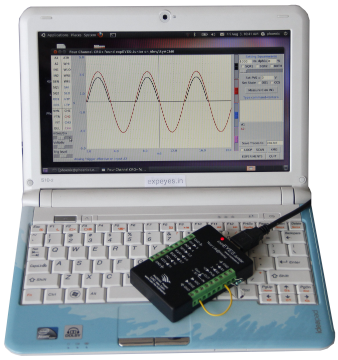
expEYES Junior



User's Manual

Experiments for
Young Engineers and Scientists

http://expeyes.in

from

PHOENIX Project
Inter-University Accelerator Centre
(A Research Centre of UGC)
New Delhi 110 067
www.iuac.res.in

Giriş

PHOENIX (Ev Yapımı Aletlerle Yenilikçi Deneyler) projesi Hindistan Inter Üniversitesi Hızlandırıcı Merkezi tarafından Hindistan Üniversitelerindeki bilim eğitimini geliştirmek amacıyla 2004 yılında başlatılmıştır. Düşük bütçeli laboratuvar deney aleti geliştirmek ve öğretmenleri eğitmek bu projenin iki temel amacıdır.

expEYES Junior, daha önce tasarlanmış olan expEYES'ın değiştirilmiş halidir. Bu alet, lise ve daha yüksek eğitim seviyesindeki sınıfların keşfederek öğrenmesi için tasarlanmıştır. Bu aletin tasarlanırken; basit, her ortama uyarlanabilen, dayanıklı ve düşük bütçeli olması çalışılmıştır. Alet düşük bütçesi ile herkese hitap etmektedir. Öğrencilerin, duvarla kapalı olan ve zil çaldıktan sonra kapanan laboratuvarın dışına çıkıp deneyleri gerçekleştirmesini umuyoruz.

Alet donanımı açık kaynak koduna sahiptir. Yazılımı, GNU Genel Halk Lisansına sahiptir. Bu aleti kullanan IUAC dışındaki toplulukların ve birçok insanın katkısı bu projenin yol almasına neden olmuştur. Bu belgedeki deneyleri birbirinden bağımsız olarak gerçekleştirerek, hataların düzeltilmesinde yardımcı olan S Venkataramanan ve Prof. R Nagarajan'a teşekkür ederiz.

 Bu proje hakkında daha fazla bilgi için *expeyes.in* sayfasını ziyaret ediniz.

