Study of ExpEYES junior kit and its applications in Experimental Physics

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Abstract: The PHOENIX (Physics with Home-made Equipment & Innovative Experiments) project was started in 2004 by Inter-University Accelerator Centre (IUAC) with the objective of improving the science education at Indian Universities. Development of low-cost laboratory equipment and training teachers are the two major activities under this project. The *expEYES (experiments for Young Engineers & Scientists)* kit is designed to support a wide range of experiments, from school to post graduate level. It also acts as a test equipment for electronics engineers and hobbyists. The simple and open architecture of expEYES allows the users to develop new experiments, without getting into the details of electronics or computer programming. The *expEYES Junior* is a modified version of expEYES released earlier. It is meant to be a tool for learning by exploration, suitable for high school classes and above. The design is simple, flexible, rugged and low cost. The software is released under GNU General Public License. The project has progressed due to the active participation and contributions from the user community and many other persons outside IUAC. In this paper we have discussed the detail design of expEYES junior kit and how we can use this kit to perform various experiments in physics.

***Index Terms*: PHOENIX, expEYES, IUAC, experiments using expEYES.**

I. INTRODUCTION

Science is the study of the physical world by systematic observations and experiments. Science education is also essential for training enough technicians, engineers and scientists for the economy of the modern world. However, almost everywhere science is mostly taught from the text books without giving importance to experiments, partly due to lack of equipment. As a result, most of the students fail to correlate their classroom experience to problems encountered in daily life. To some extent this can be corrected by learning science based on exploration and experimenting. Keeping in mind the above situation, IUAC started PHOENIX and expEYES programs which helps the teachers and students to design and perform experiments in just few simple steps. The T. Y. B. Sc. syllabus of Pune University, Pune includes some experiments based on PHOENIX. The same experiments can also be studied using expEYES junior kit.

II. STUDY OF expEYES Junior KIT

The expEYES junior kit is shown in figure 1. It has total 18 pins as shown. The table 1 shows pin functions.

Figure 1:expEyes Junior Kit

Table 1: Pin Functions of expEYES junior kit

PIN #	SYMBOL	DESCRIPTION
1	GND	ground
2	IN1	0 to 5V range Analog /Digital Input, Current Source
3	IN2	0 to 5V range Analog /Digital Input, Current Source
4	SEN	0 to 5V range Analog/Digital Input, with 5K pullup, for resistive sensors
5	SQR1	.7Hz to 200kHz Square Wave Output, 100Ω series resistor
6	SQR2	.7Hz to 200kHz Square Wave Output, no series resistor
7	OD1	Digital Output, no series resistor
8	CCS	1 mA Constant Current Source with ON/OFF Control
9	GND	Ground
10	GND	Ground
11	SINE	Sinewave output, around 150 Hz, 4 volts
12	MIC	Output of the microphone, amplified 51 times
13	IN	Inverting Amplifier Input, maximum gain = 51
14	OUT	Amplifier output, of Pin13
15	PVS	Programmable Voltage Output, from 0 to 5 volts
16	A2	±5V range Analog Input
17	A1	±5V range Analog Input
18	GND	Ground

III. RUNNING the LIVE CD

To work with the kit, first we insert this live CD of expEYES kit into the computer. After insertion the computer has to be restarted. When the computer restarts it enters into the program on which the expEYES kit runs i.e. the LINUX program. After entering the program and selecting the second option we get window of the expEYES kit. Selecting the option of 'applications' we get next options, in next options selecting 'science' we again get further options, we select 'expEYES junior' over there.By doing this procedure we get the plot window on the computer screen as shown in figure 2.

