonic or three times the fundamental frequency) and 5f (5th harmonic or five times the fundamental frequency) respectively.

Amplitude: Keep it at 1for each receiver

Gain 1 and Gain 2: Each receiver has two channels namely channel 1 (I) and channel 2 (U) and hence there are two gains namely Gain 1 and Gain 2 respectively.

Gain settings if the receiver is used for 1f: Set this gain such that the peak response (on screen) for any type of scan lies between 1000 and 5000. Increase in gain improves sensitivity but if you increase it too much you may have signal saturation, so keep the value below 5000. Gain settings depend on the type of experiments and will vary for each user.

Gain settings if the receiver is used for 3f: Set this gain to the maximum value, i.e. 52 as the amplitude of oscillation at 3f will be significantly smaller compared to that at 1f.

Gain settings if the receiver is used for 5f: Set this gain to the maximum value, i.e. 52 as the amplitude of oscillation at 5f will be significantly smaller compared to that at 1f.

***Apply calibration** (This feature is currently not used)

Loads calibration file for each receiver

Tick off the box to apply calibration for each receiver

Additional Controls:

Keep file size below: Avoids the generation of bigger files (usually lesser than 2 Mb). Unticking the box gets rid of the restriction in terms of file size.

Raw data (This feature is currently not used): Stores raw data which are undecimated and unfiltered.

Drawing Options

Maximum 6 curves can be displayed simultaneously in the scan window for a particular scanning mode (frequency, amplitude or constant scans) and a particular receiver (1f, 3f or 5f) respectively.

For each receiver, there are 2 channels:

Channel 1 or (I)

Channel 2 or (U)

For each channel, 3 transduced signal components (essentially voltage as current is difficult to measure) can be displayed simultaneously on a scan window. Transduced signal is always in the form of a complex number. A complex number can be expressed as $Z = x + jy$ where x is the real part of the complex number, y is the imaginary part of the complex number and j is equal to $\sqrt{-1}$. The absolute value of the complex number is given by $|Z| = \sqrt{x^2 + y^2}$. The curves for display pertaining to the signal are as follows:

Absolute value curve (a): e.g. I (a) is the curve pertaining to the absolute value of the transduced complex signal in case of channel 1.

In-phase or real value curve (i): e.g. I (i) is the curve pertaining to the real value of the transduced complex signal in case of channel 1.

Quadrature or imaginary value curve (q): e.g. I (q) is the curve pertaining to the imaginary value of the transduced complex signal in case of channel 1.

Note: Hence, maximum 18 curves can be displayed simultaneously in the scan window if all the receivers are enabled (provided the respective boxes in the settings panel are ticked).

Steps for selection of gain settings for 1F drive

SensAND sensor is connected.
Boxes pertaining to the curve of the absolute value of the transduced electrical signal for the receiver Hetero DDS2 (1f) are ticked.
A particular gain is applied to 1f receiver.
A particular scan (fms, ams or cms) is taken and the value of the signal in the scan window is viewed.
The value of the transduced signal should lie between 1000 and 5000 and if it’s not the case, then the gain settings need to be modified to ensure proper analog to digital conversion.

Frequency scan mode panel

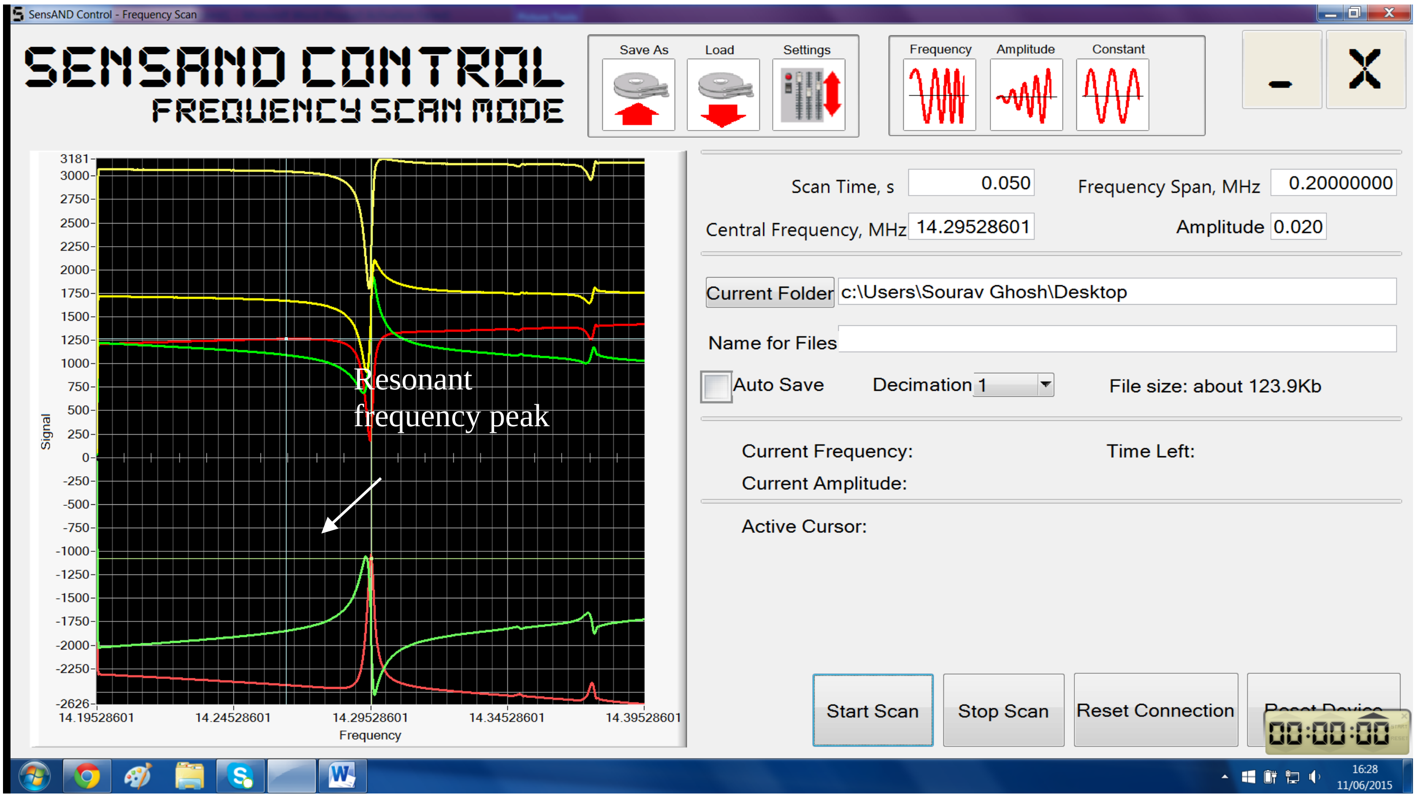


Figure 11: Snapshot of frequency scan mode

Scan time: It refers to the scan time in seconds.
Frequency Span: It refers to the width of the frequency window based on central frequency value in MHz unit.
Central Frequency: It refers to the resonant frequency of the quartz resonator or a frequency closer to resonance frequency of the quartz resonator in MHz unit.
Amplitude: It refers to the percentage of the max voltage applied to quartz crystal (e.g. 0.1 = 10%, 0.01 = 1%)
Current folder: It refers to the folder where scanned files are saved
Name for Files: It refers to the name of the scanned files.
Auto save: It should be ticked it if the user wants to save data
Decimation: It governs the size of the saved data file. Smaller decimation factor means larger file size and vice versa.

Parameters to set:

Scan time: It depends on the user.

Frequency Span: It has to be set in such a way that it covers only the peak and the shoulders of the real value curve's signal (indicated by the red curve on the frequency scan mode panel located above). Generally, it is set at 0.02 MHz.
Central Frequency: It should be set to 14.3 MHz at first and a frequency scan is taken. The peak of the real value curve (indicated by the red curve on the frequency scan mode panel located above) is noted by having a right click on the peak and the new central frequency value is selected based on that peak value.
Amplitude: It depends on the environment analyzed.

An example of raw fms scan file is shown below:

```
Frequency mode scan

Scan time        0.500064
Amplitude        0.020000
Central frequency, MHz  14.254863
Span frequency, MHz     0.020000
Decimation factor       1

DDS1 settings:
Function         1

DDS2 settings:
Function         1
Amplitude        1.000000
Gain1    51.943000
Gain2    51.943000

DDS3 settings:
Function         3
Amplitude        1.000000
Gain1    51.943000
Gain2    51.943000

DDS4 settings:
Function         0
Amplitude        1.000000
Gain1    51.943000
Gain2    51.943000
```

Channel#1-I-i	Channel#1-I-q	Channel#2-U-i	Channel#2-U-q	Channel#3-I-i	Channel#3-I-q	Channel#4-U-i	Channel#4-U-q
0.125000	-0.148438	-0.195312	-0.062500	-0.070312	-0.546875	-0.093750	-0.117188
42.140625	23.429688	-87.109375	-35.640625	-0.531250	-0.148438	-0.062500	-0.203125
542.226562	440.617188	-1112.226562	-717.664062	-0.179688	0.312500	-0.007812	0.046875
1018.781250	937.531250	-2117.570312	-1567.000000	0.359375	0.015625	-0.171875	0.125000
1087.054688	955.398438	-2250.765625	-1636.476562	-0.031250	-0.164062	-0.031250	-0.054688
1102.281250	969.914062	-2260.187500	-1659.515625	-0.734375	0.117188	-0.070312	0.132812
1094.664062	973.015625	-2250.187500	-1659.234375	0.023438	0.398438	-0.062500	0.046875
1094.843750	969.734375	-2252.054688	-1655.640625	0.382812	-0.648438	-0.210938	-0.140625
1095.804688	970.500000	-2253.085938	-1657.367188	-0.031250	-0.843750	0.164062	0.046875
1095.585938	970.937500	-2252.906250	-1657.617188	-0.054688	-0.117188	0.187500	0.070312
1095.382812	970.187500	-2253.148438	-1656.570312	0.593750	0.054688	-0.046875	-0.031250

Amplitude scan mode panel

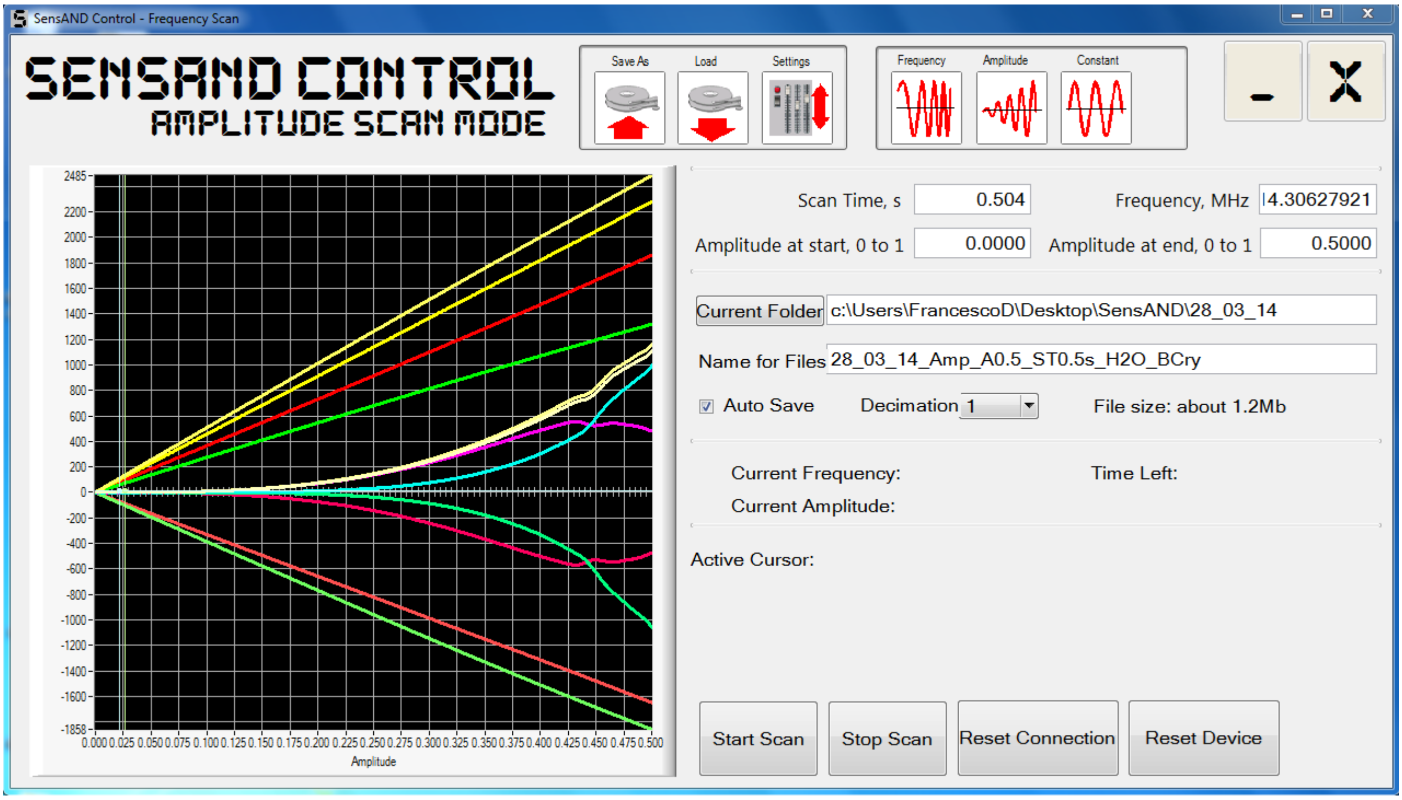


Figure 12: Snapshot of amplitude scan mode

Scan time: It refers to the scan time in seconds.
Frequency: It refers to the central frequency value in MHz unit obtained from frequency scans
Amplitude at start: It refers to the starting value (in percentage of the max voltage applied to crystal) of the amplitude ramp
Amplitude at end: It refers to the finishing value (in percentage of the max voltage applied to crystal) of the amplitude ramp
Current folder: It refers to the folder where scanned files are saved
Name for Files: It refers to the name of the scanned files
Auto save: It should be ticked it if the user wants to save data
Decimation: It governs the size of the saved data file. Smaller decimation factor means larger file size and vice versa.

Parameters to set

Scan time: It depends on the user
Amplitude range: It depends on the user. But, in general, a maximum value of 0.5 is preferred.

A raw ams scan file looks like as follows:

```
Amplitude mode scan

Scan time        0.100161
Frequency, MHz   14.254820
Amplitude from   0.000000        to      0.500000
Decimation factor        8

DDS1 settings:
Function         1

DDS2 settings:
Function         1
Amplitude        1.000000
Gain1    3.009000
Gain2    3.009000

DDS3 settings:
Function         3
Amplitude        1.000000
Gain1    51.943000
Gain2    51.943000

DDS4 settings:
Function         0
Amplitude        1.000000
Gain1    1.003000
Gain2    1.003000
```

Channel#1-I-i	Channel#1-I-q	Channel#2-U-i	Channel#2-U-q	Channel#3-I-i	Channel#3-I-q	Channel#4-U-i	Channel#4-U-q
-0.006012	-0.105794	-0.154762	-0.086312	0.045649	-0.167765	0.180440	-0.391404
0.012235	-0.072845	-0.154543	-0.104391	0.058083	-0.147991	0.142660	-0.345026
0.234179	0.234714	-0.600233	-0.541011	0.080540	-0.097022	0.090138	-0.268413
1.012944	1.366353	-2.336581	-2.207892	0.067832	-0.048844	0.044629	-0.185816
2.499512	3.568193	-5.687861	-5.445573	0.037292	-0.014885	0.024897	-0.123870
4.604455	6.724455	-10.430190	-10.070078	0.007830	0.007356	0.028347	-0.078365
7.128934	10.554245	-16.151726	-15.689955	0.007313	0.000081	0.031665	-0.059456
9.898908	14.782599	-22.462226	-21.914018	0.015813	0.003036	0.032349	-0.047303
12.817128	19.219354	-29.090165	-28.471295	0.008657	-0.024318	0.032805	-0.034801
15.809093	23.759060	-35.878580	-35.180383	0.013357	-0.039736	0.019771	-0.015166
18.825808	28.350802	-42.745218	-41.973001	-0.006977	-0.021164	0.005774	-0.009677
21.843144	32.976129	-49.634371	-48.794058	-0.059638	0.023793	-0.002664	-0.018130
24.874852	37.610045	-56.526880	-55.618414	-0.128550	0.072212	-0.006761	-0.013508
27.920157	42.263110	-63.443477	-62.462117	-0.174011	0.097399	0.000920	0.001640