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İçindekiler

Bölüm 1

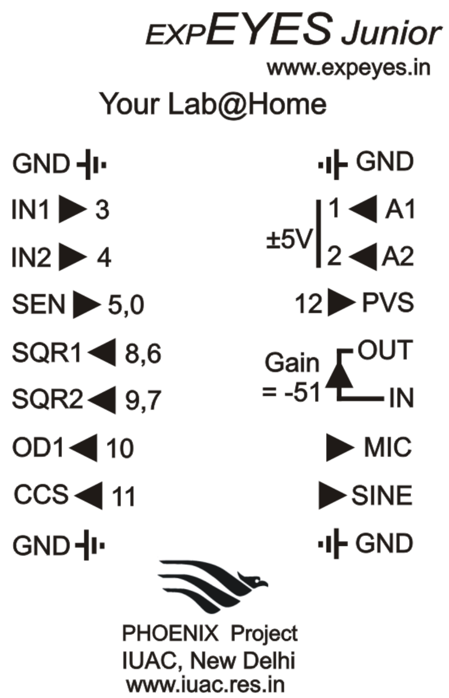
Başlarken

1.1 Giriş

Bilim, fiziksel dünyanın sistemli olarak gözlemlenmesi ve deneylerin yapılmasıdır. Batıl inanç ve körü körüne inanmanın yerine mantıklı düşünmenin oluşması için uygun bilim eğitimi gereklidir. Bilim eğitimi, Teknikerlerin, mühendislerin ve bilim adamlarının eğitimi günümüz dünyası ekonomisi için de gereklidir. Öğretmenler tarafından yapılan gösteri deneyleri ya da öğrenciler tarafından gerçekleştirilen deneyler pedagojik açıdan kişilerin deneyim kazanması açısından önemlidir. Fakat bilim çoğunlukla deney yapılmadan çoğunlukla kitaplardan öğretilmektedir. Bunun sonucunda, birçok öğrenci sınıfta elde ettiği deneyim ile günlük hayatta karşılaştığı sorunlar arasında bağlantı kurmada başarısız olmaktadır. Bilim eğitiminin keşif ve deney tabanlı olması ile bu bir ölçüde düzeltilebilir.

Kişisel bilgisayarların keşfi ve bunların kolay erişebilir olması, laboratuvar deney aleti yapılması için yeni yollar açtı. Bilgisayarlara bazı donanım eklenerek, bilgisayarlar bilim laboratuvarına çevrilebilir. Hızlı bir şekilde deneylerin iyi bir doğrulukla yapılması, doğadaki birçok olayın çalışılmasını mümkün kılar. Genelde bilim deneyleri, sıcaklık, basınç, hız, voltaj, akım gibi değerlerin ölçülmesini ve kontrol edilmesini kapsar. Eğer ölçülen fiziksel özellik hızlı bir şekilde değişiyorsa, ölçümlerin otomasyonu sağlanmalıdır. Bilgisayar bu durumda faydalı bir alet olur. Örneğin, AC'nin (Değişken Akım) değişimini anlamak için mili saniyeler aralıklarında ölçüm almak gerekir.

Kabül edilebilir doğrulukla deneyleri gerçekleştirmek, araştırma temelli bilim eğitiminin kapısını açar. Öğrenciler, elde ettikleri deneysel verileri matematik modeller ile karşılaştırabilir ve çevremizdeki birçok doğal olayı inceleyebilir. Bu, bilim araştırmacalarının daha karmaşık aletlerle yaptıkları deneylere benzerlik göstermektedir. expEYES(expEriments for Young Engineers & Scientists- Genç Bilim Adamları ve Mühendisler için Deneyler) seti, okuldan üniversite sonrası eğitime kadar geniş aralıktaki deneyleri desteklemek için tasarlanmıştır. Aynı zamanda elektrik-elektronik mühendislerinin ve hobicilerin bunu test aleti olarak kullanmasını sağlar. expEYES'in basit ve açık kaynak kodlu olması, kullanıcıların *detaya inmeden yeni deneyler geliştirmesine) olanak verir.* Bu kullanıcı kılavuzu expEYES Junior'ı birkaç deney ile birlikte açıklar. Bu kılavuza ek olarak, programcı kılavuzu da mevcuttur.



Şekil 1.1: ExpEYES Junior'un üst yüzeyinin her iki tarafındaki bağlantılarının şekli. Bazı uçların üzerindeki numaralar, program yazarak bu uçlara erişmek isteyenler için verilmiştir. Oklar, sinyallerin yönünü göstermektedir. Örnek olarak $A1 \Rightarrow 1$ oku, A1 ucuna verilen sinyalin, 1 numaralı kanala gittiğini göstermektedir.

1.2 Donanım

expEYES Junior, bilgisayarın USB portundan güç alır ve bu portu kullanarak bilgisayar ile iletişime geçer. Dış sinyalleri bağlamak içinse, şekilde gösterildiği gibi 1.1 her iki tarafta birkaç tane giriş/çıkış uçlarına sahiptir. expEYES, bu uçları kullanarak voltaj değişimlerini izleyebilir ve kontrol edebilir. Diğer değişkenleri (sıcaklık, basınç vb.) ölçebilmek içinse, bunları uygun algılayıcılar kullanarak elektrik sinyallerine çevirmek gerekir.

Temel amacımız deney yapmak olsa bile, aşağıda verilen donanımın kısa bir açıklamasını okumanız tavsiye edilir. Bu cihaz, elektrik-elektronik mühendislik deneyleri için de kullanılabilir.