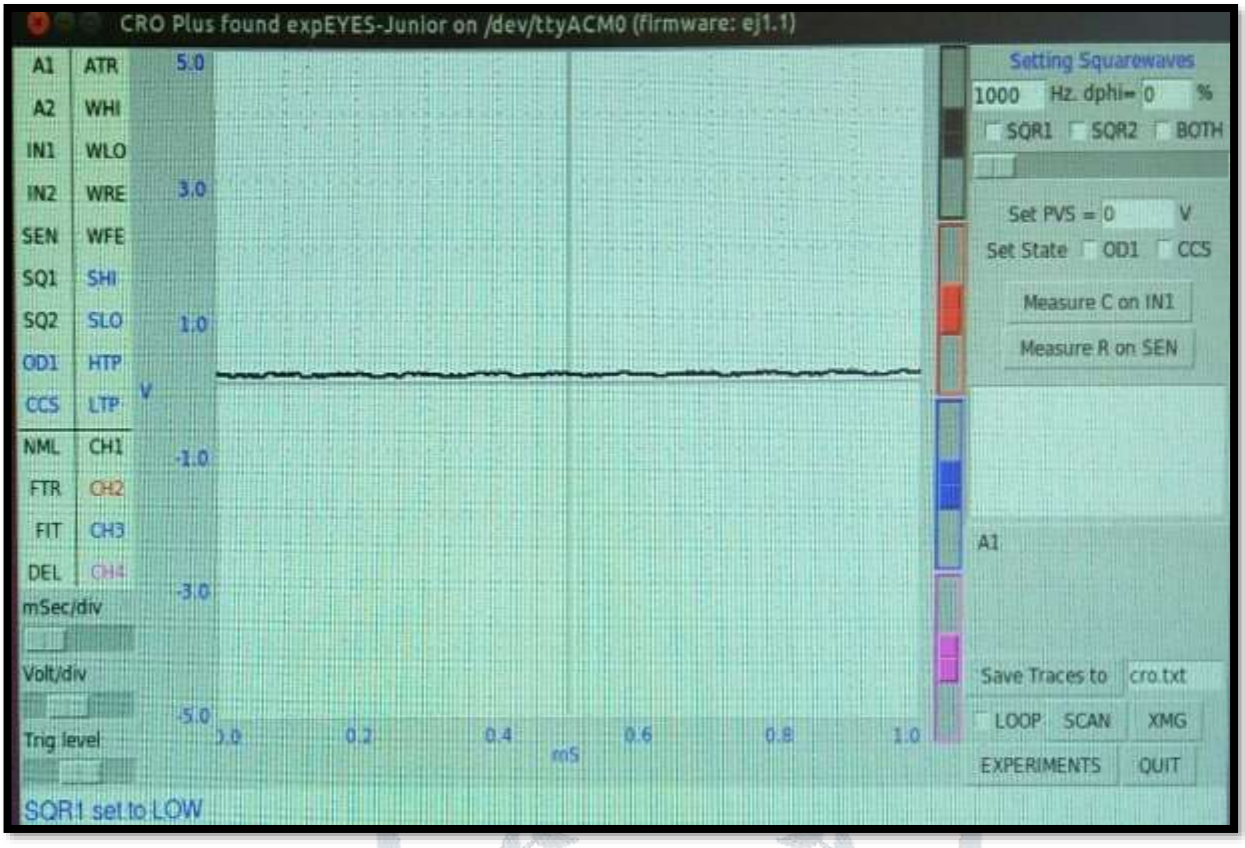

Figure 2: Plot window of expEYES kit

The plot window works like a low frequency four channel oscilloscope. .The maximum sampling rate is 250 kHz only, sufficient for exploring audio frequency range. A brief description of this GUI program is given below.

- On the left side, the INPUTS (A1, A2, IN1, IN2SEN and read backs of SQR1& SQR2) are shown.Clicking on any one of them will display the voltage/logic level present. To plot any one of them, drag it to the desired channel (CH1 to CH4). The name of inputs selected for display is shown on the right side of the plot window, using a unique colour for each channel.
- Dragging any of the channels, CH1 to CH4, to FIT will enable calculating amplitude and frequency by fitting the data using the equation $V=V_0\sin(2\pi ft+\theta)+C$, V_0 and f will be displayed.
- Right clicking on IN1, IN2, SEN, SQR1, and SQR2 will measure the frequency and duty cycle of the voltage waveform present at the terminal.
- Vertical scale (volts/division). Maximum values are 5 volts per division.
- Dragging a channel to FTR will show the Fourier Spectrum of the waveform in a separate window.
- SAVE button to save the data to the specified file in two column text format.
- SQR1 can be set using a slider also.
- Check buttons are provided to control OD1 and CCS.
- Capacitance connected between IN1 and GND can be measured.
- Python functions to communicate to the hardware can be entered in a Command Window.

IV. BASIC MEASUREMENTS

Before proceeding with the experiments, one should become familiar let us do some simple exercises to become familiar with expEYES Junior. Boot your computer from the Live CD, connect the device a USB port and start the ExpEYES-Junior program from the menu *'Applications->Science'*. Follow the given steps for basic measurements. These are useful in almost all experiments.

1) Generate & measure voltages

- Connect PVS to IN1 and Assign IN1 to CH1
- Set PVS to some voltage and observe the trace
- Click on IN1 to display the voltage.

2) Observe voltage waveforms

- Connect SINE to A1 and Assign A1 to CH1
- Adjust the horizontal scale (ms/Div) to view 4 or 5 cycles of the square wave • Set frequency to 100 and Check SQR1.
- Assign SQR1 to CH2
- Change frequency. Uncheck and Check SQR1.
- Explore the FIT and FTR options.

3) Measure frequency & Duty cycle

- Set SQR1 to 1000
- Right Click on SQR1 to display frequency and duty cycle.
- To set 488 Hz 30% PWM, enter set_sqr1_pwm (30)2 inside the Command window.
- Measure again by Right Clicking on SQR1

4) Measurement of resistance

According to Ohm's law, the voltage across a conductor is directly proportional to current flowing through it. The constant of proportionality is called Resistance. This is known as Ohm's Law, expressed mathematically as

$$V \propto I; \qquad V = IR \text{ or } R = V/I$$

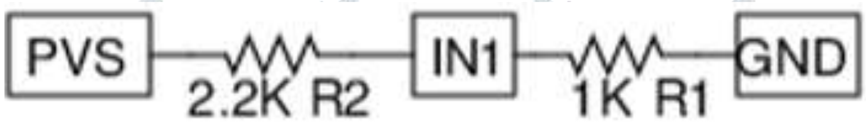

Figure 3: Resistance measurement

Procedure:

- Make connections as shown in figure 3 and 4.
- Set PVS to some voltage, read the actual value set from the message field.
- Click on IN1 to measure its voltage.
  • Repeat for different values of PVS.
  • Repeat for other resistance values.

Observation: The total voltage and the voltage across R1 are measured. The voltage across R2 is $V_{PVS} - V_{R1}$. The current through R1, $I = V_{R1}/R1$. The same amount of current flows through R2 and the voltage across R2 can be calculated using $V_{R1} = IR1$.