Constant scan mode panel

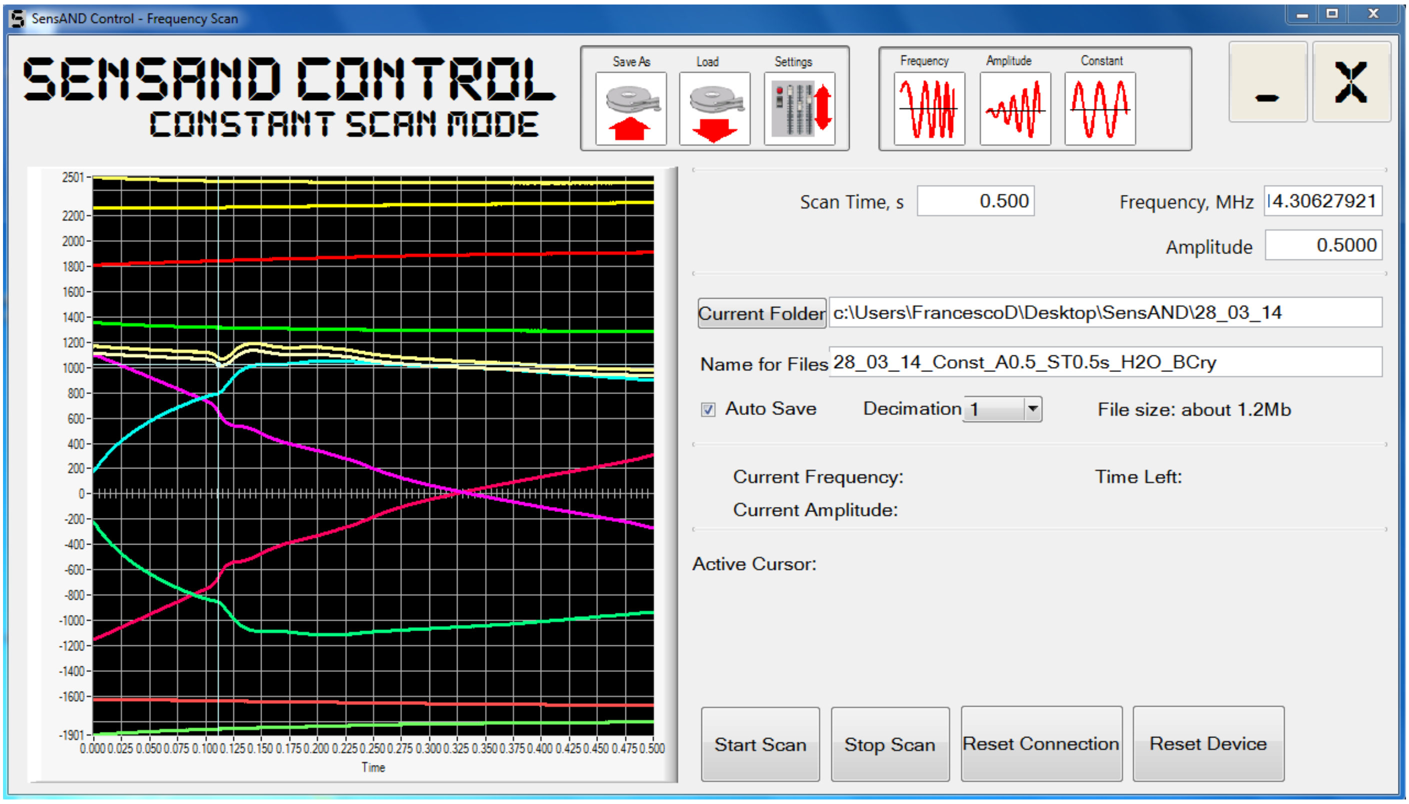


Figure 13: Snapshot of cms scan mode

Scan time: It refers to the scan time in seconds.
Frequency: It refers to the central frequency value in MHz unit obtained from frequency scans or any other frequency at which the user wants to drive the quartz sensor.
Amplitude: It refers to the value of the applied constant amplitude.
Current folder: It refers to the folder where scanned files are saved
Name for Files: It refers to the name of the scanned files
Auto save: It should be ticked it if the user wants to save data
Decimation: It governs the size of the saved data file. Smaller decimation factor means larger file size and vice versa.

Parameters to set
Scan time: It depends on the user
Amplitude: It depends on the environment analyzed

A raw cms scan file looks like as follows:

```
Constant mode scan

Scan time        5.000004
Frequency, MHz  14.254863
Amplitude        0.020000
Decimation factor       8

DDS1 settings:
Function         1

DDS2 settings:
Function         1
Amplitude        1.000000
Gain1    51.943000
Gain2    51.943000

DDS3 settings:
Function         3
Amplitude        1.000000
Gain1    51.943000
Gain2    51.943000

DDS4 settings:
Function         0
Amplitude        1.000000
Gain1    1.003000
Gain2    1.003000
```

Channel#1-I-i	Channel#1-I-q	Channel#2-U-i	Channel#2-U-q	Channel#3-I-i	Channel#3-I-q	Channel#4-U-i	Channel#4-U-q
14.190534	16.888423	-29.555362	-24.998869	-0.060690	-0.069936	-0.080090	0.023478
123.796251	167.879374	-269.358079	-249.956652	-0.083497	-0.054530	-0.063386	0.015459
307.716622	441.848728	-679.662380	-652.926432	-0.090132	-0.029777	-0.035837	-0.001077
486.500870	718.988054	-1082.749320	-1057.939773	-0.027076	-0.010356	-0.010907	-0.007380
619.552250	930.119237	-1384.579997	-1365.306067	0.053337	-0.006078	-0.010034	-0.000090
704.099511	1066.346635	-1577.116678	-1563.095493	0.102312	-0.005141	-0.010869	0.004574
752.468332	1145.159074	-1687.617413	-1677.317638	0.095686	-0.005041	-0.007814	0.013212
778.138464	1187.378740	-1746.435594	-1738.404740	0.070529	-0.017805	-0.004967	0.002498
791.024785	1208.705359	-1776.073939	-1769.208510	0.063059	-0.055394	0.000090	-0.024254
797.236487	1219.000473	-1790.422271	-1784.066805	0.064315	-0.068986	-0.002132	-0.056612
800.140199	1223.809350	-1797.130590	-1791.000490	0.083546	-0.069732	-0.014019	-0.079381

6. SensAND Calibration Manual

Create a directory to store the SensAND scan files by clicking on the current folder button available on each kind of scan window. Generally, for creating calibration files, we should take fms scans only for each kind of measurement.

- **Voltage circuit measurement**

Procedure to obtain RMS voltage value from oscilloscope is depicted below:

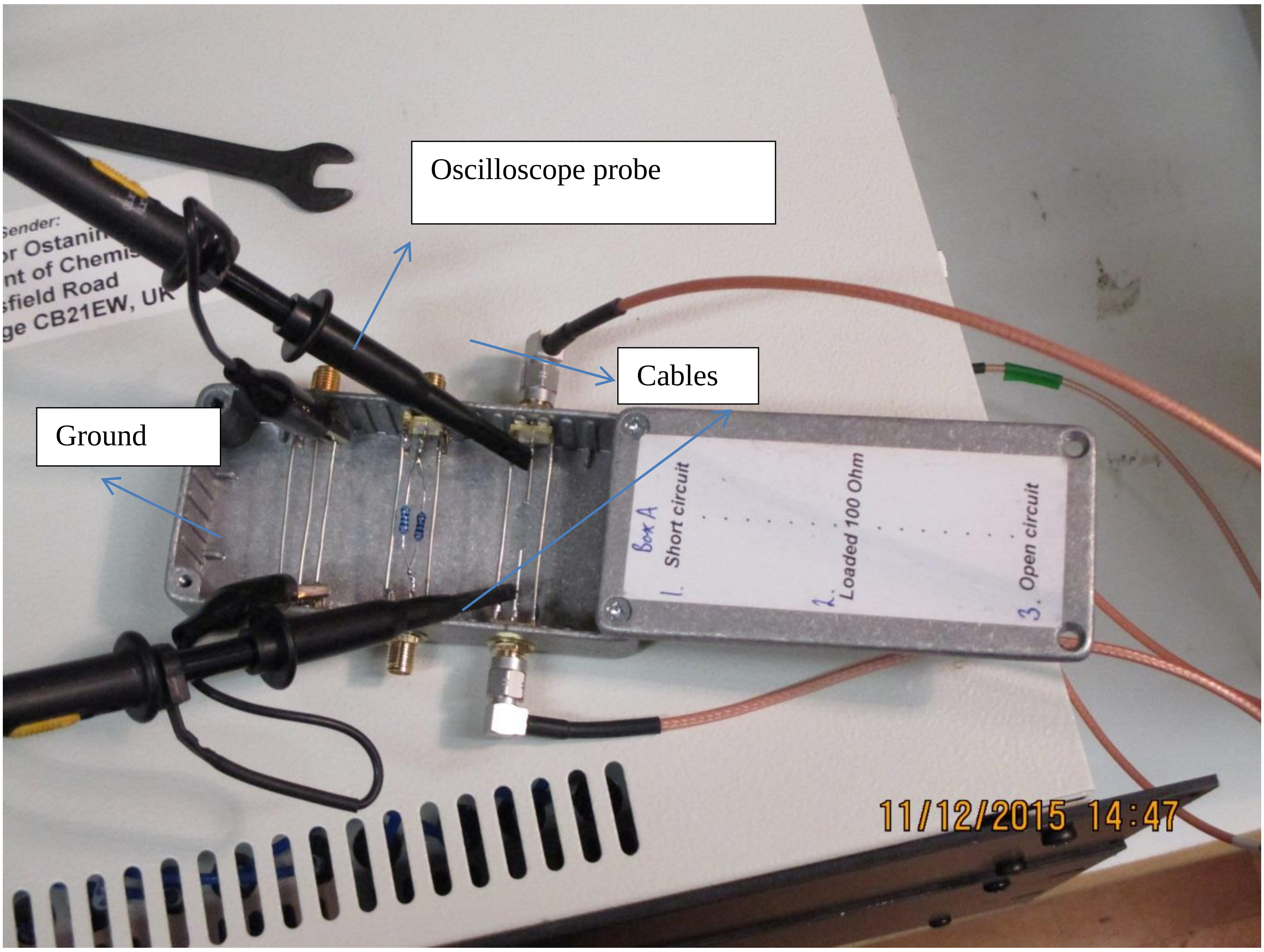


Figure 14: Snapshot of oscilloscope connections with calibration box required for voltage circuit measurement

Connect your oscilloscope probes and SensAND cables to the calibration box as shown in the Fig: 8 for obtaining the RMS voltage reading. The SensAND cables should be connected to open circuit while taking the measurements for voltage circuit.

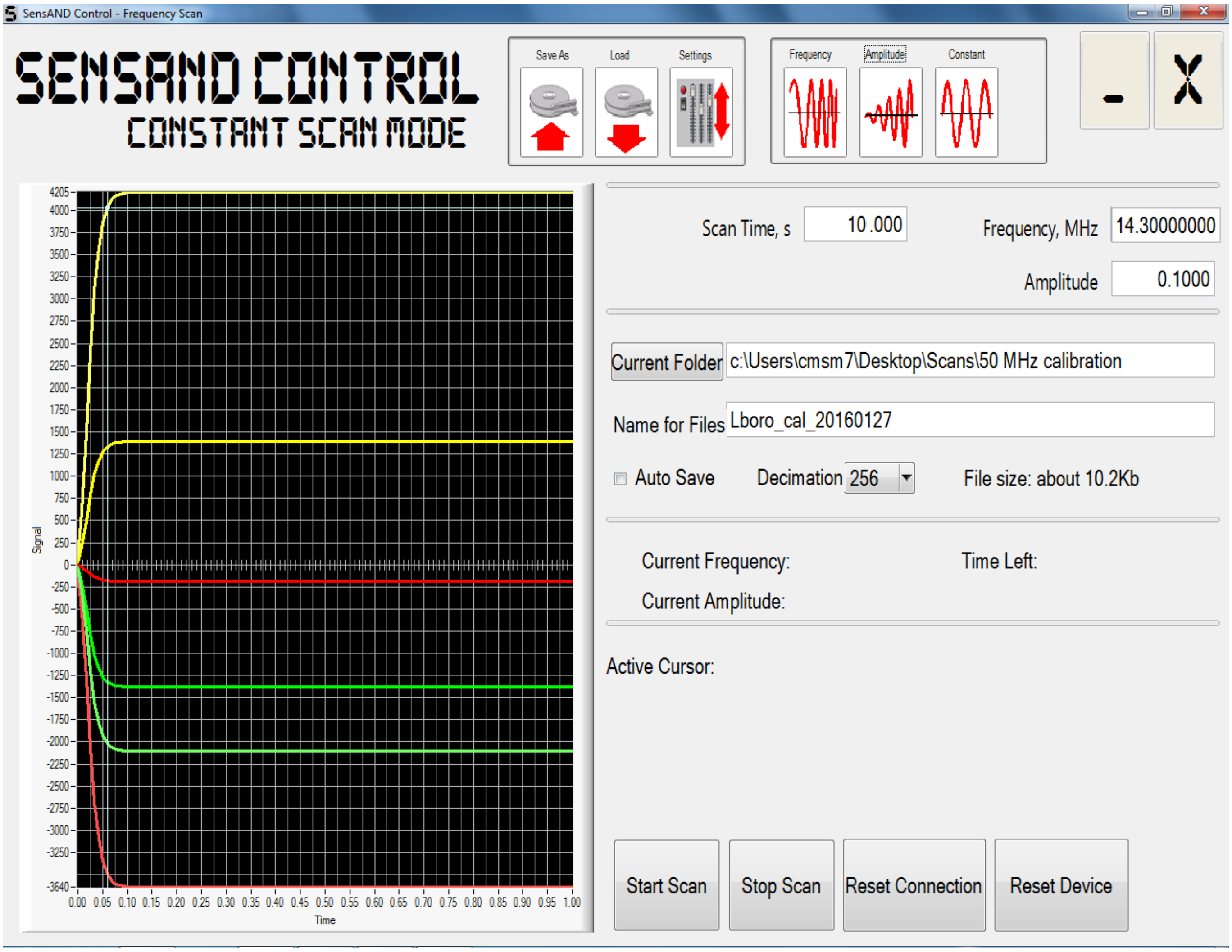


Figure 15: Snapshot of cms scan settings for production of voltage signals on oscilloscope window

Take a cms scan as shown in Fig 14 and then run the oscilloscope for obtaining the rms value of the (A-B) voltage as shown in Fig 16 (below) where A and B are the two ports of oscilloscope. Please note the maximum value of the absolute curves should be between 1000 and 5000 for the cms scan.

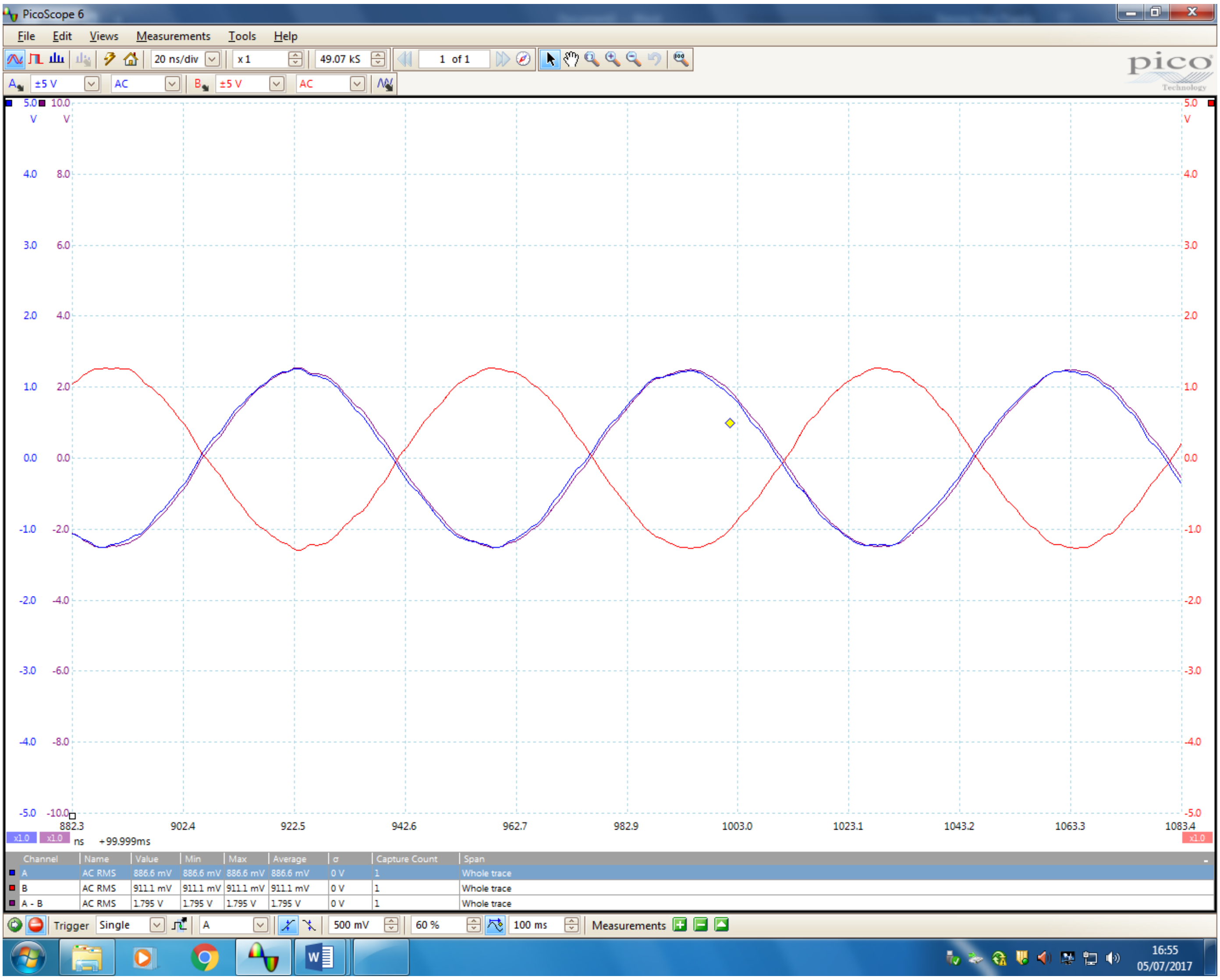


Fig 16: Snapshot of oscilloscope settings for obtaining rms value of the voltage

After obtaining the rms voltage value from the oscilloscope window (1.795 V as shown in Fig 16), take two fms scans with decimation 4 on SensAND (one scan after another). Wait for few seconds between the consecutive scans. The value of rms voltage will differ from instrument to instrument. A typical fms scan with oscilloscope attached to the open circuit looks like as follows:

