IMPEDANCE MEASUREMENT USING AUDIO I/O

Group B - 09:

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ABSTRACT:

We are trying to make a low cost RLC meter which is an instrument used to measure an unknown impedance. It makes use of a hardware which is already present in laptops/PC's "The Sound Card". The PC takes I/O from the audio Jack and estimates the value of the unknown impedance and displays the value with a proper Graphical User Interface.

OBJECTIVES:

The RLC meters which are available commonly are expensive. Not every household is lucky enough to own such an instrument or an expensive RLC meter however, PCs and sound cards, are ubiquitous. A low precision RLC meter costs around 40$ and high precision RLC meter costs around 800$.The High precision RLC meter is considerably heavy and not portable. So the aim is to make a RLC meter using an audio I/O which is affordable, accurate and portable.

INTRODUCTION:

Impedance is essentially the degree of opposition to current flow. It is a complex quantity, that is, it has real and imaginary parts. The impedance of a pure resistor has zero imaginary part, although the impedance of a practical resistor will have a small imaginary part. Ideal inductors and capacitors have a purely imaginary impedance, but again real inductors and capacitors have a small real part to their impedance along with an imaginary part. This deviation from the ideal gives rise to power dissipation or losses in the component. For this project we imagine a real component to comprise an ideal component in series with a pure resistance, the latter representing the losses. At a specified frequency, an impedance can be expressed in polar coordinates or in Cartesian coordinates: $Z = |Z|\angle\theta = R + jX$ where $|Z| = \sqrt{(R^2+X^2)}$

$\theta = \arctan(X/R)$. Here Z is the (complex) impedance, measured in ohms, $|Z|$ is the magnitude of Z, and θ is the argument of Z. Z has real part R and imaginary part jX.

SPECIFICATIONS:

1) Customer specification

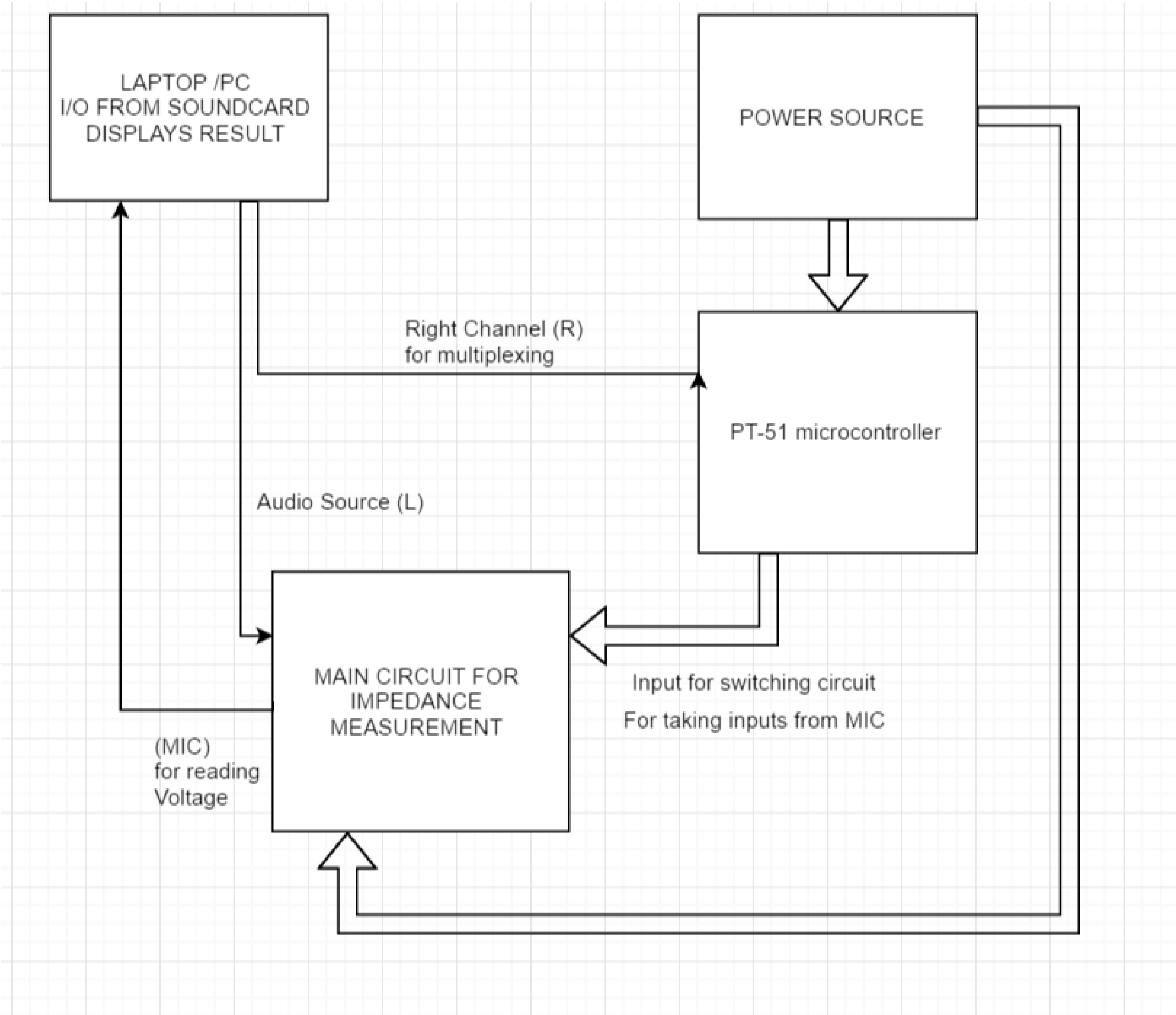
- LCR meter measuring program with professional standard
- high accuracy