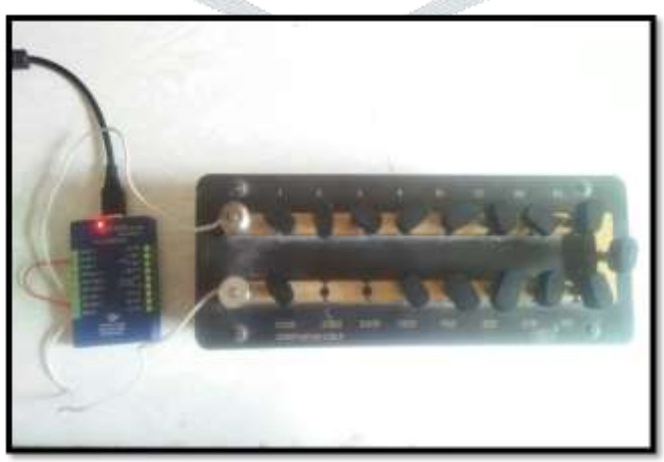

Figure 4: Actual connections for resistance measurement

Table 2 : Measured values of resistance

Sr. No.	Resistance in ohm	Observed value of voltage	Estimated resistance in ohm
1.	500	0.486	486
2.	1000	0.976	976
3.	1500	1.463	1463
4.	2000	1.944	1944
5.	2500	2.430	2430
6.	3000	2.916	2916
7.	3500	3.398	3398
8.	4000	4.383	4383

V. EXPERIMENTS

The expEYES hardware can generate and measure different kinds of voltage signals. For measuring any other parameter, it should be converted into a voltage, using appropriate sensor elements. For example, a temperature sensor will give a voltage indicating the temperature.

A GUI program is provided for every experiment given in this manual. However, it is possible to do the same by writing few lines of code in Python language. All the communication to expEYES is done using a Python library called **eyesj.py.** Data analysis and graphical display is also done in Python. If you are interested in developing new experiments based on expEYES, it would be a good idea to learn Python programming language. Almost every experiment can be extended in several ways and some hints are given in this direction. The following are some of the experiments from different topics like electricity and electronics.

Experiment 1: Transient Response of RC circuits
Aim: To study charging and discharging of capacitor through Resistance.
Procedure:
1) Make connections as shown in figure 5 and 6.
1) From **EXPERIMENTS,** select **RC CIRCUIT**.
2) Click on *0>5V STEP* and *5>0V step* buttons to plot the graphs.
3) Adjust the horizontal scale, if required, and repeat,
4) Calculate RC time constant.
5) Use CCS instead of OD1 to charge capacitor with constant current.

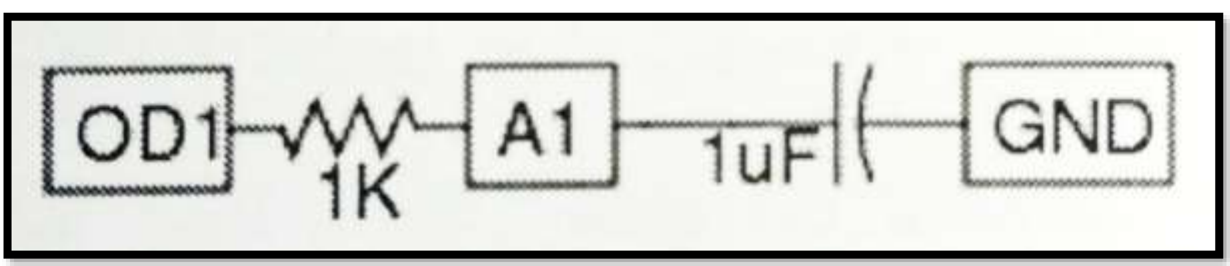

Figure 5 : Connection digram for RC circuit

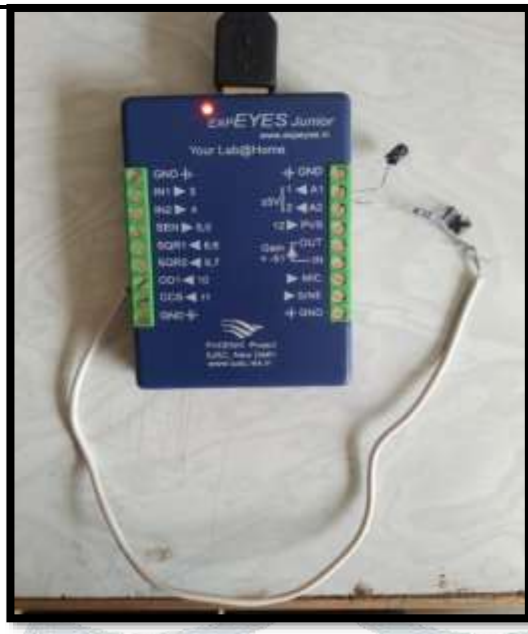

Figure 6 : Actual connections for RC circuit

Table 3: Observation table for RC circuit

SR.NO.	Resistance	Capacitor	RC time constant calculated	RC time Constant observed
1.	1 K	1 µF	1 m sec	0.94 m sec
2.	2.2 K	1 µF	2.2 m sec	2.03 m sec
3.	10 K	1 µF	10 msec	9.02 m sec
4.	51 K	1 µF	51 msec	49.08 m sec