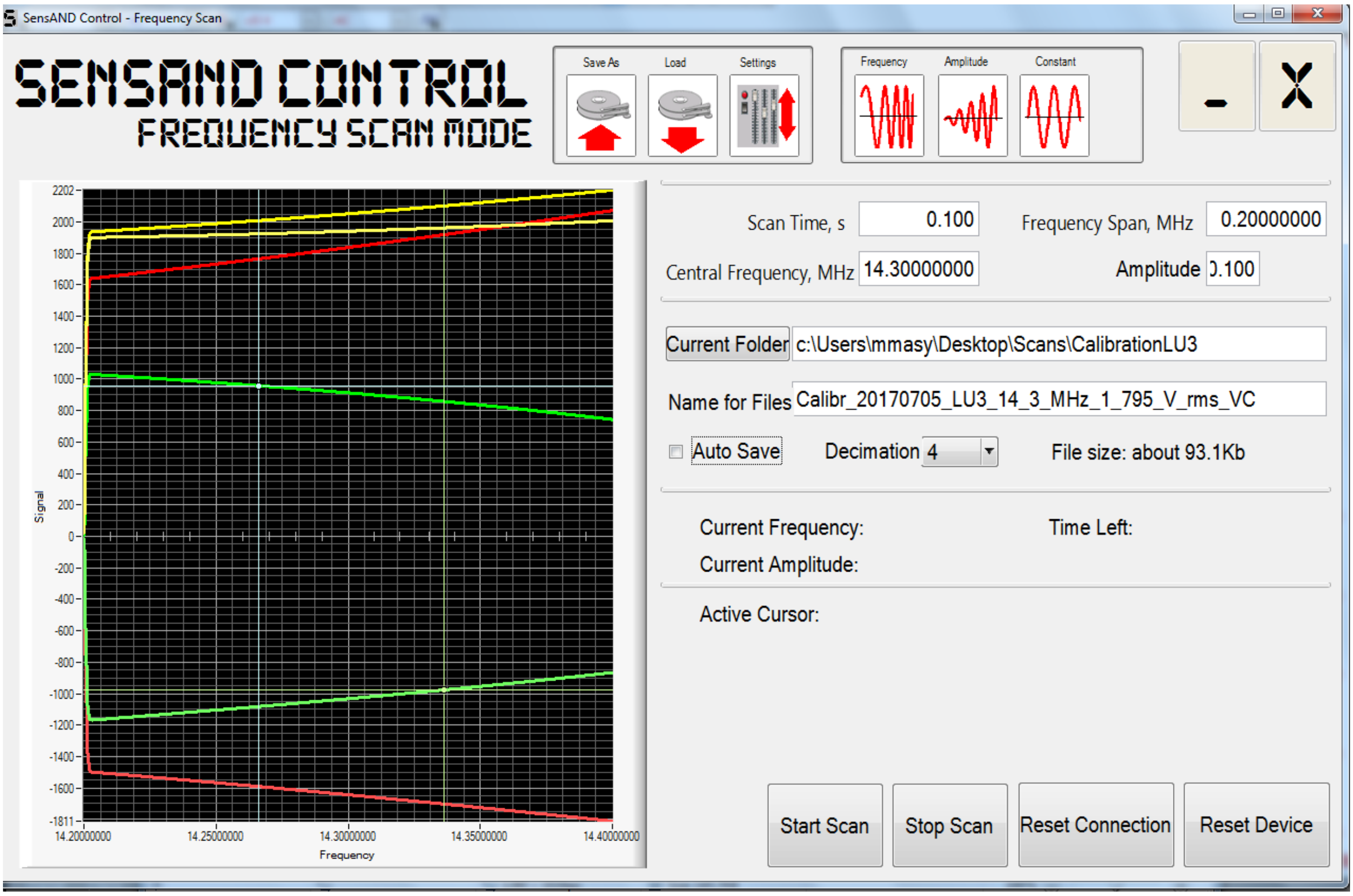


Fig 17: Snapshot of 1f absolute value curves in yellow for a fms scan after RMS voltage measurement. (Note: the signal value lies between 1000 and 5000)

- **Open circuit measurement**

Refer to Fig 14 and disconnect the oscilloscope probes and grounds and take two fms scans decimation 4 on SensAND (one scan after another). Wait for few seconds between the consecutive scans. A typical fms scan for open circuit looks like as follows:

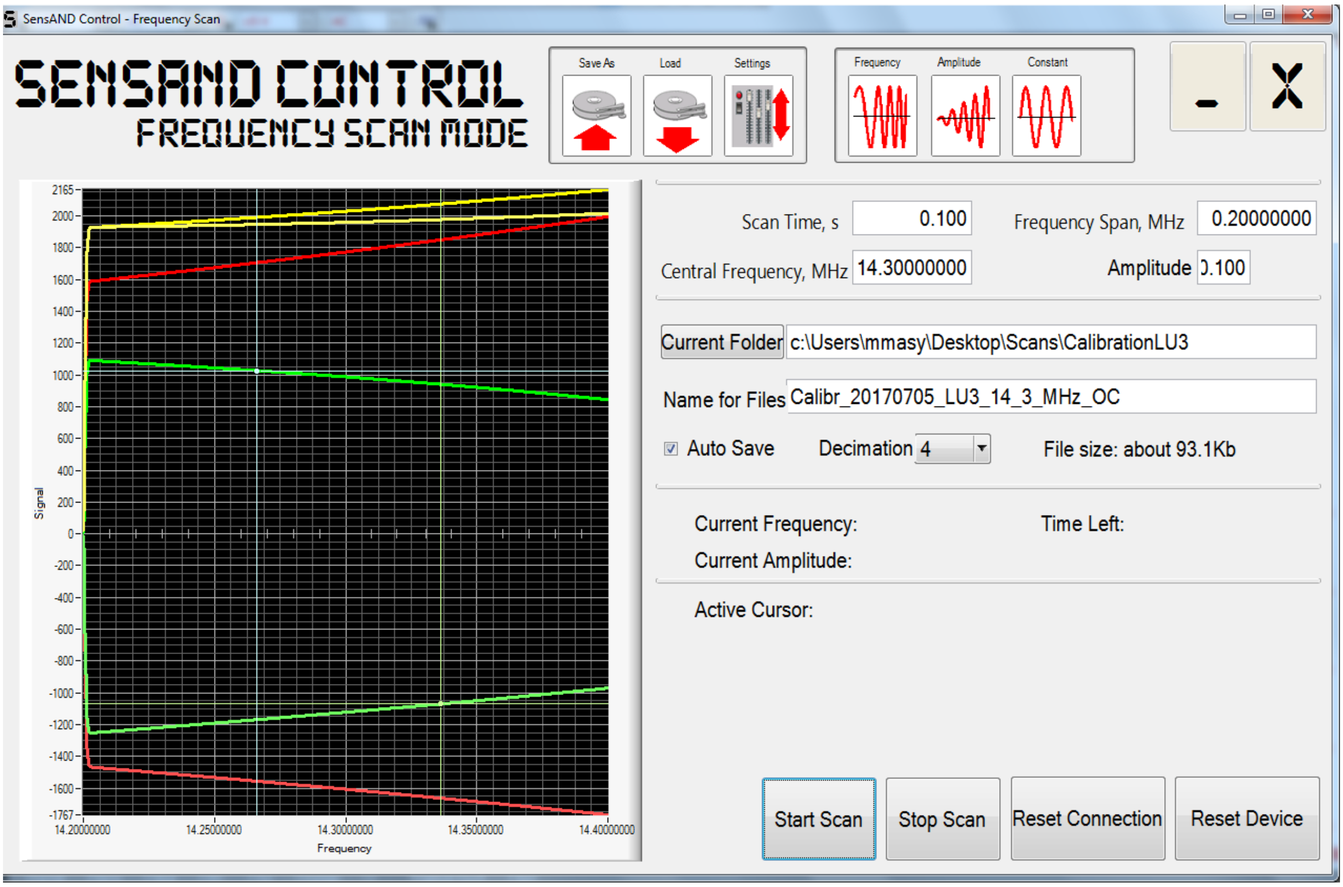


Fig 18: Snapshot of 1f absolute value curves in a fms scan during open circuit measurement. (Note: the signal value lies between 1000 and 5000

Short circuit measurement

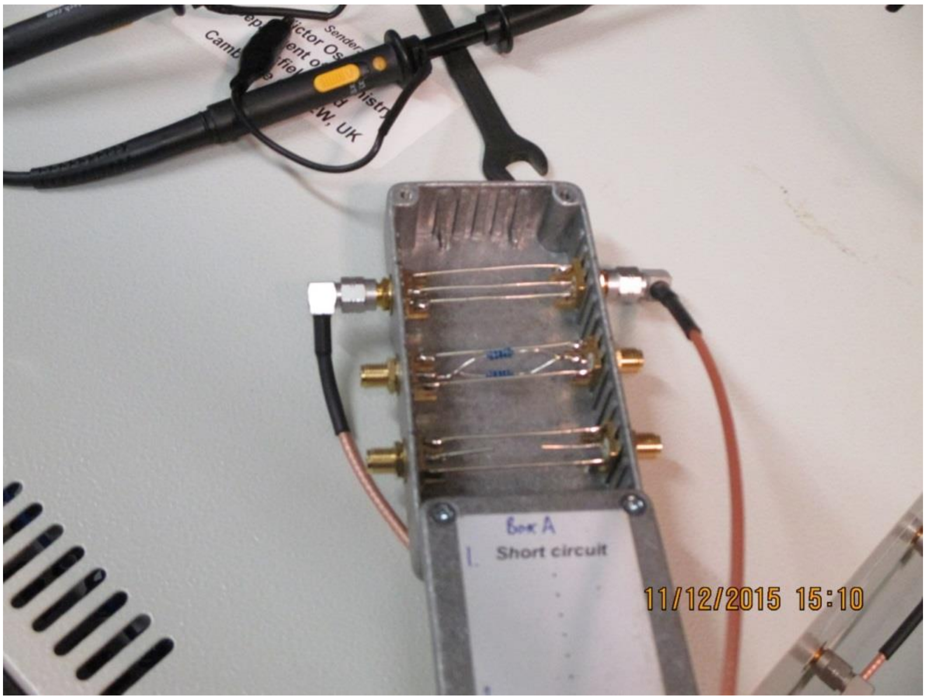


Fig 19: Snapshot for Short circuit connection with ADT

Connect the SensAND cables with the calibration box as shown in Fig 19 and then take fms scans.

Take two fms scans with decimation 4 on SensAND (one scan after another). Wait for few seconds between the consecutive scans. Click on Auto Save button for saving the files. A typical fms scan for short circuit looks like as follows:

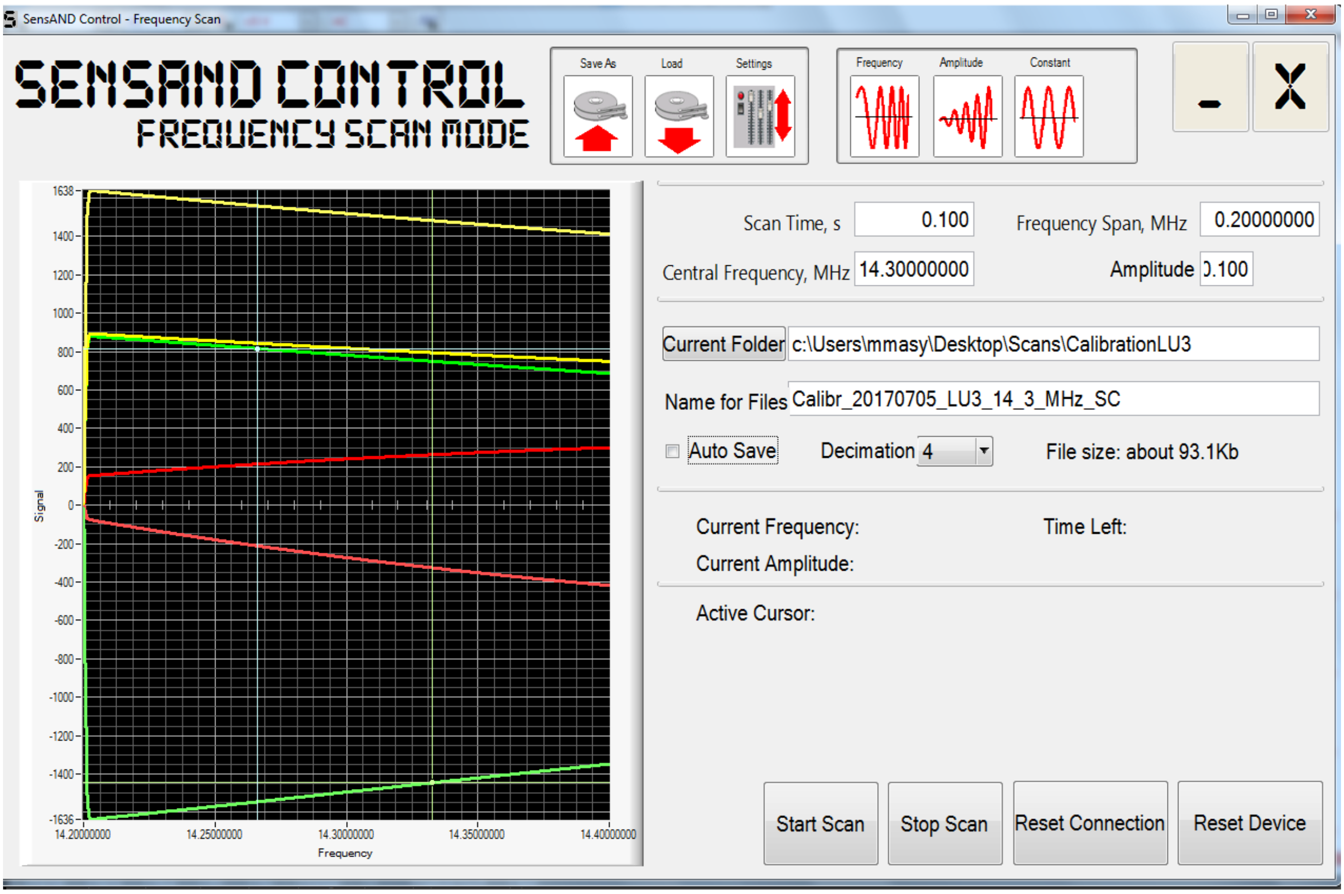


Fig 20: Snapshot of 1f absolute value curves in a fms scan during short circuit measurement. (Note: the signal value lies between 1000 and 5000)