ÖNEMLİ : *expEYES'in uçlarına bağlanan voltaj değerleri izin verilebilen değerler arasında olmalıdır. A1 ve A2 girişlerinin voltaj değerleri ±5 voltaj aralığında; IN1 ve IN2 değerleri ise 0'dan 5V'a kadar olmalıdır. Bu değerleri azıcık aşmak cihazın hata mesajı vermesine yol açacaktır. Eğer program donarsa, USB kablosunu çıkarıp, yeniden takarak cihazı başlatınız. Daha büyük voltaj değerleri ise cihaza kalıcı bir hasar verecektir. Daha yüksek voltajları ölçmek için, potansiyel bölücü devre kullanarak bu voltajları 5V'un altına düşürün.*

1.2.1 Expeyes'in Uçları

Giriş/Çıkış uçları kısaca aşağıda açıklanmıştır.

Programlanabilir Voltaj Kaynağı (PVS) : Bu ucun değeri, yazılım kullanarak 0 ile +5V arasında herhangi bir değere ayarlanabilir. Bu voltajın çözünürlük değeri 12 bittir ve bu da her bir voltaj değeri arasındaki değer farkının 1.25 milivolt'dan küçük olamayacağını işaret eder. Bu uç tekrak okuma özelliği sayesinde PVS değerini doğrular.

$\pm 5V$ **Analog Girişler (A1 & A2) :** Bu uçlar, ±5 voltar aralığındaki voltaj değerlerini ölçebilir. Bu ucun ADC (Analog Dijital Çevirici) değeri 12 bit'tir. Bu uçlardaki voltaj değerleri zamana bağlı olarak bilgisayar ekranında gösterilebilir. Bu da cihazın düşük frekansta osiloskop olarak kullanılmasını sağlar. Bu oskilloskopun en yüksek örnekleme değeri saniyede 250,000 dir. Herbirinin giriş direnci $10M\Omega$ dır.

$0 - 5V$ **Analog Girişler (IN1 & IN2):** Bu uçlar 0 ile 5V arası voltaj değerlerini ölçebilir.

Dirençsel Algılayıcı Girişi(SEN): Bu uç, Işık Orantılı Direnç, Isı Orantılı Direnç (Thermistor), Foto-Transistör gibi algılayıcılar için tasarlanmıştır. SEN'in ucu içindeki $5.1k\Omega$'lık direnci ile 5V'ta bağlanır. Bu uç aynı zamanda gömülü analog karşılaştırıcıya sahiptir.

Dijital Girişler (IN1 & IN2): IN1 ve IN2 girişleri analog ve digital girişler olarak kullanılabilir. Dijital giriş

Dijital Çıkış (OD1) : expEYES'in yazılımı kullanılarak OD1 Voltaj değeri 0 veya 5 volta ayarlanabilir.

Kare Dalga Üreticisi SQR1 & SQR2 : Bu uçların çıkışları 0'dan 5 volta kadar değiştirilebilir. Frekans ise 0.7Hz'den 100kHz'e kadar ayarlanabilir. Bu aralık içindeki bütün frekans değerleri mümkün değildir. SQR1 ve SQR2 birbirinden farklı frekans değerlerine ayarlanabilir. Bunları birbirleriyle belli bir faz farkı olacak şekilde aynı frekansa ayarlamak mümkündür. Bu çıkışlar, darbe genişliği değişebilecek şekilde de programlanabilir. SQR1, geri okumalı olarak kanal 6'ya; SQR2 ise kanal 7'ye bağlanmıştır.

Frekansı 0Hz'ye ayarlamak çıkışı yüksek (5V), -1'e ayarlamak ise çıkışı düşük(0V) yapacaktır. Her iki durumda da dalga üretimi devredışı bırakılmış olur. Bu iki çıkış devre dışı bırakıldığında, SQR1 ve SQR2, kanal 8 ve 9 için dijital çıkıs olarak davranır.