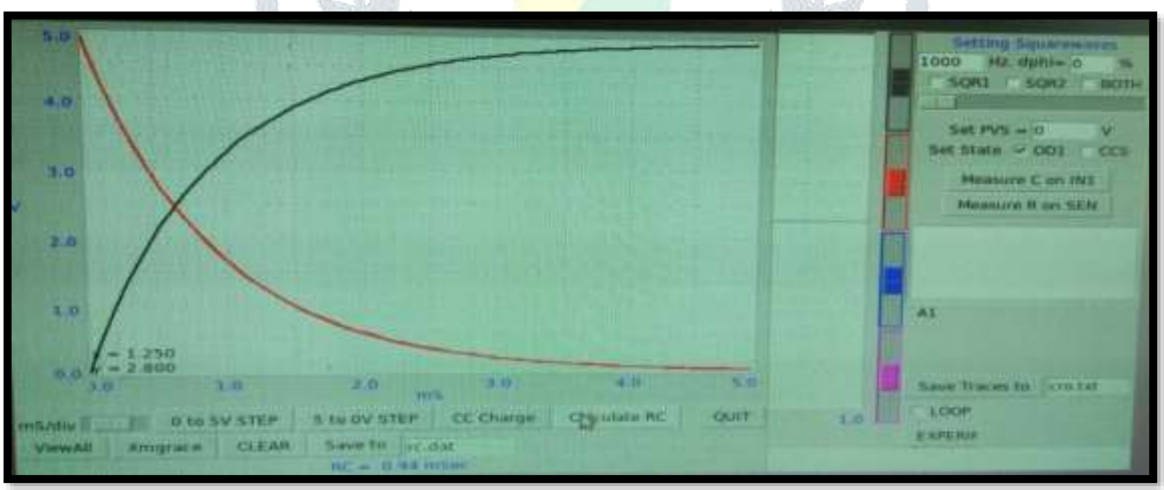

Figure 7: Charging discharging observed on plot window.

Experiment 2: Transient Response of LR circuit

Aim: To **e**xplore the nature of current and voltage when a voltage step is applied to resistor and inductor in series. By measuring the voltage across the inductor as a function of time, we can calculate its inductance.

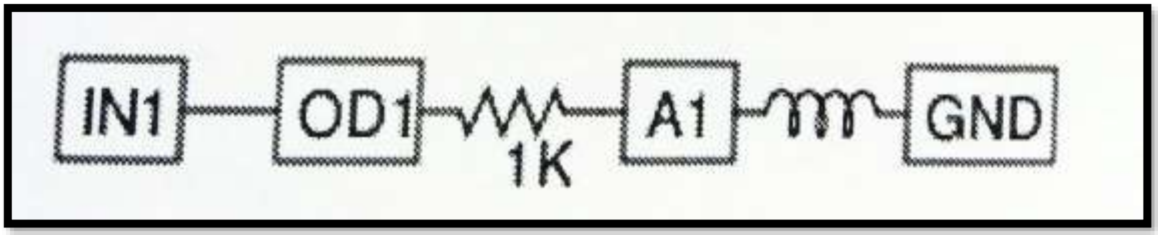

Figure 8 : Connection of LR circuit

Procedure:

1) Make connections as shown in figure 8 and 9.
2) From **EXPERIMENTS** select **LR circuit.**
3) Click on *0>5 step* and *5>0 step* buttons to plot the graph.
4) Adjust the horizontal scale, if required, and repeat.
5) Calculate the value of Inductance.

Figure 9 : Actual connections of LR circuit

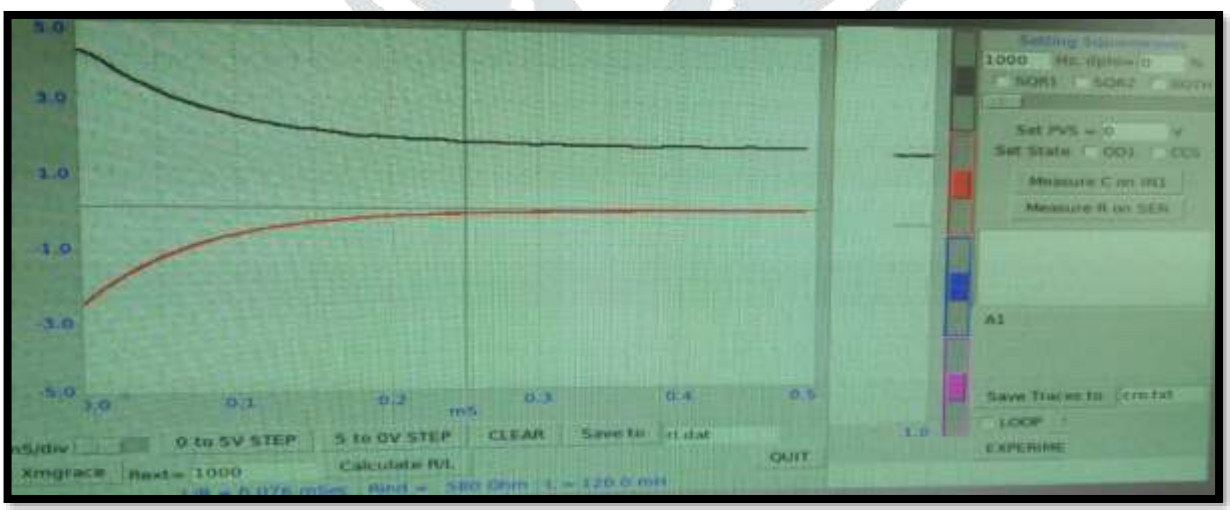

Figure 10 : Plot window for LR circuit

Table 4: Observation table for LR circuit

SR.NO.	Resistance value used	Inductor value observed	$\frac{L}{R}$ time constant	Actual inductor value
1.	580 ohm	120 m H	0.076 m sec	100 mH
2.	2.2 K	54.5 m H	0.043 m sec	50 mH
3.	10 K	10.6 m H	0.010 m sec	10 mH

Experiment 3: Transient Response of LCR circuit

Aim: To study the oscillatory nature of L and C in series. Resonant frequency of series LC circuit is given by $\omega_0 = \frac{1}{2\pi\sqrt{LC}}$.