Loaded circuit measurement

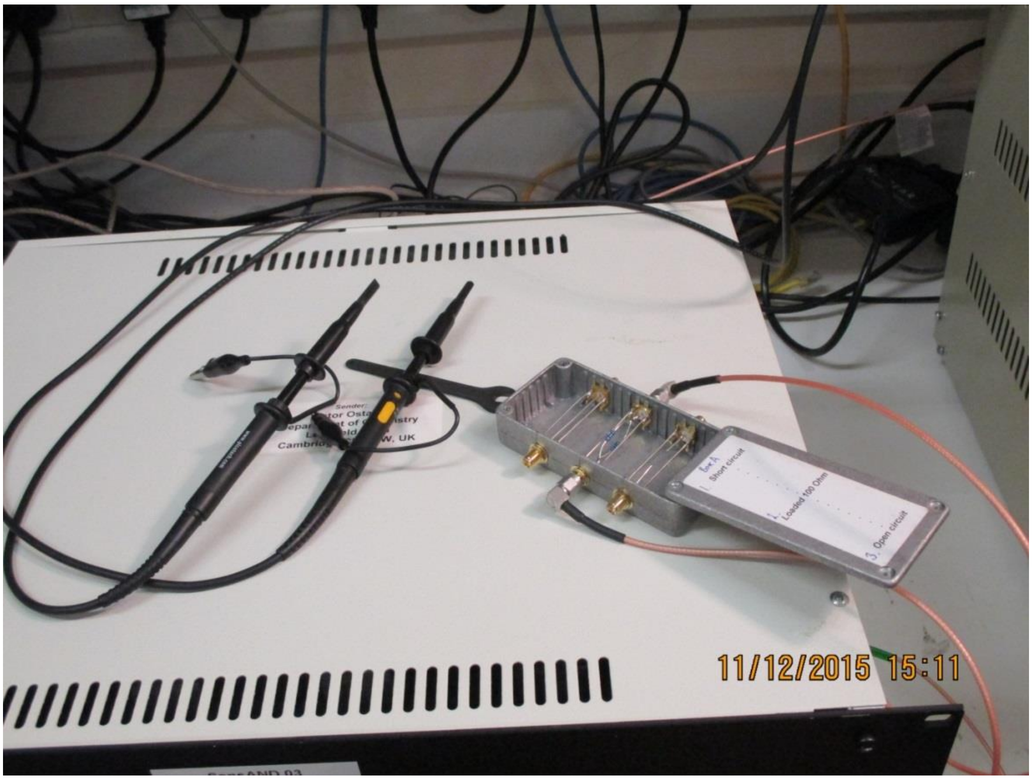


Fig 21: Snapshot for Loaded circuit connection with SensAND instrument

Connect the SensAND cables with the calibration box as shown in Fig 15 and then take fms scans. Take two fms scans with decimation 4 on ADT (one scan after another). Wait for few seconds between the consecutive scans. A typical fms scan for loaded circuit looks like as follows:

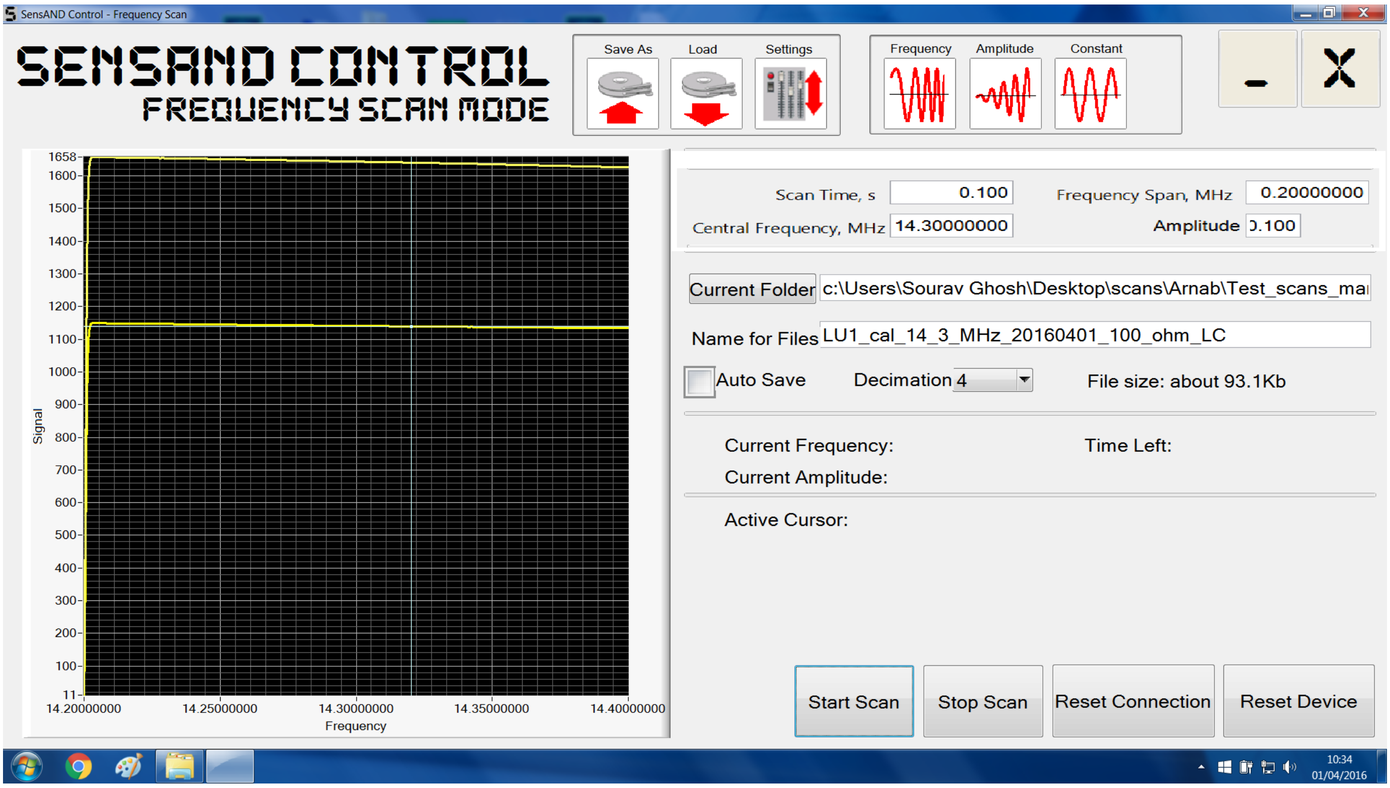


Fig 22: Snapshot of 1f absolute value curves in a fms scan during loaded circuit measurement. (Note: the signal value lies between 1000 and 5000)

Explanation of Mathematica code for obtaining abcd.dat files

The following segment narrates the steps to obtain an abcd.dat file using Mathematica.

Open a calibration Mathematica file (Calibr_Data_1F_14_3MHz_with_0.25MHz_span.nb) and put the value of rms voltage obtained from oscilloscope measurements as shown below:

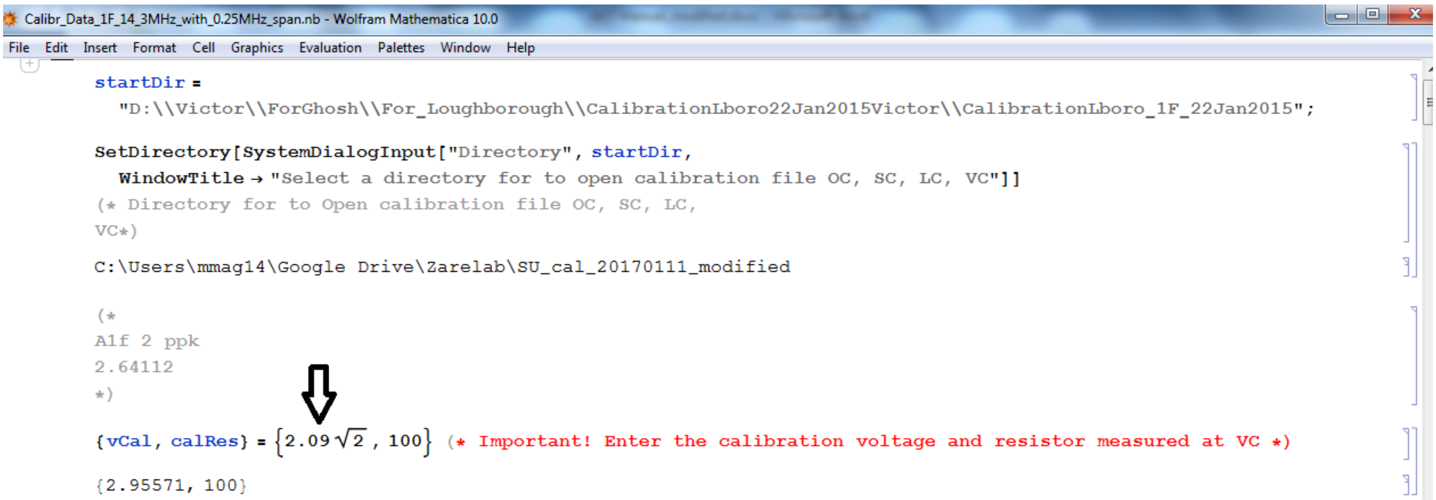


Fig 23: Snapshot of Mathematica window for inserting the rms value.

The commands of the Mathematica script have been explained below in details.

startDir = "B:\\LboroCalibration"; : The following command allows the user to choose the starting directory where all the necessary files related to calibration are stored.

SetDirectory[SystemDialogInput["Directory",startDir, WindowTitle -> "Select a directory for to open calibration file OC, SC, LC, VC"]]

The abovementioned command allows the user to select a directory from his workspace for opening the calibration files. OC, SC, LC and VC represent the frequency scan files related to open circuit, short circuit, loaded circuit and diode measurements (voltage circuit) using ADT machine.

Output:

```
B:\LboroCalibration\1FCalibrationVictor13Jan2015_200kHz
```

{vCal, calRes} = {(2.09$\sqrt{2}$, 100.0} : The following command allows the user to enter the value of measured rms voltage obtained from oscilloscope and the resistance of the loaded circuit.

Output: {2.96, 100}

FilesinDir = FileNames["Lboro13Jan2015Victor*.fms", IgnoreCase -> True] : The following command lists all the calibration files with 'fms' extension from the required directory starting with the phrase 'Lboro13Jan2015Victor'.

Output:

```
{Lboro13Jan2015Victor_200kHz_100ohm_LC_0000.fms,
 Lboro13Jan2015Victor_200kHz_100ohm_LC_0001.fms,
 Lboro13Jan2015Victor_200kHz_180ohm_100pF_test_0000.fms,
 Lboro13Jan2015Victor_200kHz_180ohm_100pF_test_0001.fms,
 Lboro13Jan2015Victor200kHz_5_43volt_VC_0000.fms,
 Lboro13Jan2015Victor200kHz_5_43volt_VC_0001.fms,
 Lboro13Jan2015Victor200kHz_OC_0000.fms,
 Lboro13Jan2015Victor200kHz_OC_0001.fms,
 Lboro13Jan2015Victor_200kHz_SC_0000.fms,
 Lboro13Jan2015Victor_200kHz_SC_0001.fms}
```

DirFile = MatrixForm[Transpose[{Table[i, {i, 1, Length[FilesinDir]}], FilesinDir}], TableAlignments -> Left] : The following command lists the calibration files in a tabular manner.

Output:

```
1   Lboro13Jan2015Victor_200kHz_100ohm_LC_0000.fms
2   Lboro13Jan2015Victor_200kHz_100ohm_LC_0001.fms
3   Lboro13Jan2015Victor_200kHz_180ohm_100pF_test_0000.fms
4   Lboro13Jan2015Victor_200kHz_180ohm_100pF_test_0001.fms
5   Lboro13Jan2015Victor200kHz_5_43volt_VC_0000.fms
6   Lboro13Jan2015Victor200kHz_5_43volt_VC_0001.fms
7   Lboro13Jan2015Victor200kHz_OC_0000.fms
8   Lboro13Jan2015Victor200kHz_OC_0001.fms
9   Lboro13Jan2015Victor_200kHz_SC_0000.fms
10  Lboro13Jan2015Victor_200kHz_SC_0001.fms
```

namPatt = {"OC_", "SC_", "LC_", "VC_"} : The following command is used to assign the open circuit, short circuit, loaded circuit and voltage circuit calibration files.

Output:

```
{OC_, SC_, LC_, VC_}
```

```
{OCfile, SCfile, LCfile, VCfile} = Table[FilesinDir [Last[Position[StringCases[FilesinDir, namPatt[i]],namPatt[i]]][[1]],{i,Length[namPatt]}]
```

The abovementioned command lists the name of the last file among each category namely open circuit, short circuit, loaded circuit and voltage circuit calibration files respectively.

Output:

```
{Lboro13Jan2015Victor200kHz_OC_0001.fms,
 Lboro13Jan2015Victor_200kHz_SC_0001.fms,
 Lboro13Jan2015Victor_200kHz_100ohm_LC_0001.fms,
 Lboro13Jan2015Victor200kHz_5_43volt_VC_0001.fms}
```

```
fCalibr[a_, b_, c_, d_, M1_, M2_] = {{a, b}, {c, d}}.{M1, M2}
```

The abovementioned command defines the calibration equation.

Output:

```
{a M1 + b M2, c M1 + d M2}
```

```
fCalibrMx[calMatr_, M1_, M2_] := calMatr.{M1, M2}
```

The abovementioned command establishes relationship between calibration matrix and the arbitrary voltages obtained under different conditions.

```
{TrueCurrent[a_, b_, c_, d_, M1_, M2_], TrueVoltage[a_, b_, c_, d_, M1_, M2_]} =
 fCalibr[a, b, c, d, M1, M2]
```

The above command defines the calibration equation for true current and true voltage respectively.

Output:

```
{a M1 + b M2, c M1 + d M2}
```

```
Fabcd[M1oc_, M2oc_, M1sc_, M2sc_, M1Lc_, M2Lc_, M1vc_, M2vc_, RL_, vVcalib_] =
  {{(M2oc (M1sc M2Lc - M1Lc M2sc) vVcalib) /
      ((M1oc M2Lc - M1Lc M2oc) (M1vc M2sc - M1sc M2vc) RL),
    - (M1oc (M1sc M2Lc - M1Lc M2sc) vVcalib) /
       ((M1oc M2Lc - M1Lc M2oc) (M1vc M2sc - M1sc M2vc) RL)},
   {M2sc vCal / (M1vc M2sc - M1sc M2vc), M1sc vCal / (-M1vc M2sc + M1sc M2vc)}};
```

The above command line assigns the mathematical expressions for a, b, c and d respectively.

extradrop = 40;

The above command assigns the maximum number of rows to be dropped off from the beginning of any frequency scan file.

headSize = 31;

The above command assigns the header size of any frequency scan file.

```
header = Take[Import[VCfile, "TSV"], headSize - 2];
```

The above command reduces the headSize of VC file to 29.

Dimensions [Header]

The above command will display the current headSize.

Output: {29}

```
hdList = MatrixForm[{Range[Length[header]], header}ᵀ]
```

The above command will display the list of headers of VC file in matrix format.

Output:

```
1   {Frequency mode scan}
2   {}
3   {Scan time, 0.100012}
4   {Amplitude, 0.1}
5   {Central frequency, MHz, 14.3}
6   {Span frequency, MHz, 0.2}
7   {Decimation factor, 2}
8   {}
9   {DDS1 settings:}
10  {Function, 1}
11  {}
12  {DDS2 settings:}
13  {Function, 1}
14  {Amplitude, 1.}
15  {Gain1, 5.015}
16  {Gain2, 5.015}
17  {}
18  {DDS3 settings:}
19  {Function, 0}
20  {Amplitude, 1.}
21  {Gain1, 51.943}
22  {Gain2, 51.943}
23  {}
24  {DDS4 settings:}
25  {Function, 0}
26  {Amplitude, 1.}
27  {Gain1, 51.943}
28  {Gain2, 51.943}
29  {}
```

```
headerOC = Take[Import[OCfile, "TSV"], headSize];

CdOCd = Drop[Import[OCfile, "TSV"], headSize];

headerSC = Take[Import[SCfile, "TSV"], headSize];

CdSCd = Drop[Import[SCfile, "TSV"], headSize];

headerLC = Take[Import[LCfile, "TSV"], headSize];

CdLCd = Drop[Import[LCfile, "TSV"], headSize];

headerVC = Take[Import[VCfile, "TSV"], headSize];

CdVCd = Drop[Import[VCfile, "TSV"], headSize]; (*Data*)
```

The above command lines allow the user to import and drop off the headSize from all category of fms files, i.e., OC, SC, LC and VC.

```
gains1F = {headerOC[[15, 2]], headerSC[[15, 2]], headerLC[[15, 2]], headerVC[[15, 2]]}
```

The above command will read and display1F gain among the header portion of each file.

Output:

```
{5.015, 5.015, 5.015, 5.015}
```

```
gains3F = {headerOC[[21, 2]], headerSC[[21, 2]], headerLC[[21, 2]], headerVC[[21, 2]]}
```

The above command will read and display 3F gain among the header portion of each file.