SQR1'in çıkışı 100Ω ***series resistor*** direnç değerine sahiptir. Böylece bu çıkışa bağlanan bir LED'i direk olarak çalıştırabilir.

Kızılötesi İletim SQR1'e bağlanacak bir kızılötesi (IR, infrared) diyot ile bu uç IR iletişim sağlayabilir. 4 byte'lik iletişim ile bu uç bir TV kumandası gibi davranabilir. Bu uç 1 byte'lik iletişimi de destekler. Bu iletişim 1 byte'lik iletişimi destekleyen mikroişlemciler tarafından alınabilir. [1].

Sinüs Dalgası: Bu uç sabitlenmiş 150 Hz'lik frekans değerinde bir sinüs dalgası üreticidir. Bu çıkış genliği 4V olan çift kutuplu(+4V,-4V) bir dalga üretir.

Sabit Akım Üretici (CCS) : Sabit akım üreticisi, yazılım tarafından açılıp kapanabilir. Bu akımın yaklaşık değeri 1mA dir, fakat bu değer elektronik parçalarındaki hata payı yüzünden herbir cihazda farklılık gösterebilir. Bu akımın tam değerini ölçmek için, CSS'den GND'ye bir akım ölçer takın. Diğer bir yöntem ise değeri bilinen bir direnç (~3.3k) kullanarak, direnç üzerindeki voltaj değerini ölçmektir. Bu direncin değeri 4k değerinden daha düşük olması gereklidir.

Mikrofon (MIC) : Cihaz'ın yan tarafında, CCS'ye yakın dahili bir mikrofon vardır. 51 kere yüksetilen bu çıkış, MIC çıkışına verilir. Bu çıkışı gözlemlemek için A1 veya A2 uçları kullanılabilir.

Ters Çevirici Yükseltici (IN->OUT) : Bu uç, ters çeviricili (evirici) yükselteç görevini görür. Yükselteç (Op-Amp) olarak TL084 yongası (chip) kullanılmıştır. Rf = 51000 ve Ri = 1000, direnç değerleri kullanarak bu ucun en yüksek kazanç değeri $\frac{51000}{1000} = 51$ olarak bulunur. Bu değer giriş ucuna bir direnç bağlanarak azaltılabilir. Örnek olarak bu girişin ucuna bağlanacak 50k'lık bir direnç ile, kazancı 1 olan bir tersleyici yükseltici yapılabilir.

Ground : GND olarak işaretlenen uçlar toprak anlamına gelmektedir. Bütün ölçülen voltajlar bu uçlara göre ölçülmektedir.

1.2.2 Cihaz ile Birlikte Gelen Parçalar

Bu cihaz ile birlikten gelen parçaların resmi bu kılavuzun arka kapağında gösterilmiştir.

- Timsah ağızlı bağlantı kabloları (4) : Eğer uçlar arasındaki bağlantılar deney sırasında sıkça değiştirilirse, timsah ağızlı kabloları kullanarak bağlantılar kolayca yapılır.
- 3000 Sarımlı Bobin (2) : 44SWG(0.0813 cm yarıçaplı standart ölçüde kablo), İndüksiyon'u yaklaşık 125 mH, Direnci $\approx 500\ \Omega$. Bu bobinler indüksiyon, elektromanyetik indüksiyon, vb. çalışmalarında kullanılabilir.
- Piezo Elektrik Diskleri (Basınç duyarlı voltaj üreteçleri) (2) : Rezonans frekansı yaklaşık 3500 Hz. dir. Bu disklere SQR1 veya SQR2 ile enerji verilir. Diskler plastik bir kılıf içine yerleştirilmiştir. Bu kılıfın içinde oluşan oyuk, disk tarafından oluşturulan sesin genliğini arttırır.
- DC (Doğru Akım) Motor : Bu motor 3 volt'dan daha az bir doğru akım gerilimle çalıştırılmalıdır.
- Mıknatıs : (a) 10mm yarıçap & uzunluğunda (b) 5 mm yarıçap & 10 mm uzunluğunda (c) Düğme boyutunda mıknatıs (2)