- Only a soundcard and is required
- Measurement of functions like R,L,C .

2) Technical specification

- Range of R: 10 ohms to 1Mohm
- Range of C: 0.02nF to 1uF
- Range of L: order of mH

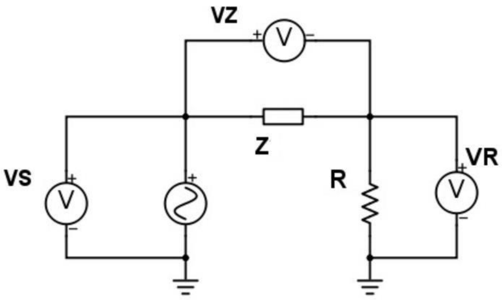
BLOCK DIAGARAM

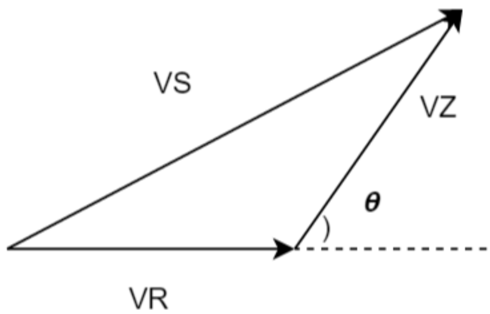


DESCRIPTION OF BLOCKS

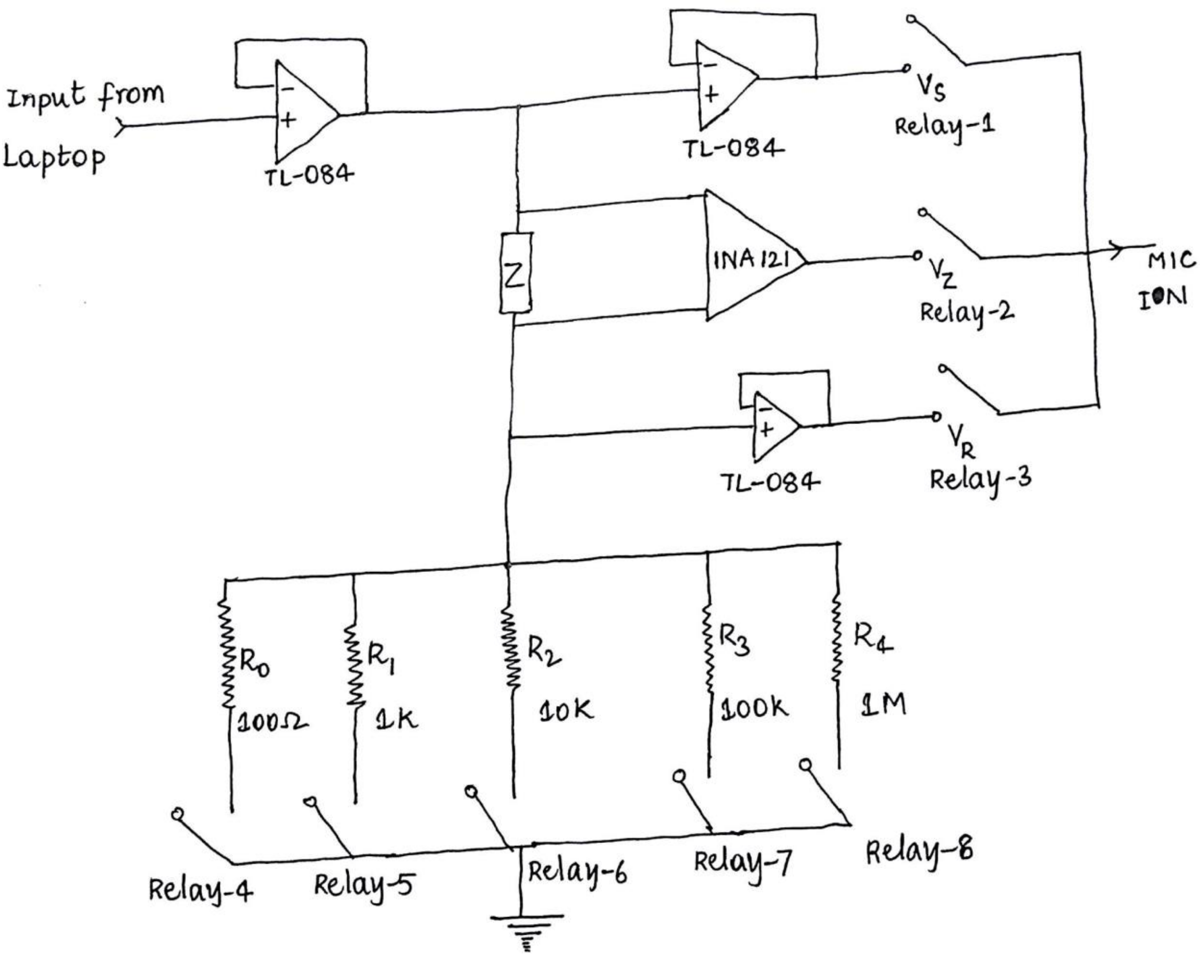
IMPEDANCE MEASUREMENGT CIRCUIT

The main functioning of the circuit is as follows:





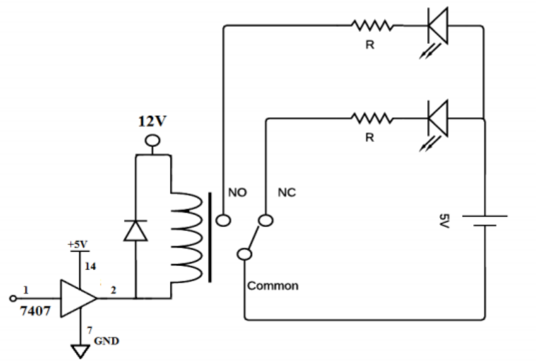
We need to measure the voltages V_S , V_R, V_Z.



IMPEDANCE MEASUREMENT CIRCUIT .

SWITCHING USING MICRONTROLLER:

The PC/Laptop can only read one signal at a time. But, we have to read voltages across the source, reference resistor and DUT. Therefore, Multiplexing of the three signals must be done. Since, the signals to be multiplexed are analog signals, we are using Relays to avoid switching resistance. These Relays are controlled using Microcontroller. The multiplexing is done as follows, first the PC sends a sinusoid of certain frequency to the Microcontroller, then the Microcontroller Switches the signal to be read according to the frequency received. Also, to get accurate results, the voltage across reference resistor should be comparable to the voltage across DUT. This requires that the value of reference resistor should be comparable to the impedance of the DUT. We are overcoming this by the following process. First read all the Voltages across source, DUT and reference resistor. Then, calculate the ratio of VZ/VR. If it lies within 1/ sqrt(10) and sqrt(10), then continue with the same reference resistor. If it lies out of the specified range, then change the reference resistor such that the ratio of VZ/VR lies within 1/sqrt(10) and sqrt(10). By doing this we are improving the accuracy of the device to some extent.



The interfacing circuit for the relay with the microcontroller using SN7407 is as follows.

SOFTWARE IMPLEMENTATION:

We are using Python as our platform. This is used to generate an Alternating sinusoidal voltage which is used to excite the impedance measurement circuit. Then we will be reading the voltages V_R, V_Z and V_S. Then estimate the unknown impedance.