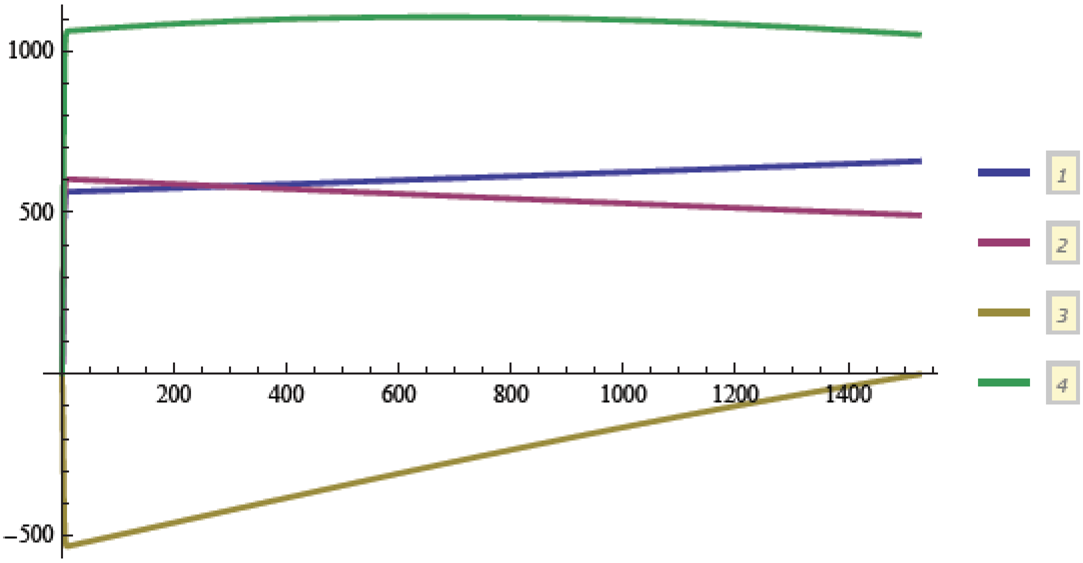
Output:

```
{51.943, 51.943, 51.943, 51.943}
```

```
ListLinePlot[{CdOCdᵀ[[1]], CdOCdᵀ[[2]], CdSCdᵀ[[1]], CdSCdᵀ[[2]]},
  PlotStyle → Thick, PlotLegends → Automatic]
```

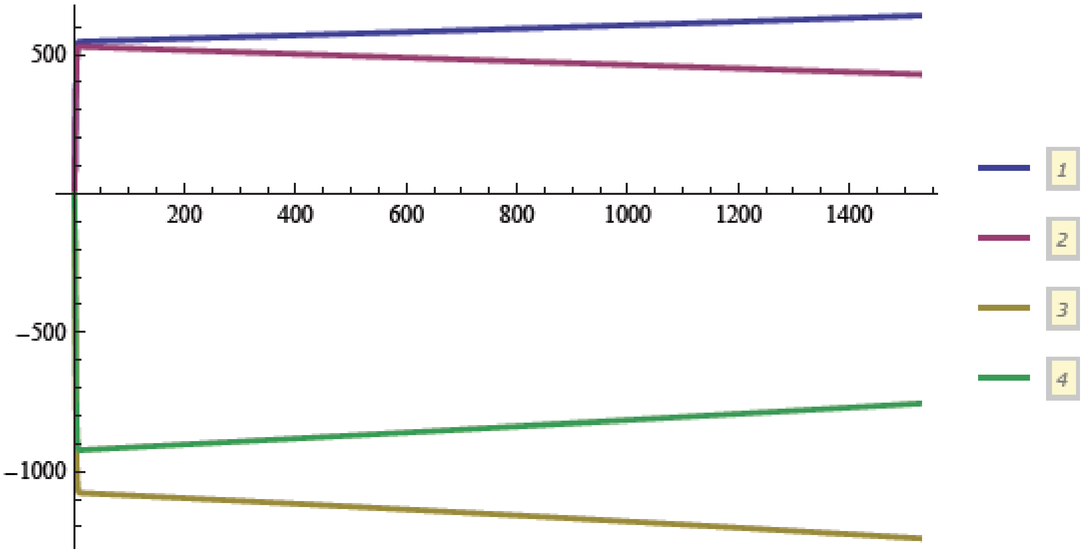
The above command transposes the column matrix to a row matrix for a particular file and plots it with the number of observations**.** For example, **CdOCd^T[[1]]** represents the transposed form of the first column of data for a fms scan file of an open circuit measurement.

Output:




```
ListLinePlot[{CdVCdᵀ[[1]], CdVCdᵀ[[2]], CdVCdᵀ[[3]], CdVCdᵀ[[4]]},
 PlotStyle → Thick, PlotLegends → Automatic]
```

Similarly, the above command will give the output displayed below:




```
datLength = Dimensions[CdOCd][[1]]
```

The above command will display the number of data points pertaining to 1st column of an open circuit fms file.

Output: **1526**

```
{headerOC[[3]], headerSC[[3]], headerLC[[3]], headerVC[[3]]}
```

The above command will display the third row of the headSize for each category of file.

Output:

```
{{Scan time, 0.100012}, {Scan time, 0.100012},
 {Scan time, 0.100012}, {Scan time, 0.100012}}
```

```
{Dimensions[CdOCd][[1]], Dimensions[CdSCd][[1]],
 Dimensions[CdLCd][[1]], Dimensions[CdVCd][[1]]}
```

The above command allows the user to verify the number of data points pertaining to each file.

Output: **{1526, 1526, 1526, 1526}**

```
sizeOK = (Dimensions[CdSCd][[1]] == datLength) &&
   (Dimensions[CdLCd][[1]] == datLength) && (Dimensions[CdVCd][[1]] == datLength)
```

The above command verifies that whether the dimensions of a particular column in each fms file (SC, LC, VC etc) is same or not.

Output: **True**

```
inDex = Range[Length[CdOCd]];
```

```
inDHead = Range[Length[headerOC]];
```

The above command allows the user to perform the indexing of the number of rows for the data and header related files for an open circuit measurement.

Length[headerOC] : The following command will display the length of the header file for an open circuit measurement file.

Output: **31**

datLength : The following command will display the length of the data points for each files.

Output: **1526**

$$\text{midIndx} = \text{Round}\left[\frac{\text{datLength} + 0.5}{2}\right]$$

The above command finds the index number for the central data.

Output: **763**

$$\{\text{TimSc}, \text{CentF}, \text{SpanF}, \text{Decim}, \text{GainAll}, \text{AmplSc}\} = \{\text{headerOC}[[3, 2]], \text{headerOC}[[5, 2]]\ 10^6, \text{headerOC}[[6, 2]]\ 10^6, \text{headerOC}[[7, 2]], \text{headerOC}[[15, 2]], \text{headerOC}[[4, 2]]\};$$

The above command will provide information about scan time, central frequency, frequency span, decimation factor, 1F gain and amplitude from the header portion of the open circuit file.

Output:

```
({TimSc, CentF, SpanF, Decim, GainAll, AmplSc})
```

$\{0.100012, 1.43\times 10^7, 200000., 2, 5.015, 0.1\}$

```
parF[head1F_] := {head1F[[3, 2]], head1F[[5, 2]] 10^6,
    head1F[[6, 2]] 10^6, head1F[[7, 2]], head1F[[15, 2]], head1F[[4, 2]]};
```

The above command assigns a vector for scan time, central frequency, frequency span, decimation factor, 1F gain and amplitude from the header portion each file.

```
paraM =
  MatrixForm[{parF[headerOC], parF[headerSC], parF[headerLC], parF[headerVC]}]
```

The above command displays scan time, central frequency, frequency span, decimation factor, 1F gain and amplitude in a matrix format for each type of file.

Output:

$$\begin{pmatrix} 0.100012 & 1.43\times 10^7 & 200000. & 2 & 5.015 & 0.1 \\ 0.100012 & 1.43\times 10^7 & 200000. & 2 & 5.015 & 0.1 \\ 0.100012 & 1.43\times 10^7 & 200000. & 2 & 5.015 & 0.1 \\ 0.100012 & 1.43\times 10^7 & 200000. & 2 & 5.015 & 0.1 \end{pmatrix}$$

$$\text{nPointsEstim} = \text{Floor}\left[\frac{1.0\times 10^9}{1024\times 32\ \text{Decim}}\ \text{TimSc}\right]$$

The above command estimates the length of data points based on decimation factor and time scan.

Output: **1526**

```
nPointsEstim == datLength
```

The above command checks whether the estimated number of data points matches with that of the actual length of the data.

Output: **True**

```
cU1Aoc = (Transpose[CdOCd][[1]] + i Transpose[CdOCd][[2]]) / gains1F[[1]];
cU2Aoc = (Transpose[CdOCd][[3]] + i Transpose[CdOCd][[4]]) / gains1F[[1]];
cU1Asc = (Transpose[CdSCd][[1]] + i Transpose[CdSCd][[2]]) / gains1F[[2]];
cU2Asc = (Transpose[CdSCd][[3]] + i Transpose[CdSCd][[4]]) / gains1F[[2]];
cU1ALc = (Transpose[CdLCd][[1]] + i Transpose[CdLCd][[2]]) / gains1F[[3]];
cU2ALc = (Transpose[CdLCd][[3]] + i Transpose[CdLCd][[4]]) / gains1F[[3]];
cU1Avc = (Transpose[CdVCd][[1]] + i Transpose[CdVCd][[2]]) / gains1F[[4]];
cU2Avc = (Transpose[CdVCd][[3]] + i Transpose[CdVCd][[4]]) / gains1F[[4]];
```

The above command calculates the array of input voltages obtained from two channels pertaining to each type of circuit measurement. The above command also takes into account the real and imaginary components of the measured voltages for each kind of circuits.

```
cU1oc =
  (Transpose[CdOCd][[1, midIndx]] + i Transpose[CdOCd][[2, midIndx]]) / gains1F[[1]];
cU2oc = (Transpose[CdOCd][[3, midIndx]] + i Transpose[CdOCd][[4, midIndx]]) /
   gains1F[[1]];
cU1sc = (Transpose[CdSCd][[1, midIndx]] + i Transpose[CdSCd][[2, midIndx]]) /
   gains1F[[2]];
cU2sc = (Transpose[CdSCd][[3, midIndx]] + i Transpose[CdSCd][[4, midIndx]]) /
   gains1F[[2]];
cU1Lc = (Transpose[CdLCd][[1, midIndx]] + i Transpose[CdLCd][[2, midIndx]]) /
   gains1F[[3]];
cU2Lc = (Transpose[CdLCd][[3, midIndx]] + i Transpose[CdLCd][[4, midIndx]]) /
   gains1F[[3]];
cU1vc = (Transpose[CdVCd][[1, midIndx]] + i Transpose[CdVCd][[2, midIndx]]) /
   gains1F[[4]];
cU2vc = (Transpose[CdVCd][[3, midIndx]] + i Transpose[CdVCd][[4, midIndx]]) /
   gains1F[[4]];
```

The above command will provide information about the input voltages (OC, SC, LC and VC) for the central data point, i.e. for the central frequency.

```
cU1Avc[[midIndx]] - cU1vc
```

The above command allows the user to verify that whether the code for **cU1Avc** and **cU1vc** were written correctly or not.

Output:

```
0. + 0. i
```

```
{cU1oc, cU2oc, cU1sc, cU2sc, cU1sc, cU1Lc, cU2Lc, cU1vc, cU2vc}
```

The above command will display information about the input voltages (OC, SC, LC and VC) for the central data point, i.e. for the central frequency.

Output:

```
{121.528 + 108.751 i, -225.942 - 180.34 i, -49.5025 + 220.156 i,
 25.7908 - 213.047 i, -49.5025 + 220.156 i, 52.0799 + 128.89 i,
 -137.261 - 165.518 i, 117.808 + 95.3111 i, -230.262 - 167.984 i}
```

$$\{cC, dC\} = \left\{\frac{cU2sc\ vCal}{cU1vc\ cU2sc - cU1sc\ cU2vc}, \frac{cU1sc\ vCal}{-cU1vc\ cU2sc + cU1sc\ cU2vc}\right\}$$

The above command will display the value of c and d based on the central data point.

Output:

```
{-0.0128377 + 0.0127698 i, -0.0147802 + 0.0120022 i}
```

```
voltMeasCal = FullSimplify[Chop[{cC, dC}.{cU1vc, cU2vc}]]
```

The above command will allow the user to recalculate the value of voltage obtained from oscilloscope measurements based on the value of c and d based on central data point.

Output:

2.69

```
abcdM = Fabcd[cU1oc, cU2oc, cU1sc, cU2sc, cU1Lc, cU2Lc, cU1vc, cU2vc, calRes, vCal]
```

The above command will display the value of a, b, c and d based on the central data point.

Output:

```
{{-0.000289635 - 0.000358546 i, -0.000151739 - 0.000211146 i},
 {-0.0128377 + 0.0127698 i, -0.0147802 + 0.0120022 i}}
```

```
voltMeasCal = FullSimplify[Chop[abcdM.{cU1Lc, cU2Lc}]]
```

The above command will display the value of true current and true voltage for a loaded circuit.

Output:

```
{0.0170084 - 0.00190652 i, 1.70084 - 0.190652 i}
```

```
Chop[voltMeasCal[[2]] / voltMeasCal[[1]]]
```

The above command will allow the user to calculate the value of true impedance for the loaded circuit.

Output: **100**

cU1Lc : The following command will display the value of input voltage based on central data point for channel 1.

Output:

```
52.0799 + 128.89 i
```

```
singleFile = SystemDialogInput["FileSave", startDir, WindowTitle →
    "Save a single frequency point calibrating file (a,b,c,d) file"]
```

The above command will allow the user to create an abcd.dat file pertaining to a single frequency point in the working directory.

Output:

```
B:\LboroCalibration\abcd_single_1f
```

```
ValueQ[singleFile]
```

The above command verifies that whether a single file has been created or not.

Output: **True**

```
If[ValueQ[singleFile], Export[singleFile,
  {{Re[abcdM[[1, 1]]], Im[abcdM[[1, 1]]]}, {Re[abcdM[[1, 2]]], Im[abcdM[[1, 2]]]},
   {Re[abcdM[[2, 1]]], Im[abcdM[[2, 1]]]}, {Re[abcdM[[2, 2]]], Im[abcdM[[2, 2]]]}},
  "TSV"] , Print["abcd file name not given"]]
```

The above command will export the value of a, b, c and d based on central frequency point to the single file created.

Output:

```
B:\LboroCalibration\abcd_single_1f
```

```
singleFile =.
```

The code for obtaining an abcd.dat file for central frequency point finishes here.

```
abcdMA = Table[Fabcd[cU1Aoc[[i]], cU2Aoc[[i]], cU1Asc[[i]], cU2Asc[[i]], cU1ALc[[i]],
    cU2ALc[[i]], cU1Avc[[i]], cU2Avc[[i]], calRes, vCal], {i, 1, datLength}];
```

The above command will tabulate the complex values of a, b, c and d pertaining to each data point and will store that in array.

```
abcdMA[[midIndx]] == abcdM
```

The above command verifies that whether the value of a, b, c and d obtained previously for a single frequency point matches with the value of a, b, c and d obtained from the middle index of a set of data from the tabulated array.

Output: **True**

```
Dimensions[abcdMA]
```

The above command will display the dimensions of the tabulated array of a,b,c,d values.

Output: {1526, 2, 2 }

$$\texttt{frMy} = \texttt{Table}\left[\texttt{CentF} - \frac{\texttt{SpanF}}{2} + \frac{(\texttt{i} - 1)}{\texttt{datLength} - 1}\,\texttt{SpanF},\ \{\texttt{i}, 1, \texttt{datLength}\}\right];$$

The above command will produce an array of frequency based on the data length.

```
abcdMAtoF =
  Table[{frMy[[i]], Re[abcdMA[[i, 1, 1]]], Im[abcdMA[[i, 1, 1]]], Re[abcdMA[[i, 1, 2]]],
    Im[abcdMA[[i, 1, 2]]], Re[abcdMA[[i, 2, 1]]], Im[abcdMA[[i, 2, 1]]],
    Re[abcdMA[[i, 2, 2]]], Im[abcdMA[[i, 2, 2]]]}, {i, 1, datLength}];
```

The above command will tabulate the frequency and complex values of a, b, c and d pertaining to each data point in an array format.

```
Dimensions[abcdMAtoF]
```

The above command will display the dimension of the array comprising of frequency and complex values of a, b, c and d.

Output: **{ 1526, 9 }**

```
abcdMAtoF[[midIndx]]
```

The above command will display the value of frequency along with complex values of a, b, c and d of the middle index of the array **abcdMAtoF[[midIndx]].**

Output:

$$\{1.42999 \times 10^7, -0.000289635, -0.000358546, -0.000151739, -0.000211146, -0.0128377, 0.0127698, -0.0147802, 0.0120022\}$$

```
arrayFile = SystemDialogInput["FileSave", startDir,
  WindowTitle → "Save an array of frequency calibrating (a,b,c,d) file"]
```

The above command will allow the user to create an abcd.dat file pertaining to multiple frequency points in the working directory.

Output:

```
B:\LboroCalibration\abcd_array_1f
```

```
If[ValueQ[arrayFile], Export[arrayFile, abcdMAtoF, "TSV"],
 Print["abcd file name not given"]]
```

The above command will export the values of a, b, c and d based on multiple frequency points to the single file created.

Output:

```
B:\LboroCalibration\abcd_array_1f
```

```
arrayFile = .
```

The code for obtaining an abcd.dat file for multiple frequency points finishes here.

7. Verification of SensAND calibration

Take two ams scans of known electrical circuits at 14.3 MHz for calculating the percentage error between the theoretically estimated impedance and ADT calibrated impedance. Ams scans of some circuits are given below for reference.