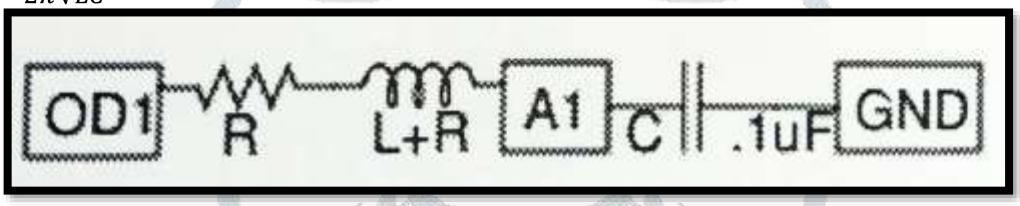

Figure 11: Connection for LCR circuit

Figure 12: LC series circuit actual connection

Procedure: 1) From EXPERIMENTS select LCR discharge.
2) Click on 5>0 V step. Adjust x-axis and repeat if required.
3) FIT the graph to find the resonant frequency & Damping.
4) Repeat the experiment with different values of L, C & R.

Table 5: Observation table for LCR circuit

SR.NO.	Capacitor	Inductor	Resonant frequency observed	Resonant frequency(calculated)
1.	0.1µF	125 mH	1.60 KHz	1.42 KHz
2.	0.01µF	125 mH	4.51 KHz	4.50 KHz

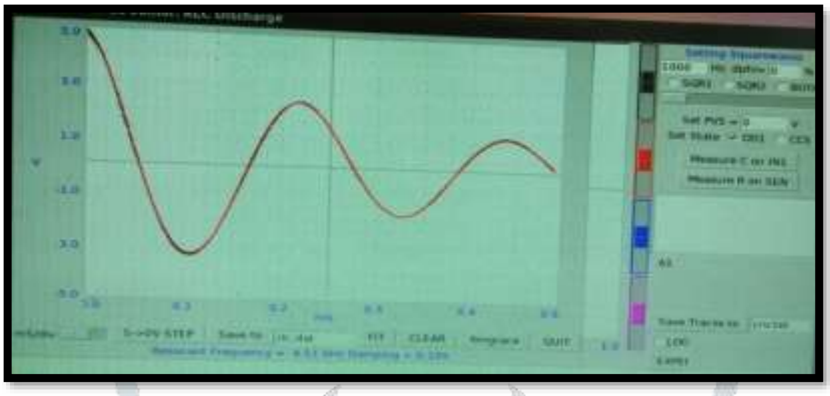

Figure 13 : Plot window for LCR circuit

Experiment 4: RC Integrator and Differentiator
Aim:-To study RC circuits as integrator or differentiator. A square wave is integrated to get a triangular wave and differentiated to get spikes at the transitions.

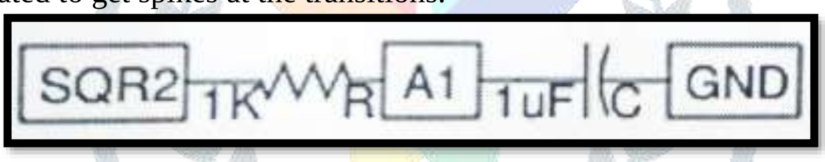

Figure 14: RC Integrator

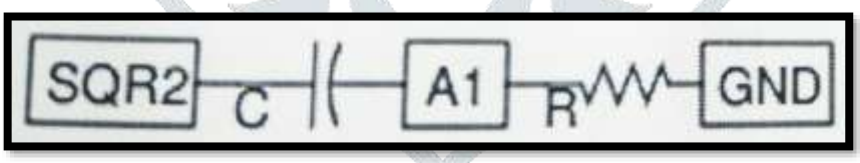

Figure 15: RC Differentiator

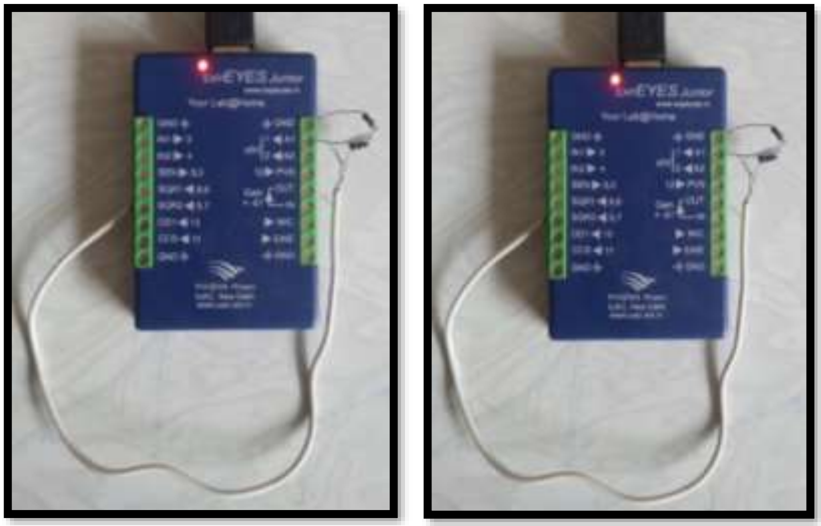

Figure 16: Actual connections of RC integrator and Differentiator

Procedure:- 1) Set SQR2 to 1000HZ
2) Assign SQR2 to CH1 and A1 to CH2.
3) Adjust the horizontal scale to view more than 4 cycles.
4) Set SQR2 to 1 kHz (T = 1 mS) and other values and view the waveforms.
5) Repeat the same for RC differentiator, at 100 Hz.