[1] http://expeyes.in/micro-controllers-for-hobby-projects-and-education

- 5mm LEDS : KIRMIZI, MAVİ, YEŞİL, BEYAZ
- Kapasitörler : 47uF, 1uF, 0.1uF & 0.01 uF
- Dirençler : 560Ω, 1$k\Omega$, 2.2$k\Omega$, 10$k\Omega$, 51$k\Omega$ and 200 $k\Omega$
- LDR(Işığa Duyarlı Direnç) & Thermistor(Sıcaklığa Duyarlı Direnç)
- İki Silikon Diyot (1N4148) and 1 Transistor(2N2222)
- 5 tane 8cm uzunluğunda

1.3 Software Installation

ExpEYES can run on any computer having a Python Interpreter and a Python module to access the Serial port. The USB interface is handled by the device driver program that presents the USB port as an RS232 port to the application programs. The communication the expEYES is done using a library written in Python language (also available in C language). Programs with GUI have been written for many experiments. There are many ways to get the software running:

The expEYES Live CD

The easiest way to get started is to boot your PC with the expEYES Live-CD. From the PC BIOS, make the CD drive as the first boot device, insert the live CD and reboot the PC. A desktop will appear and you can start expEYES Junior from the menu **Applications->Science**->EYES-Junior. You can also start it from a Terminal using the command:

```
$ python /usr/share/expeyes-junior/croplus.py
```

Installing on Debian or Ubuntu GNU/Linux distributions

Download **expeyes-3.0.0.deb** , or higher version, from the software section of **http://expeyes.in** and install it. It depends on python-serial, python-tk, python-scipy and grace (a 2D plotting program).

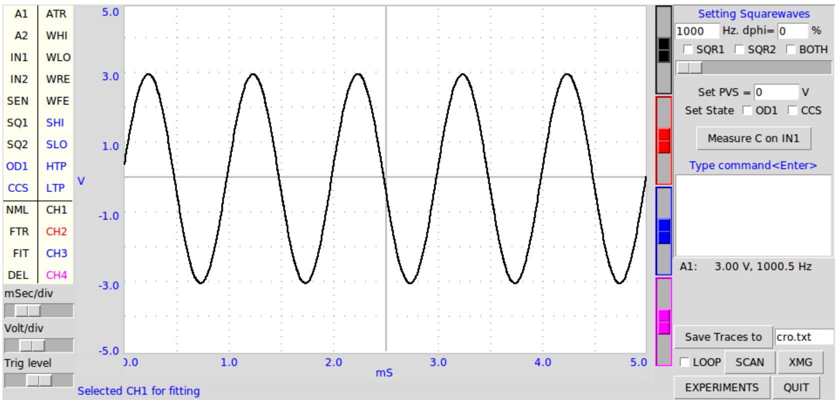
For other GNU/Linux distributions

Download **expeyes-3.x.x.zip** from **http://expeyes.in** and follow the instructions in the README file. It is important to give read/write permissions for all users on the USB port where expEYES is connected. This can be done by running the *postint* shell script, included in the zip file.

On MSWindows

Even though expEYES is Free Software and is developed using Free and Open software, it runs on non-free platforms also. To install it on MS windows, you need (1) MCP2200 drivers (2) Python-2.x version, python-serial, python-tk, python-numpy and python-scipy (3) expeyes-3.x.x.zip

Unzip the file **expeyes-3.x.x.zip**, and double click on **croplus.py** inside the newly created directory named expeyes-3.x.x\eyes-junior. If you have expEYES



Şekil 1.2: The croplus screen showing a sine-wave connected to A1.

liveCD, browse inside the directory names WINEYES. All the files mentioned above are inside that directory. Double click on them in the order mentioned above to install them. See the software section on the expeyes website for more details.