The module used for generating and reading the voltages are pyAudio. This uses the PC's sound card and generates or reads the appropriate voltages. We use math and numpy module in python for making some complex mathematical calculations. We use audioop for measuring the Vrms of the voltages obtained using pyAudio.

Procedure

1) We will generate an alternating sinusoidal voltage of frequency 10000 Hz which will excite the impedance measurement circuit through right channel of audio output.

2) Now we will read Vs1, Vr1 and Vz1 through the mic input by sending their respective switching frequencies through the left channel of audio output to microcontroller. This process goes on simultaneously with 1st step.

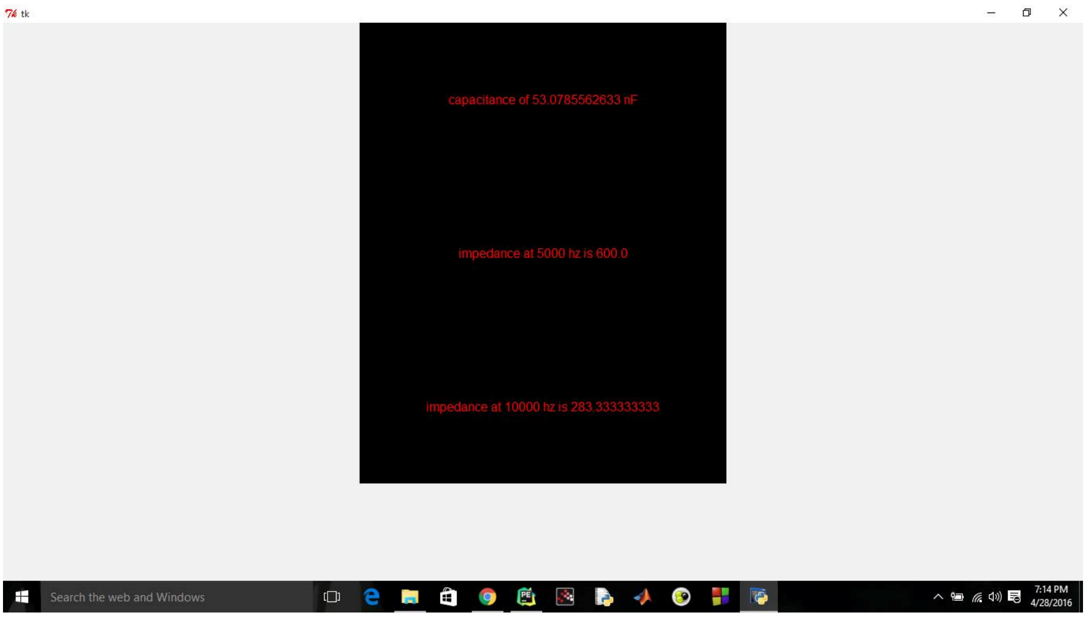
3)Now we will find the ratio between Vr1 and Vz1 .If the ratio is greater than sqrt(10) then we will switch the reference resistor to a lower resistor for accuracy else if ratio is less than 1/ sqrt(10) then we will switch the reference resistor to a higher resistor. After this again we will perform the second step and find Vs1, Vr1, Vz1.

4)Now we will generate a sinusoidal frequency of 5000 Hz and perform the 1st, 2nd and 3rd steps again to find Vr2, Vs2 and Vz2

5) Now we will compare the Vz1 and Vz2.If Vz1 and Vz2 do not change then it must be the resistor. If Vz2 is greater than Vz1 i.e., decreasing with frequency, then it must be a capacitor. If Vz2 is lesser than Vz1 i.e., increasing with frequency, then it must be a inductor.

6) Finally we will find the impedances for the respective frequencies. Since frequencies are known, we can calculate the respective capacitance or inductance.

Display of the final result (GUI)



COMPONENTS USED:

1) TL084 (1)

2) SN7407 (2)

3) Relays (8)

4) INA126 (1)

TL084

Quad JFET-Input Operational Amplifiers with a gain bandwidth product of 3 MHz and a high Input resistance of $10^{12}\ \Omega$. In our circuit, Operational amplifiers are mainly used as buffers.