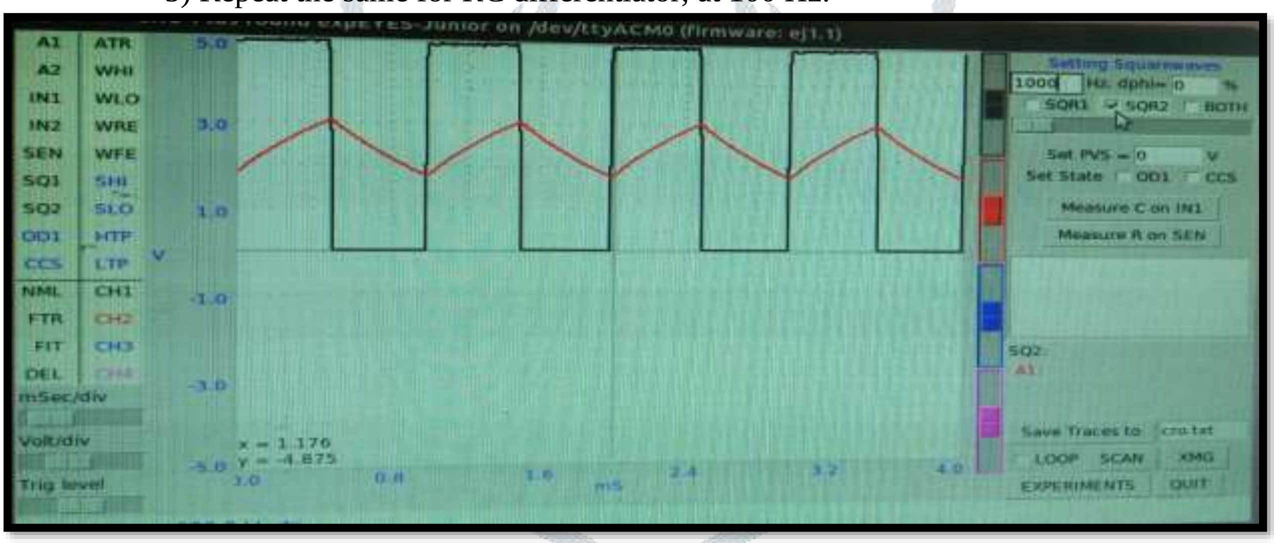

Figure 17 : Plot window for RC integrator

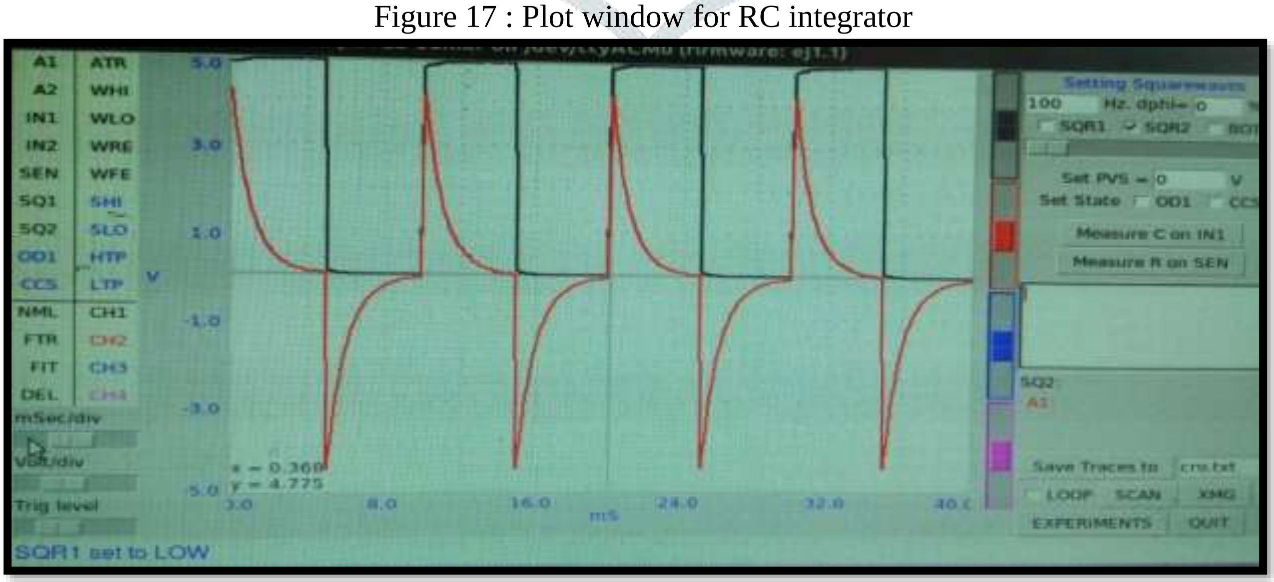

Figure 18 : Plot window for RC differentiator

Experiment 5: Diode Characteristics
Aim: To study forward IV characteristics of diode.

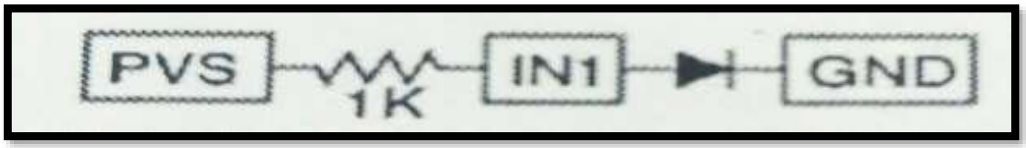

Figure 19: Connection for Diode characteristics

Procedure: 1)From EXPERIMENTS select Diode IV,
2) Click on START to draw the characteristic curve.
3) Click on FIT
4) Plot the IV curve of LED's.