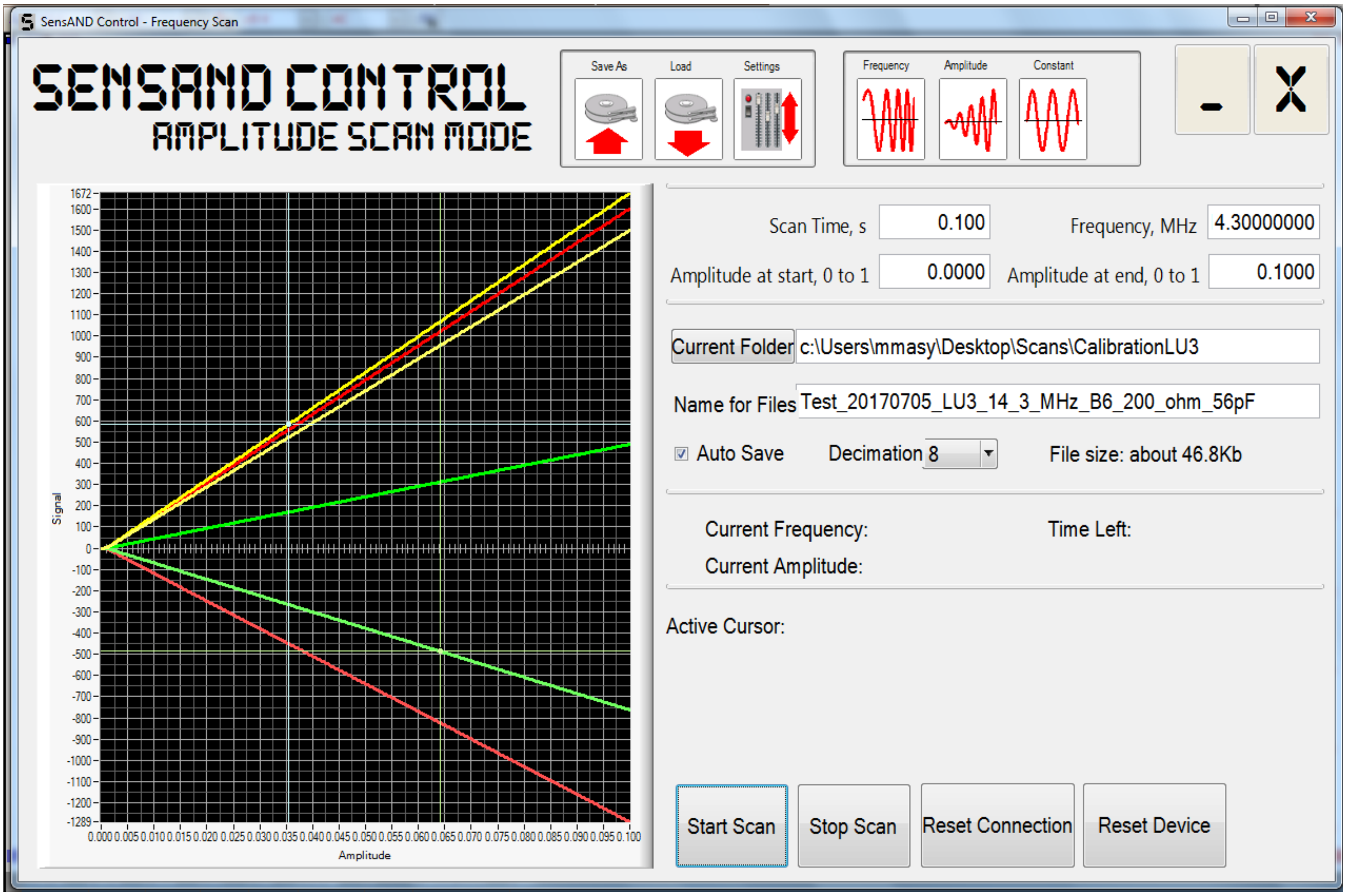


Fig 24: Snapshot of ams scan window for a 200 ohm resistor connected in series with a 56 pF capacitor.

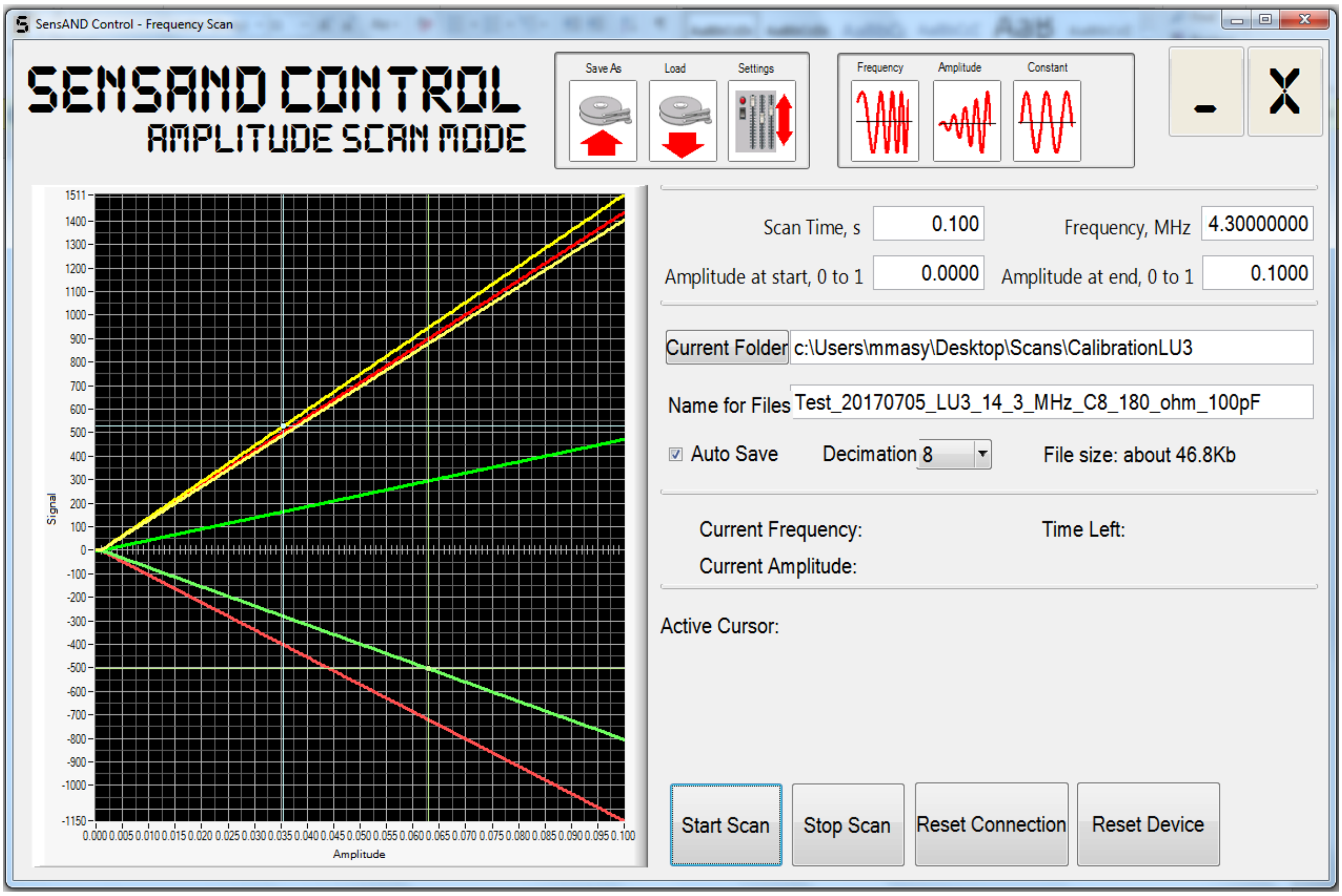


Fig 25: Snapshot of ams scan window for a 180 ohm resistor connected in series with a 100 pF capacitor.

The Mathematica script will then ask for test files as indicated below for verification of calibration once the abcd files are obtained.

```
Calibr_Data_1F_14_3MHz_with_0.25MHz_span.nb - Wolfram Mathematica 10.0
File  Edit  Insert  Format  Cell  Graphics  Evaluation  Palettes  Window  Help

(* verifying and demonstrating calibration
  ------------- Loading measured amplitude scan x
  files ---------------*)

testFilesAMS = SystemDialogInput["FileOpen", "*.ams", WindowTitle → "Open two or more test *.AMS files"]
 (*open *.AMS testing file*)

{C:\Users\mmag14\Google Drive\Zarelab\test_scans_20170117\test_SU_20170117_B6_200_ohm_56_pF_0000.ams,
 C:\Users\mmag14\Google Drive\Zarelab\test_scans_20170117\test_SU_20170117_B6_200_ohm_56_pF_0001.ams,
 C:\Users\mmag14\Google Drive\Zarelab\test_scans_20170117\test_SU_20170117_C8_180_ohm_100_pF_0000.ams,
 C:\Users\mmag14\Google Drive\Zarelab\test_scans_20170117\test_SU_20170117_C8_180_ohm_100_pF_0001.ams,
 C:\Users\mmag14\Google Drive\Zarelab\test_scans_20170117\test_SU_20170117_C9_100_pF_0000.ams,
 C:\Users\mmag14\Google Drive\Zarelab\test_scans_20170117\test_SU_20170117_C9_100_pF_0001.ams,
 C:\Users\mmag14\Google Drive\Zarelab\test_scans_20170117\test_SU_20170117_C10_538_nH_538_nH_0000.ams,
 C:\Users\mmag14\Google Drive\Zarelab\test_scans_20170117\test_SU_20170117_C10_538_nH_538_nH_0001.ams}

fnLst = MatrixForm[Table[Last[FileNameSplit[testFilesAMS[[i]]]], {i, Length[testFilesAMS]}]]

( test_SU_20170117_B6_200_ohm_56_pF_0000.ams
  test_SU_20170117_B6_200_ohm_56_pF_0001.ams
  test_SU_20170117_C8_180_ohm_100_pF_0000.ams
  test_SU_20170117_C8_180_ohm_100_pF_0001.ams
  test_SU_20170117_C9_100_pF_0000.ams
  test_SU_20170117_C9_100_pF_0001.ams
  test_SU_20170117_C10_538_nH_538_nH_0000.ams
  test_SU_20170117_C10_538_nH_538_nH_0001.ams )
```

Fig 26: Snapshot of Mathematica script for uploading the test files.

```
impedances = Table[voltAMSend[[i]] / curentAMSend[[i]], {i, Length[voltMeasCalAMS]}]

{199.575 - 191.651 i, 199.522 - 191.698 i, 179.417 - 107.999 i, 179.448 - 107.921 i,
 0.421559 - 109.54 i, 0.421067 - 109.536 i, 0.955531 + 98.3526 i, 0.933782 + 98.3582 i}

Abs[impedances]

{276.695, 276.689, 209.414, 209.401, 109.541, 109.537, 98.3572, 98.3626}

theorImped1 = 1 / (i 2 π CentF CapacLoad) + Rload /. Rload → 200 /. CapacLoad → 56 * 10^-12 (* short circuit *)

200. - 198.745 i

Abs[theorImped1]

281.957

ErrorPercents1 = (Abs[impedances] - Abs[theorImped1]) / Abs[theorImped1] 100

{-1.86609, -1.86809, -25.7284, -25.7329, -61.1498, -61.151, -65.1162, -65.1143}
```

Fig 27: Snapshot of Mathematica script for calculating the percentage error. In general, a percentage error of ± 5% is acceptable for a given circuit.

Percentage error is automatically calculated for a known circuit which is shown in the figure 27 above (in circles).

8. Maintenance

Health check of SensAND instrument

In order to ensure that SensAND instrument is working properly, we need to run some health checks time to time. The procedure for short term health check can be narrated as follows:

Figure 28: Snapshot of SensAND instrument connected to 14.318 MHz quartz circuit along with 220 ohm resistor

Connect SensAND instrument with Box C7 as shown in Fig: 22 and then take fms and ams scans. A properly working instrument will yield the following fms and ams scans which are shown below for user's convenience.

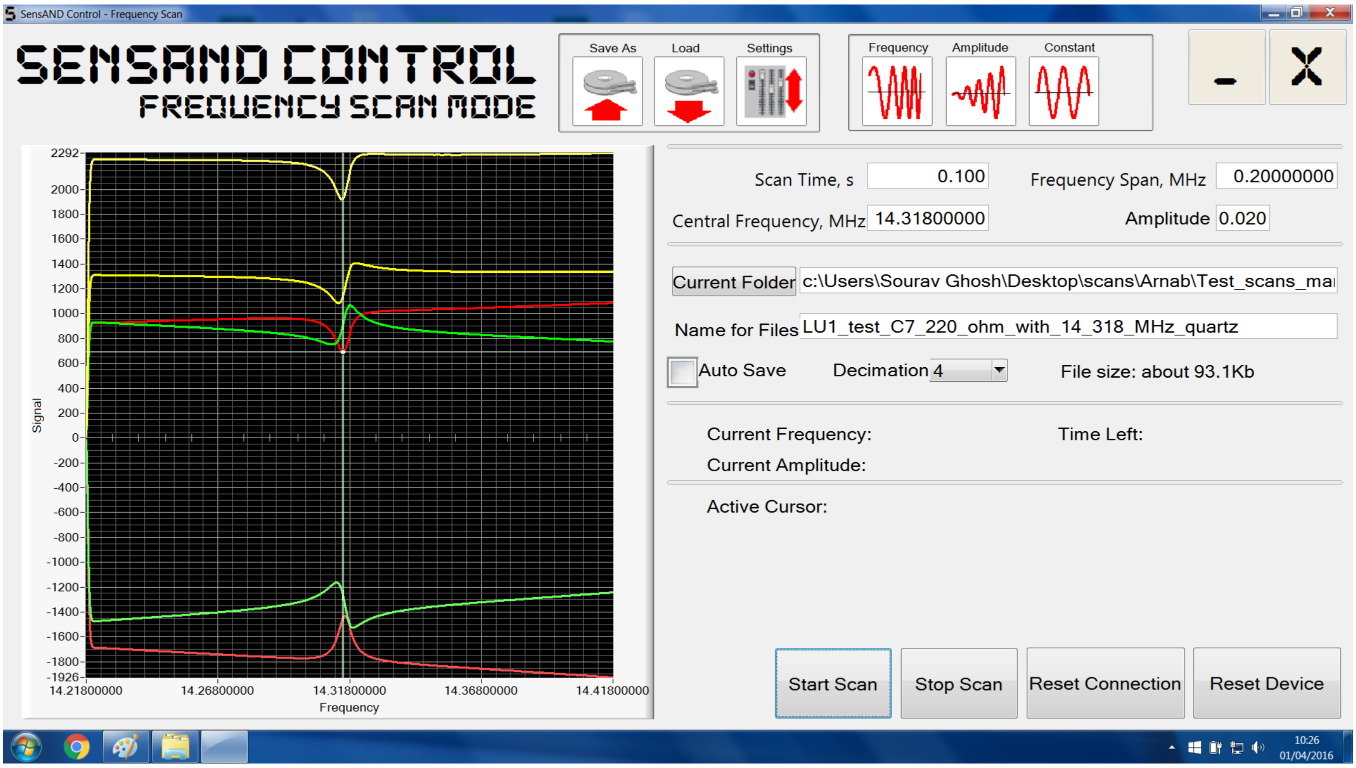


Figure 29: Snapshot of 1f fms scan while SensAND instrument is connected to 14.318 MHz quartz circuit along with 220 ohm resistor