SN7407

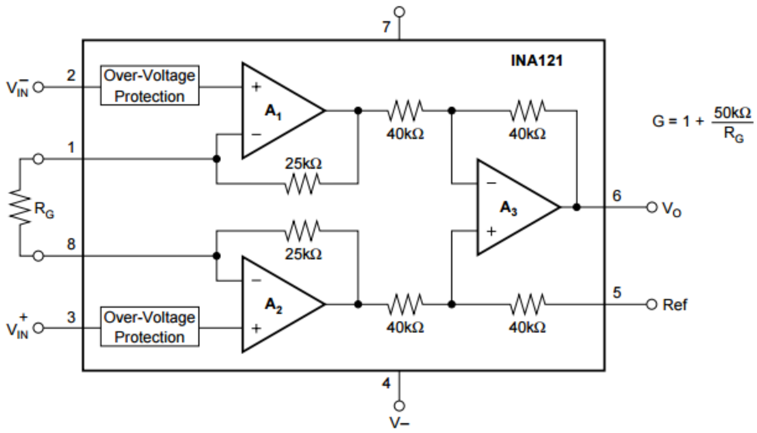
This is an open collector HEX buffer which is used to interface or control the relays with the microcontroller. As a microcontroller cannot drive the Relays.

12V RELAYS

Relays here are used to multiplex the output signals i.e. VZ, VS, VR and also used to switch the reference resistors. Relays are used to avoid switching resistances because relay acts as an ideal switch.

INA121

The INA121 is a FET-input, low power instrumentation amplifier offering excellent accuracy. The input impedance of an instrumentation amplifier is very high so it wouldn't really effect the circuit.