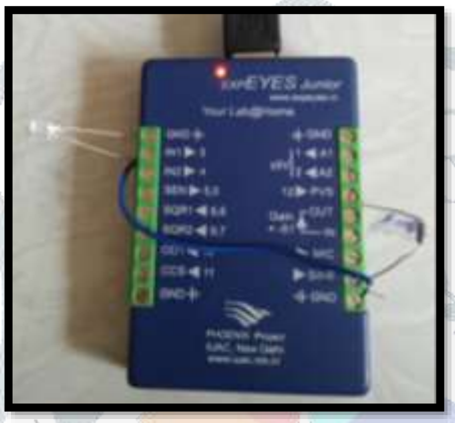

Figure 20: Actual connection to study Diode characteristics

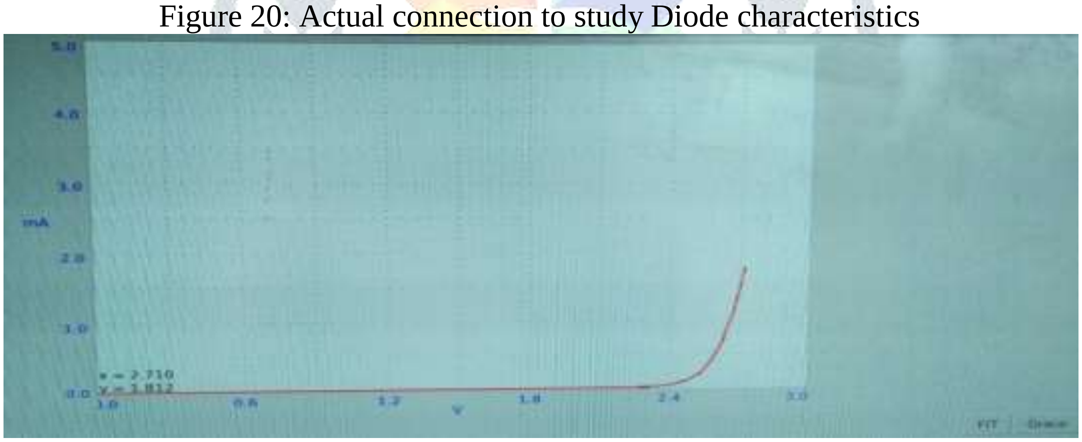

Figure 21: Iv characteristics seen on plot window.

Experiment 6: Capacitance measurement
Aim: To study Capacitance measurement using expEYES Junior.
Procedure: The expEYES junior has an internal programmable current source that can be enable on IN1.For better results stray capacitance must be subtracted. Measure C without connecting anything to IN1, and subtract the stray capacitance.

1) Measure C without anything connected, to get stray capacitance.
2) Connect the capacitor from IN1 to GND.
3) Click on button ***Measure C on IN1.***
4) Repeat with different capacitors.

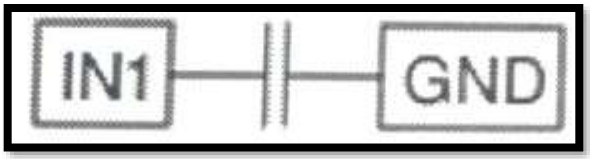

Figure 22: Capacitance measurement

Figure 23: Actual Connection for C measurement

Table 6: Capacitance measurement
Without connecting anything = stray capacitance = -0.6pF

Sr.No.	Capacitance Values connected	Observed Values	Corrected value =Observed value –(-0.6)
1.	8.2 pF	7.2 pF	7.8 pF
2.	10pF	8.7 pF	9.3 pF
3.	12pF	11.1 pF	11.7 pF
4.	22pF	21.1 pF	21.7 pF
5.	33 pF	28.2 pF	28.8 pF
6.	56 pF	54.4 pF	55 pF
7.	68 pF	62.5 pF	63.1 pF
8.	82 pF	83 pF	83.6 pF
9.	220 pF	224.5 pF	251.5 pF
10.	470 pF	448.8 pF	448.4 pF
11.	3300 pF	3192.2 pF	3192.8 pF
12.	10000 pF	9336.5 pF	9337.1 pF