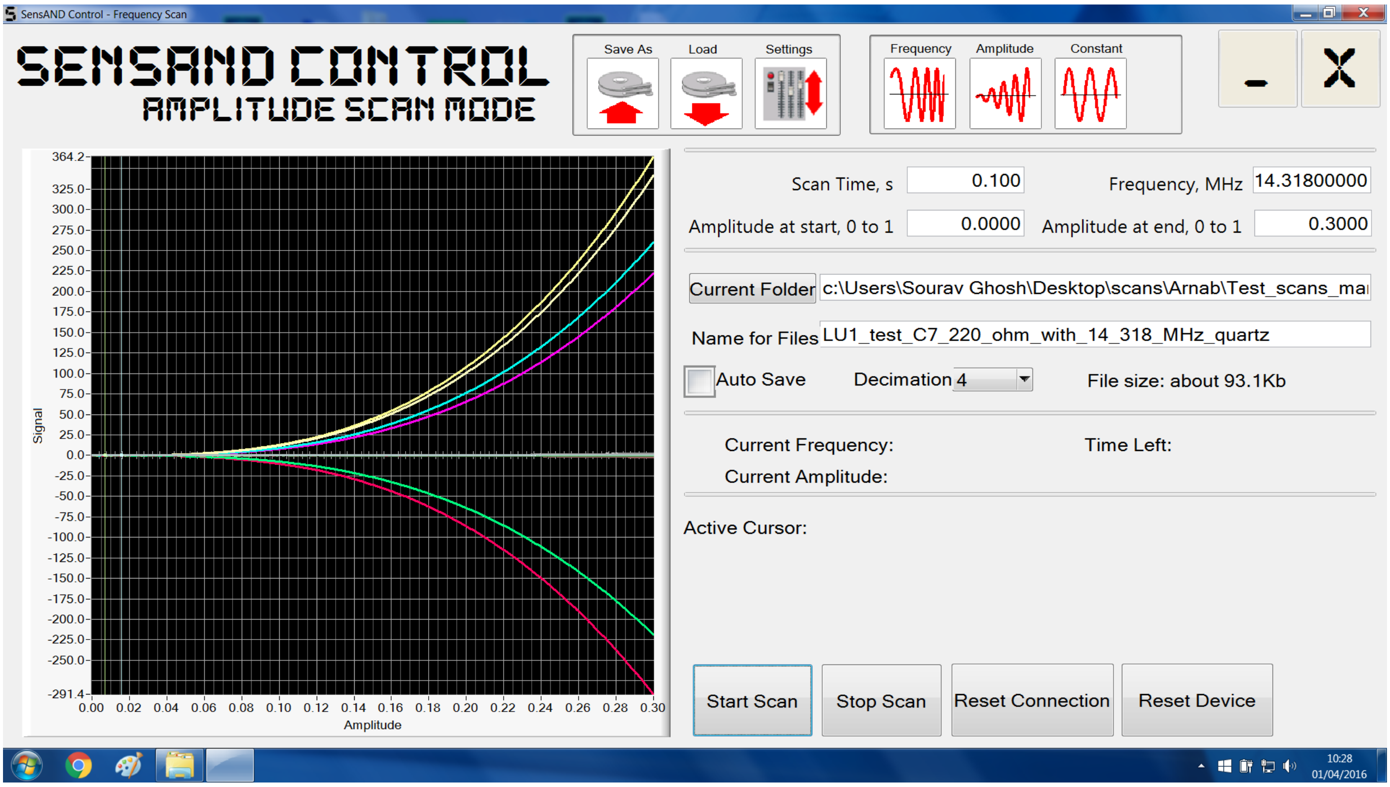


Figure 30: Snapshot of 3f and 5f ams scans while SensAND instrument is connected to 14.318 MHz quartz circuit along with 220 ohm resistor

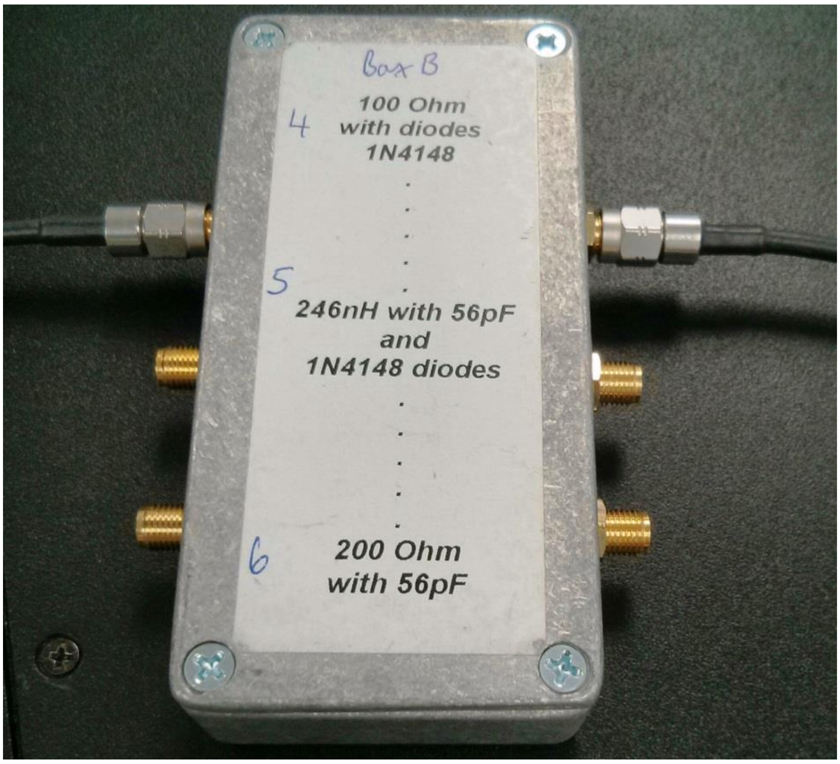


Figure 31: Snapshot of SensAND instrument connected to a circuit comprising of diodes and 100 ohm resistor

Connect SensAND instrument with Box B4 as shown in Fig: 31 and then take ams scan. A properly working instrument will yield the following fms and ams scans which are shown below for user's convenience.

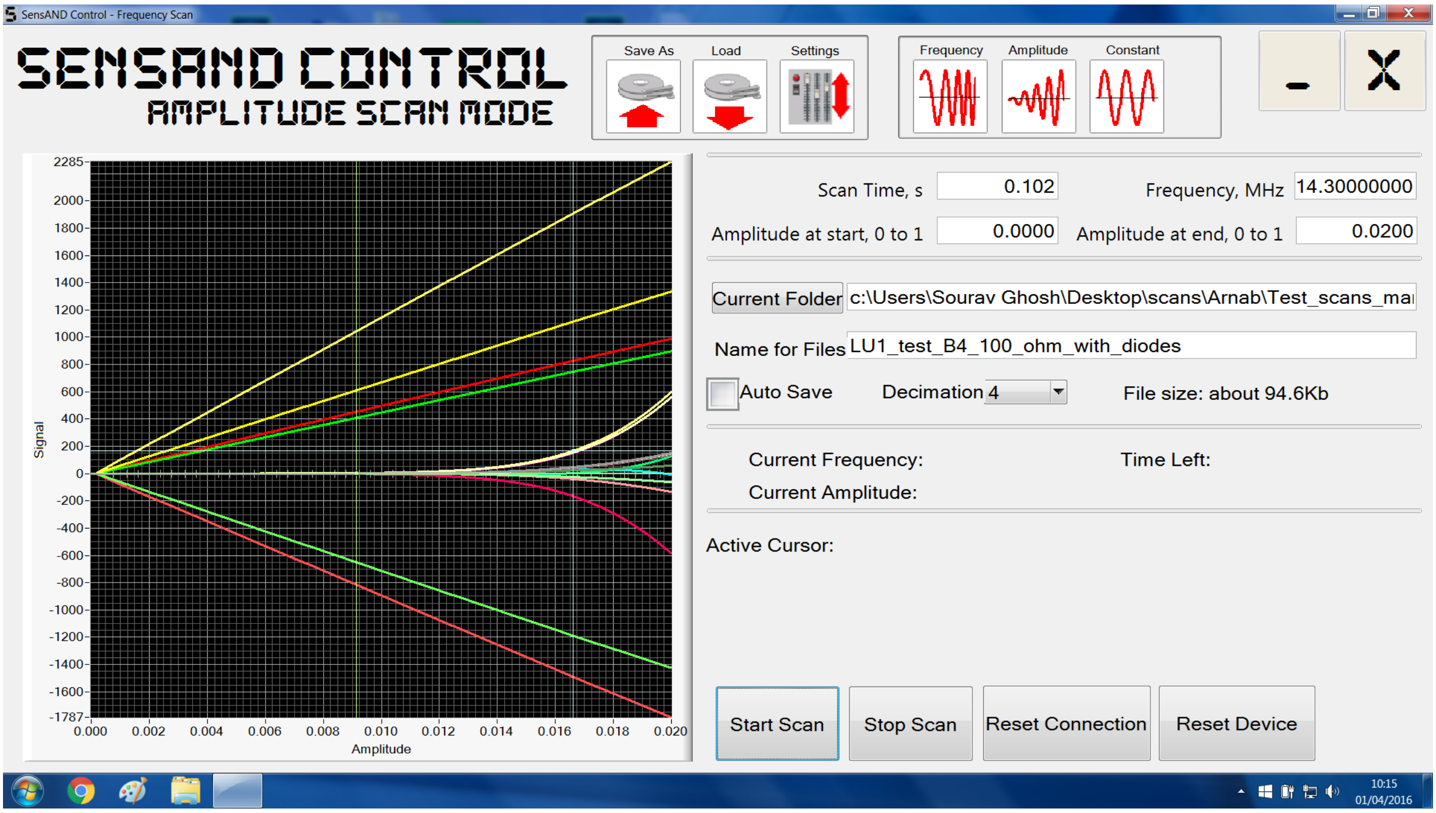


Figure 32: Snapshot of 1f, 3f and 5f ams scans while SensAND instrument is connected to a circuit comprising of diodes and 100 ohm resistor

Long term Health check for testing the instrument oscillator

Method 1

Connect the SMA cables from the instrument to open circuit (Fig 14)

Connect the oscilloscope probes with open circuit (Fig 14)

Set the trigger to repeat

Set the threshold to 0 V

Set pretrigger to 50%

Set time delay to 0 sec

Set collection time to 1 □s/div

Set the number of samples to 20 kS

Both the oscilloscope probes or channels should be connected to level 10

Apply AC voltage of 5V to each port

Add measurements for AC RMS voltages of channels A, B, A-B and frequencies for channels A and B

Take a cms scan at 14.3 MHz and 0.1 SU for 10 sec

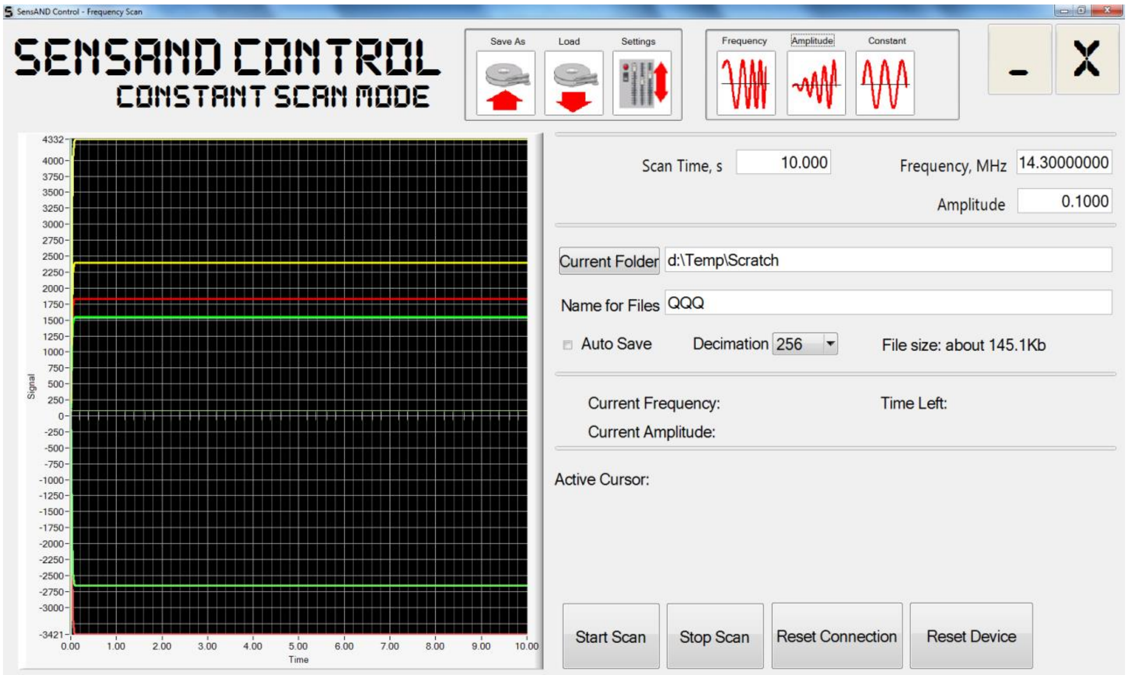


Figure 33: Snapshot of cms scan

The oscilloscope measurements for a SensAND instrument should look like the following and if not, proceed to Method 2.

Standard Operating Procedure **SOP186**

Title: The use and maintenance of the SensAND instrument

Location: CBE H34, T208B and S3 Laboratories

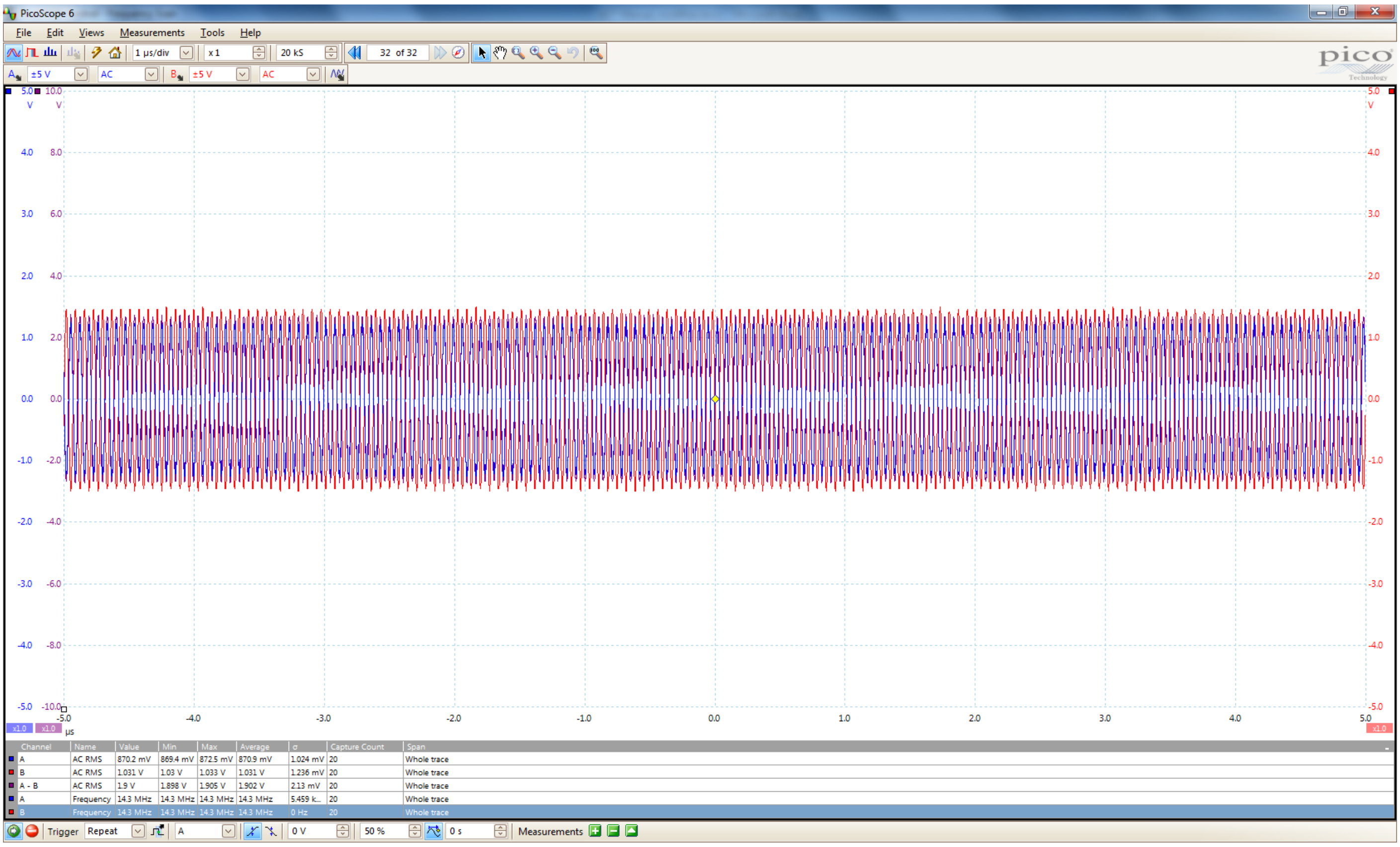


Figure 34: Snapshot of oscilloscope measurement window

Method 2

Connect the oscilloscope probes and SensAND instrument cables to open circuit (Fig 14)

Follow the oscilloscope settings as mentioned above in Method 1 and put the oscilloscope in running mode

Disconnect the oscilloscope probe from Port B and connect it to AWG and set the probe at level 1 on AWG

Switch on the signal generator in picoscope software and choose sine form

Set the start frequency as 1 MHZ and amplitude as 1 V

Go to fms scan in SensAND software and choose scan time as 0.1 sec, amplitude as 0.02 SU, central frequency as 1 MHz and frequency span as 0.001 MHz and decimation as 4