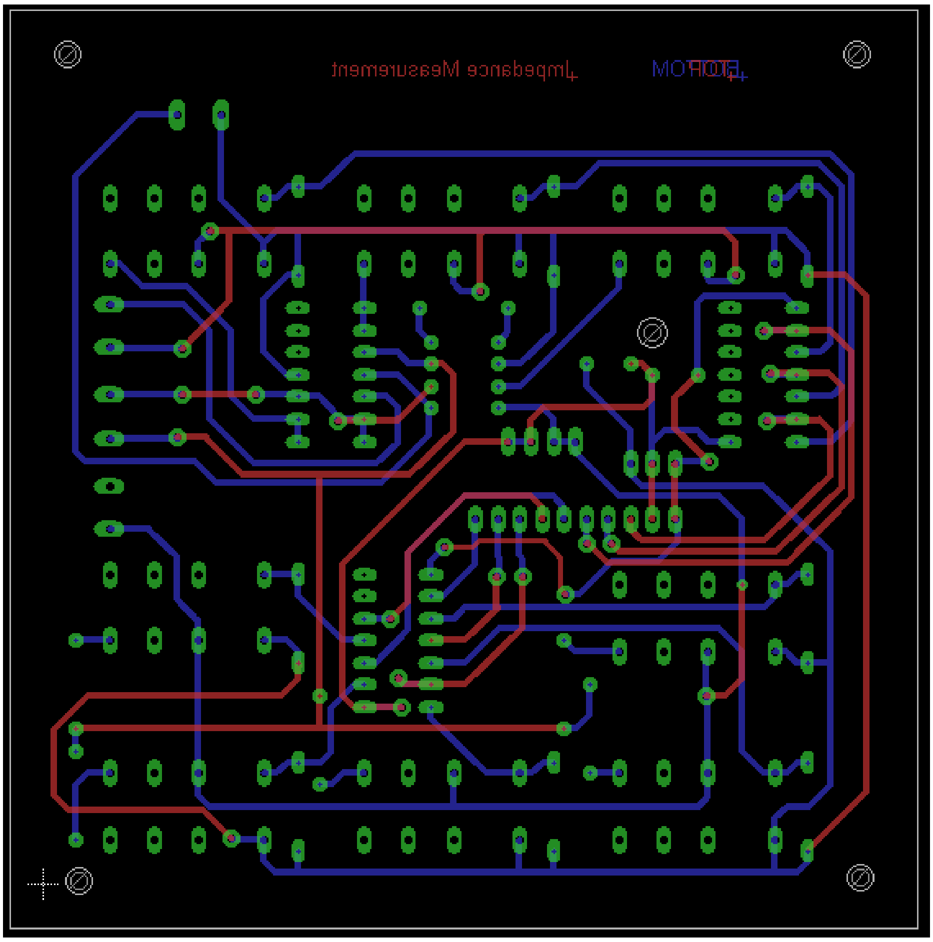


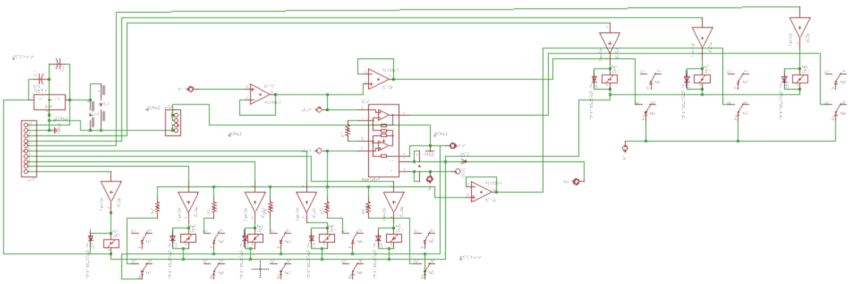
We used RG = 10M Ω so the gain G = 1.05.

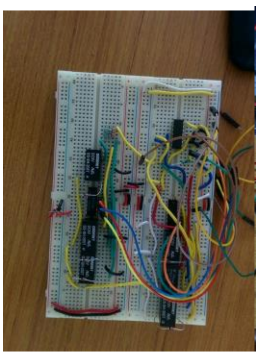
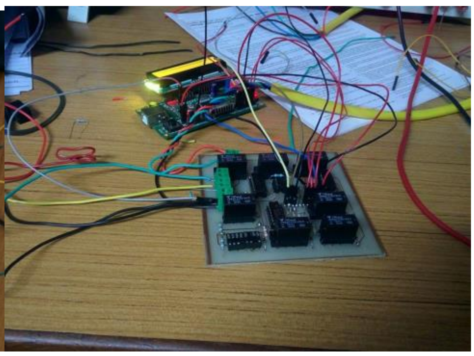
This is used to find out the differential gain across the Unknown Impedance.

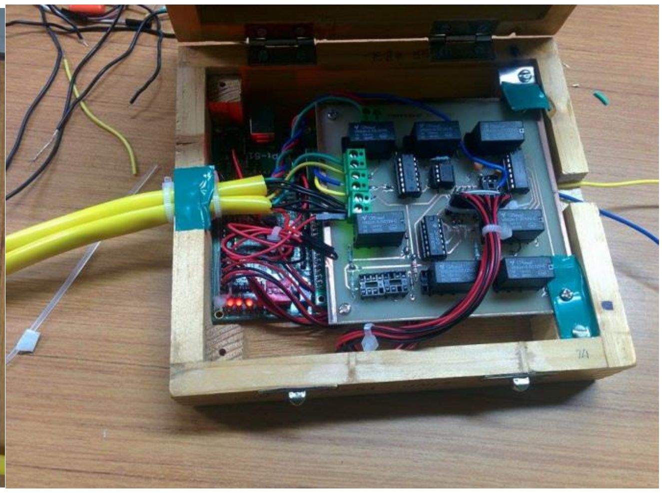