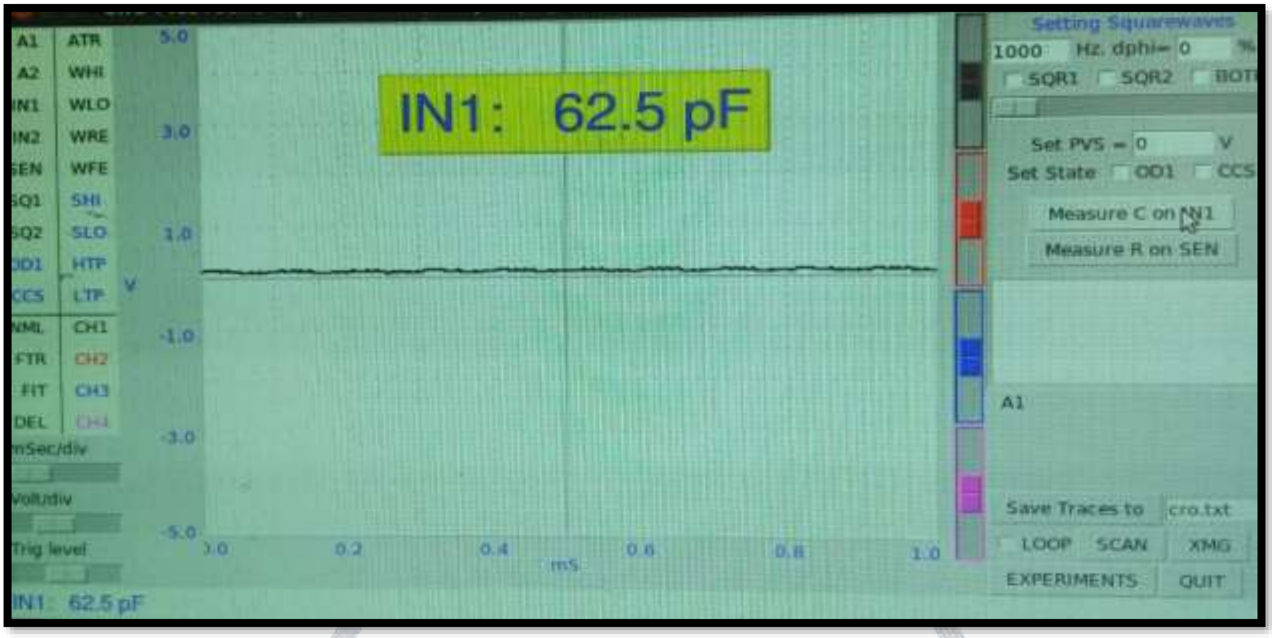

Figure 24: Plot window for capacitance measurement

VI. Measurement of Dielectric constant

Here we have used two equal pieces of copper clad. Having area of 7.5cm x 7.5cm.These two metal foils are kept to be parallel to each other by some suitable distance. The space between these two plates is filled by dielectric material. The capacitance between plates is measured in absence and in presence of material. The ratio of these capacitance values gives dielectric constant of material. Various materials of various thickness are been used to calculate the dielectric constant ‘K’.

Figure 25: Copper plates

Figure 26: Dielectric materials for measurement

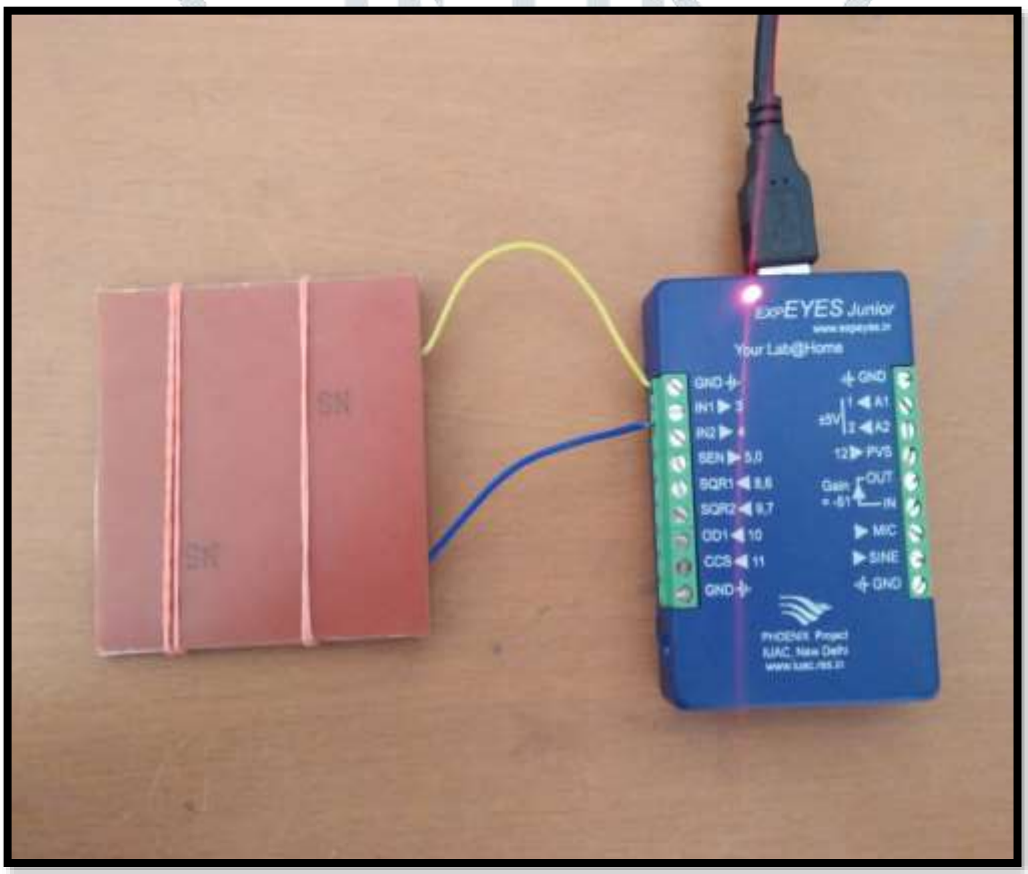

Figure 27: Measurement of stray capacitance

Table 7: Capacitance and Dielectric constant calculation
Stray capacitance = 0.9 pF

SR.NO	Material	C in pF in presence of material +(0.9)	C_{air} in pF	$k = \frac{C}{Cair}$	Standard Value of k
1.	Air	34+0.9= 34.9pF	34.9 pF	1	1
2.	Plain Paper	45.9+0.9 = 46.5pF	34.9 pF	1.33	2 - 6
3.	File Paper	51.6+0.9 = 52.5 pF	34.9 pF	1.50	2 - 6
4.	Plastic	40.3+0.9 = 41.2pF	34.9 pF	1.180	1-3
5.	Rubber	103.7+0.9 = 104.6pF	34.9 pF	2.997	3
6.	Ceramic	29+0.9 = 29.9pF	34.9 pF	6.01	2-40
7.	Glass	105.6+0.9 = 106.5pF	34.9 pF	4.27	3.7 - 10

VII. CONCLUSION

In this paper we have studied how to use the expEYES KIT for performing various experiments on small scale. This KIT gives us the simpler techniques to perform several experiments. We have performed several experiments such as measuring resistance, capacitance, RC, LR, LCR circuits, integrator and differentiator circuits, diode characteristics. We found that performing these experiments on the expEYES kit is much easy as compared to the laboratory connections.

Here we have designed the applications using expEYES KIT. We measured the capacitance and then designed one of its applications of measuring the Dielectric Constant. This Dielectric Constant of various material was been measured and using this expEYES KIT we got satisfactory results comparing the theoretical value. So this expEYES KIT is been useful for measuring many other quantities and designing various types of applications.

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