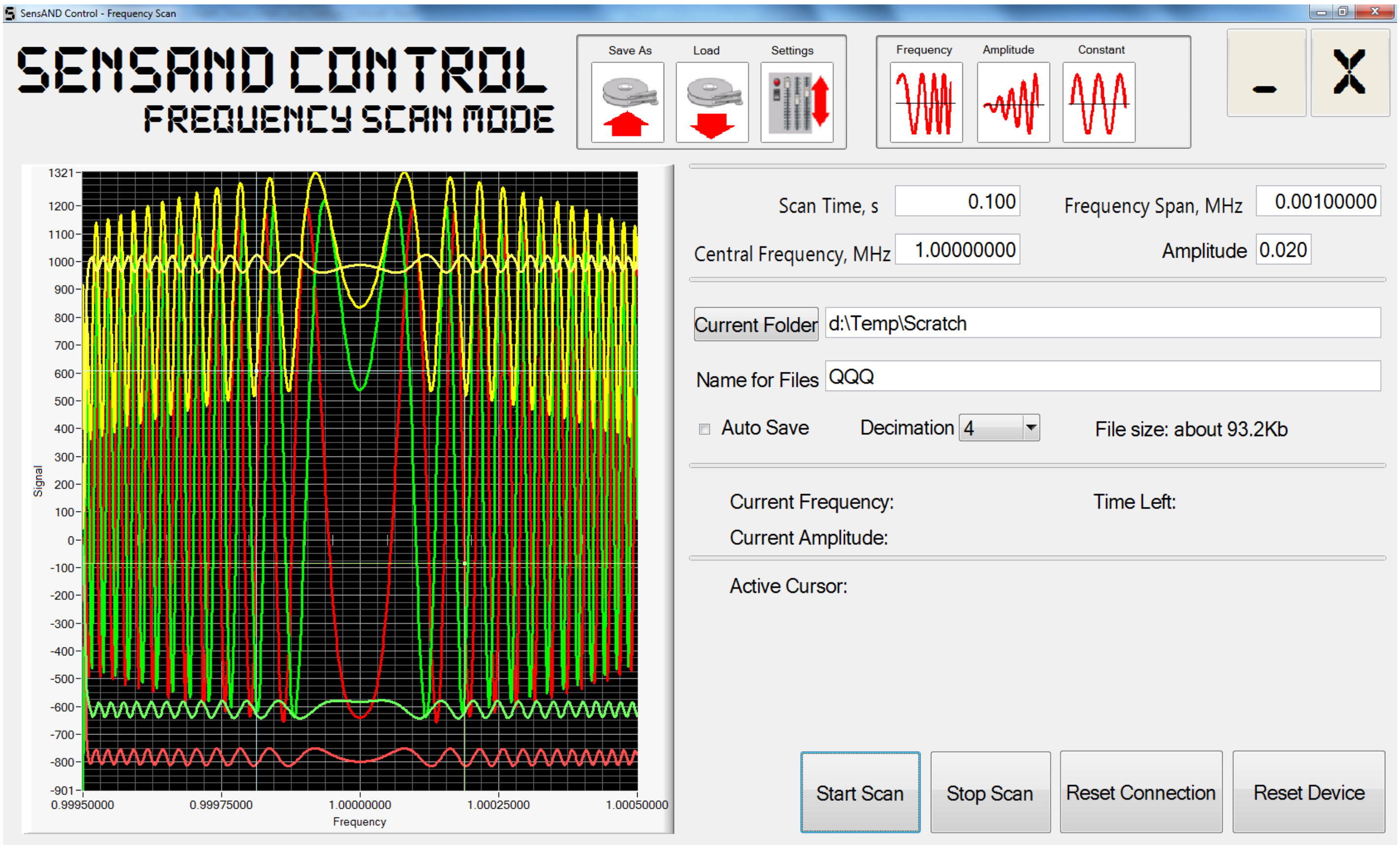


Figure 35: Snapshot of fms scan window

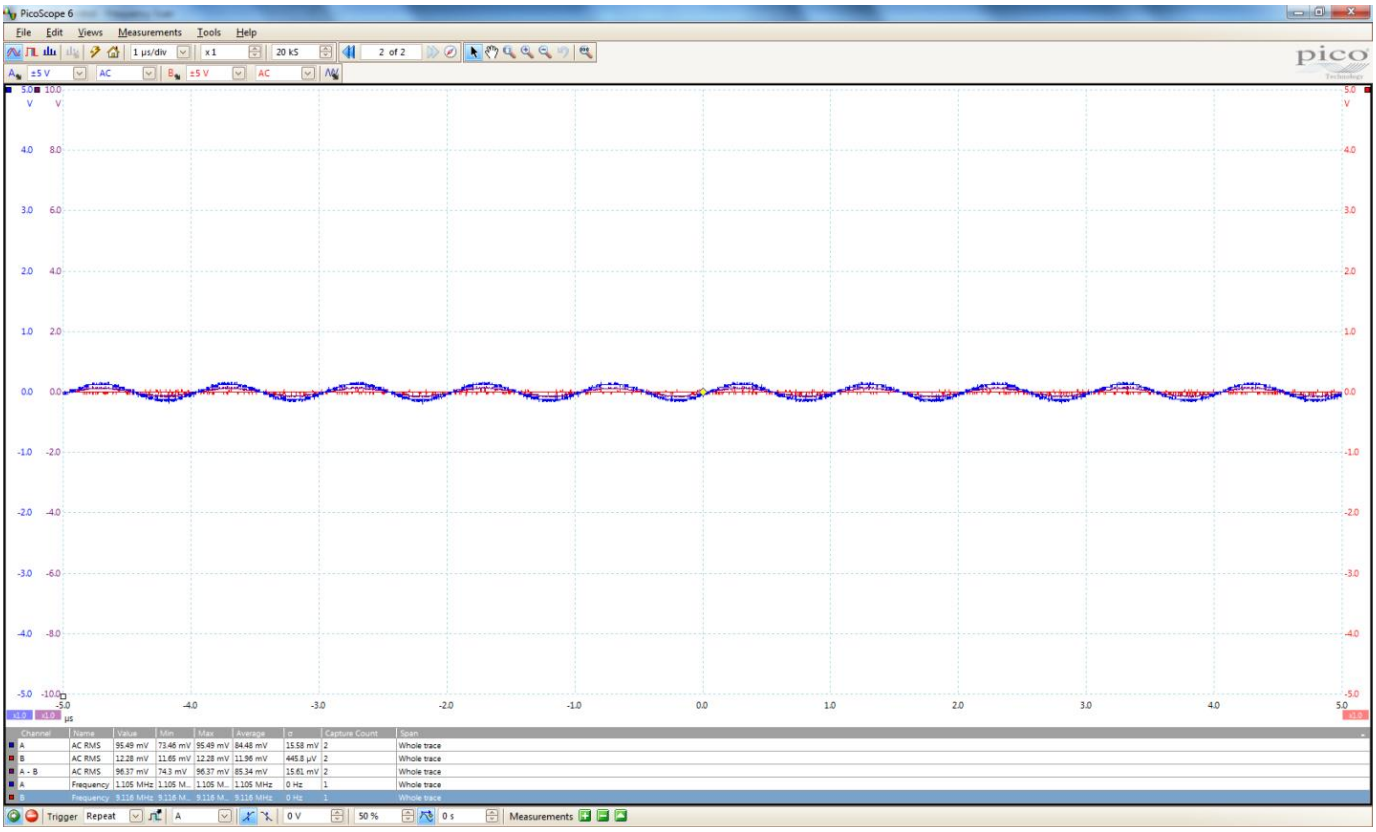


Figure 36: Snapshot of oscilloscope window

Conduct cms scan and choose scan time as 1 sec, amplitude as 0.01 SU, central frequency as 1 MHz and decimation as 1

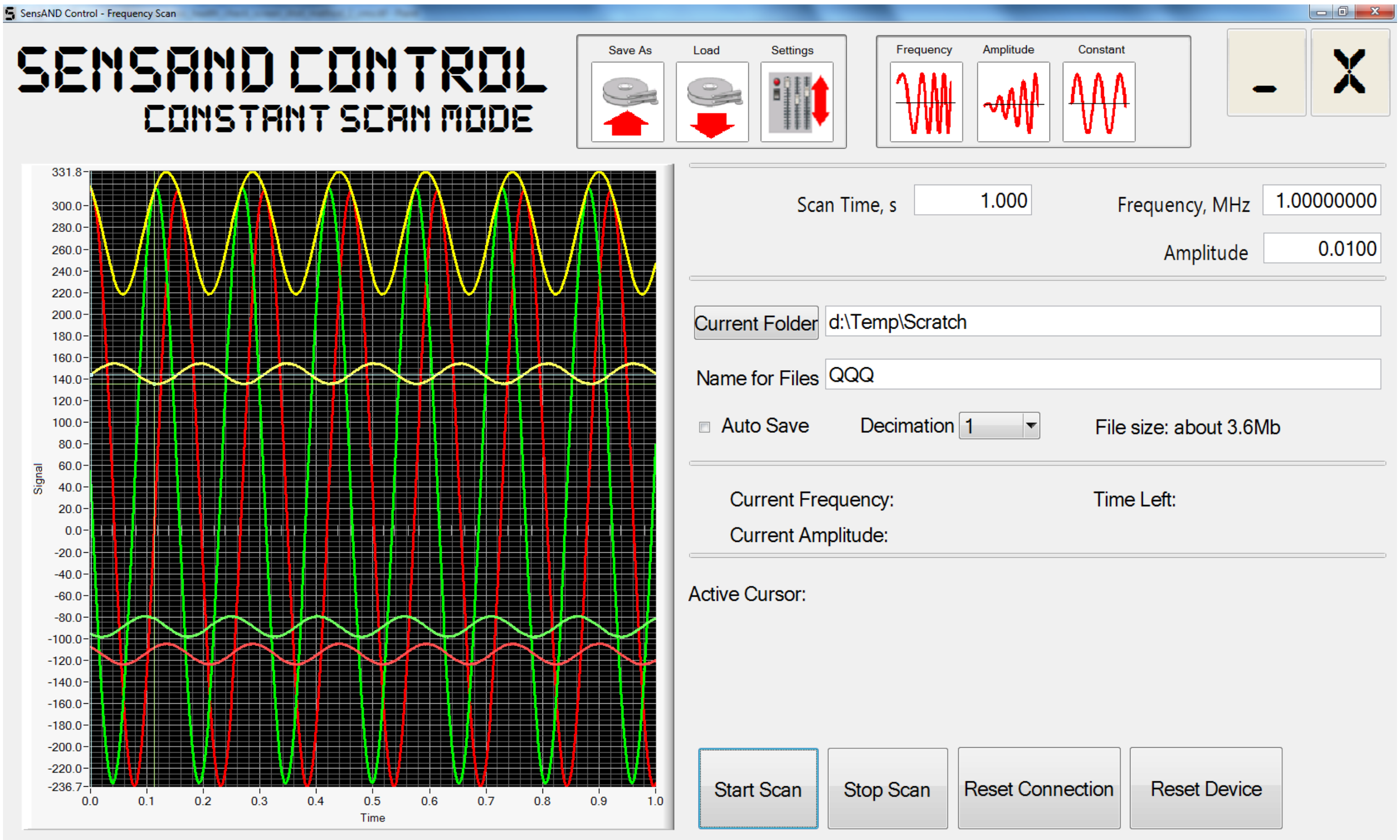


Figure 37: Snapshot of cms scan window

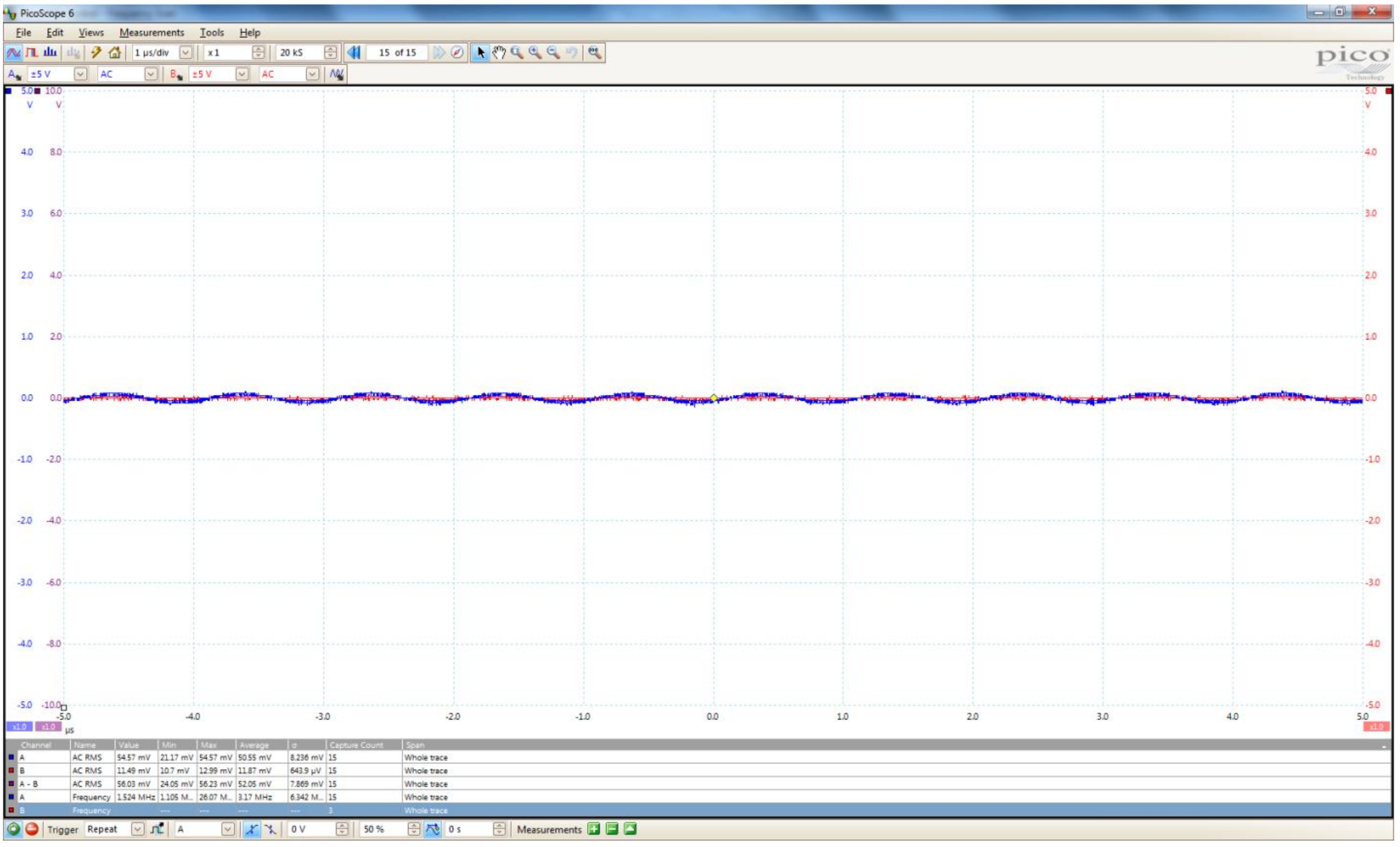


Figure 38: Snapshot of oscilloscope window

If such features are not observed, please consult with Victor Ostanin (University of Cambridge).

Considerations:

Generally, it is better to start with low amplitude and then increase gently
If we want to apply a high amplitude, we should reduce the scan time otherwise the crystal could break
High amplitude can be used for REVS mode in order to remove unwanted objects from the surface.

How to check whether SensAND instrument is plugged properly to PC:

Control panel on Windows
- System
  - Hardware
    - Device manager
      - Universal Serial USB
        - Serial Converter A
        - Serial Converter B

How to Install SensAND control SW:

It uses the audio Analog to Digital Converter from PC (normally controlled by Windows). So before installing make sure you are not playing music or otherwise using (e.g. Skype with audio jack plugged for headphones) your PC's audio device

Thoroughly following installation instructions provided in leaflet

When SensAND is running, if possible, avoid that other programs are running, disable software's auto update, and eventually increase priority of SensAND process in task manager. Otherwise connection problems are possible.

9. Malfunction of the SensAND instrument

(i) If any part of the equipment fails or malfunctions, including faults or defects, indicated by vibration, noise or by failure to operate, the user should contact the Laboratory Manager/Responsible Person. With permission of the Laboratory Manager or Responsible Person the user should consult the Operator Instruction Manuals to access fault finding, error displays, and troubleshooting procedures.

(ii) All problems and corrective actions should be recorded in the Equipment Maintenance record.

(iii) If the equipment fails to work or malfunctions and cannot be rectified according to troubleshooting procedures detailed in the Operator and Users Manuals the Laboratory Manager must be informed and the equipment must be tagged and locked-out or "Do Not Use" notice posted on the equipment. Contact the manufacturer for advice and coordinate with the Lab Manager for external maintenance and servicing.

(iv) External maintenance and servicing of the equipment can only be performed after it has been suitably disinfected (refer to SOP003 for further details) and a 'Decontamination Certificate' has been issued (a proforma is available on the CBE LEARN page). NOTE: A 'Declaration of decontamination'; available in the Operators Manual may also be required. Permit to works should be used for external contractors.

10. Documentation

The following records are outputs of this SOP:

- 8.1 QS-FORM-009 Generic equipment decontamination certificate
- Weekly Housekeeping sheet
- Lab Equipment Maintenance Record.

These records shall be filed in the Equipment File and stored in the CBE Office or otherwise archived for future review or retrieval.

SOP Version History

Version Reviewed	Date Revised/ Reviewed	Revision Summary	New Version Number
		[Insert specific changes from previous SOP] < e.g. changes in accountabilities, process steps, deviation actions, or records>.	