PCB Design:

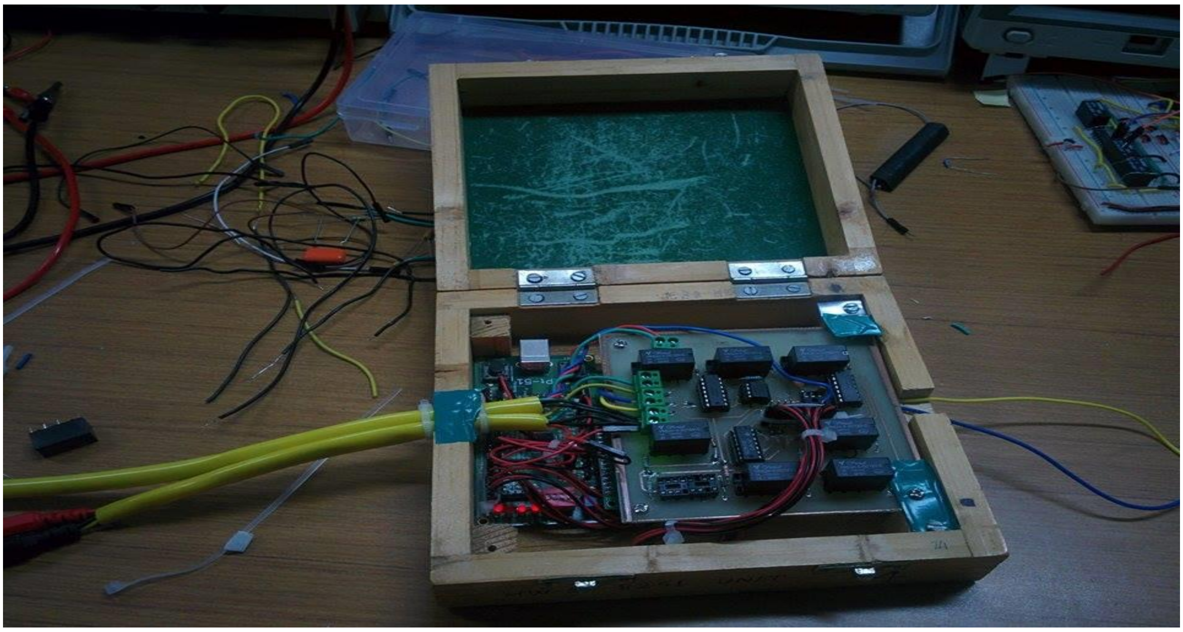
Initially we implemented the whole circuit on the bread board so it was a bit difficult to test everything as many of connections are not that rigid. We then used a PCB designing software eagle in which we made the schematic and designed the schematic.