1.4 The main GUI program

Start Applications->Science->EYES-Junior from the menu. A four channel oscilloscope screen with several extra features will open as shown in figure 1.2. The **EXPERIMENTS** button pops up a menu of programs for several experiments. The main window will become inactive when an experiment is selected and running.

The Plot Window

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,IN2,SEN and read backs of SQR1 & SQR2) are shown. *Clicking on any of them will display the voltage/logic level present.* To plot any of them, drag it to the desired channel (CH1 to CH4). The names of inputs selected for display are shown on the right side of the plot window, using a unique color for each channel.

- For online help, place cursor on any item, press and hold the left mouse button.

- Dragging ATR to any of the inputs will make it the CRO trigger source.

- This program allows different types of triggering. For example, dragging WRE to IN1 will enable rising edge triggering on it. It also supports setting levels or generating pulses on Digital outputs just before capturing the waveform. Dragging SHI to OD1 will keep OD1 HIGH during the capture process. For more details refer to the programmers manual.

- Dragging any of the channels, CH1 to CH4, to FIT will enable calculating amplitude and frequency by fitting the data using the equation $V = V_0 \sin(2\pi f t + \theta) + C$, V_0 and f will be displayed. Dragging the channel to NML will disable the FIT option.

- Right clicking on IN1, IN2, SEN, SQR1 or SQR2 will measure the frequency and duty cycle of the voltage waveform present at the terminal.

- If two adjacent channels are assigned, Right-clicking on the first will calculate frequency and phase difference between the two inputs.

- Dragging a channel to FTR will show the Fourier Spectrum of the waveform in a separate window.

- To remove a displayed input, drag it to DEL.

- Horizontal scale (ms/division) adjustment. Set this to the minimum value and increase to view more number of cycles on the screen. Drag the rider or click on the left/right sides of it.

- Vertical scale (volts/division). Maximum values is 5 volts per division.

- Vertical offset sliders are provided for each channel to shift the trace up or down.

- The Check button LOOP selects Single/Continuous mode of scanning.

- The traces can be transferred to an Grace plot window, using XMG.

- SAVE button to save the data to the specified file in two column text format.

In addition to the CRO features, you can also control SQR1, SQR2, PVS etc. from the GUI. You can execute Python functions to access the hardware from a command window.

- For the Square waves , the frequency and phase difference in percentage are entered in two text fields. SQR1 & SQR2 can be set to different frequencies or to a single frequency with desired phase difference. Re-activate the check buttons after changing frequency or phase difference.

- SQR1 can be set using a slider also.

- To Set PVS, type the voltage (0 to 5) and press Enter key. The PVS output has a readback and the read back value is displayed in the message field.

- Checkbuttons 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.

1.5 Basic measurements using expEYES

Before proceeding with the experiments, let us do some simple exercises to become familiar with expEYES Junior. Boot your computer from the LiveCD, connect the device a USB port and start the EYES-Junior program from the menu 'Applications->Science'.

1.5.1 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.

1.5.2 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 to 100 and Check SQR1.
- Assign SQR1 to CH2
- Change frequency. Uncheck and Check SQR1.
- Explore the FIT and FTR options.

1.5.3 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

1.5.4 Accuracy and resolution

Figure 1.2 shows a 3V, 3000.5 Hz sine wave from an Agilent 33220A Function generator, connected to A1. The voltage at IN1 is measured as 3.000 by a Keithley 2100 multimeter, off by 2mV. The frequency of audio frequency sine wave is measured with less than 0.1% error. The voltage measurement has 12 bit resolution but the absolute accuracy may change slightly with ambient temperature.

[2] *For information about all the commands, refer to the Programmer's manual*

1.6 Experiments

The expEYES hardware can generate/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 chapters describe experiments from different topics like electricity, magnetism, electronics, sound, heat etc. Since the expEYES kit is meant for self learning, we have included some very trivial experiments in the beginning.