Impedance Measurement



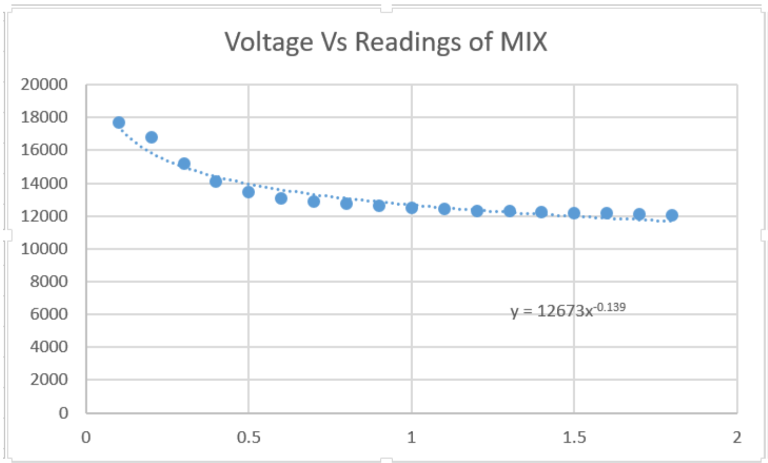




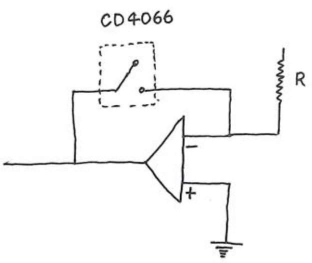
IMAGES of Final product

PROBLEMS FACED:

1) While reading the voltages through the MIC input, the values that we read are changing with the frequency. So we calibrated them accordingly



2) Initially, we used CD4066 for switching the reference resistances. And to avoid the switching resistances we used an opamp circuit.



But, when the reference resistor was 100 Ohm, the opamp was not able to supply the required current (> 10mA).

<u>CONCLUSIONS:</u>

We are able to generate a AC voltage with required frequency and also able to read the Vpp of the received wave. From there we are able to calculate the magnitude and phase of unknown impedance. Still we have to improve the accuracy of our measurement.

<u>FUTURE WORK SUGGESTIONS:</u>

1) Currently we are using voltage source available in the lab but finally one can get the required supply using a AC adaptor and a proper regulation.
2) We can eventually develop an android application and use the computation of a mobile phone as well, then this would be of potential use.
3) All the IC's used can me made SMD so that the product would become even smaller and portable.

4) For now we are using a lot of delays in between measurements , in future we could reduce this by a huge extent and make it a better product.

REFERENCES:

1) http://icom.hsr.ch/fileadmin/user_upload/icom.hsr.ch/publikationen/RLC_Meter_EN.pdf

2) https://people.csail.mit.edu/hubert/pyaudio/docs/

3) https://docs.python.org/2/library/audioop.html

4) www.ti.com for all the IC data sheets

LINK containing all the documents and codes

https://drive.google.com/file/d/0B0RIadFodxVJLU55ckY3VVZtZVk/view?usp=sharing