Bölüm 2

Electricity

We start with the simple task of measuring the voltage of a dry-cell. Current and resistance are introduced next, followed by resistances changing with temperature and light. The concept of Alternating Current is introduced by plotting the voltage as a function of time. The behavior of circuits elements like capacitors and inductors in AC and DC circuits are explored, by measuring parameters like amplitude, frequency and phase. The transient response of a resistor and capacitor in series is used for measuring the capacitance. Inductance also is measured in the same manner. The Fourier analysis of waveforms are done to study the harmonics. Integration and differentiation of a square wave using RC circuits also is explored.

For each experiment, make connections as per the diagram given.

2.1 Measuring Voltage

Objective

Learn to measure voltage using expEYES and get some idea about the concept of Electrical Ground. A dry-cell and two wires are required.

Procedure

- Click on A1 to display the voltage
- Repeat by reversing the cell connections.

Observation

Voltages measured value is +1.5 volts and it becomes -1.5 after reversing the connections.

We are measuring the potential difference between two points. One of them can be treated as at zero volts, or Ground potential. The voltage measuring points of expEYES measure the voltage with respect to the terminals marked

GND. We have connected the negative terminal of the cell to Ground. The positive terminal is at +1.5 volts with respect to the negative terminal. *Will it show correct voltage if GND is not connected ?*

If the input voltage is within 0 to 5V range, use IN1, which is directly connected to the ADC input. Resolution of bipolar inputs A1 and A2 are half of that of IN1. The offset and gain errors of the level shifting amplifiers also affect the accuracy of A1 & A2.

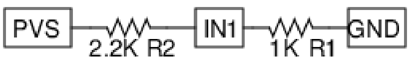
2.2 Voltage, current & resistance

Objective

Learn about Current, Resistance and Ohm's law, using a couple of resistors. 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

$$V \propto I \ ; \ \ V = IR \ \ or \ \ R = \frac{V}{I}$$

Procedure



- 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 $V_{R1} = IR1$.

V_{PVS}	$V_{IN1} = V_{R1}$	$I = \frac{V_{IN1}}{1000}$ A	$V_{R2} = V_{PVS} - V_{IN1}$	$V_{R2} = I \times 2.2k$
1	.313	.313	.687	.688
2	.626	.626	1.374	1.377
3	.94	.94	2.06	2.07

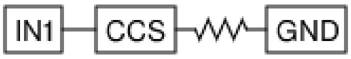
Expand this experiment by connecting three resistors in series and connecting the junctions to IN1 and IN2. Another exercise is to connect a $5.1k$ resistor from SEN to GND and measure the voltage at SEN. Remember that SEN is internally connected to 5 volts through a $5.1k$ resistor.

2.3 Calibrating Current Source

Objective

The actual output of constant current source may be different from the specified 1 mA, due to the tolerance of the resistors used. It can be measured by connecting an ammeter from CCS to GND, or by connecting a known resistance to CCS and measuring the voltage across it. The resistor should be in 2k to 4k range.

Procedure



- Enable CCS

Observation

The measured values of the resistance is 3.876k and the voltage is 3.725 volts. The actual value of the constant current source is $3.725/3.876 = .961$ mA.

For better accuracy, the measured value should be used in experiments using CCS.

2.4 Resistances in series

Objective

Finding the effective resistance of a series combination of resistors, $R = R1 + R2 + \cdots$, using a constant current source. A 560Ω and a$1k\Omega$ resistors are used.

Procedure

- Connect R1, R2 alone and then both
- Measure IN1 for each case

Observation

R(Ω)	V(volts)
560	.558
1000	0.998
1000+560	1.556

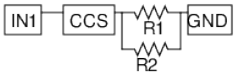
Since the current is same, the total voltage drop gives the effective resistance. It can be seen that it is the sum of the individual values, within the measurement error. For more accurate results, use the value of current measured as explained in section 2.3, instead of 1mA.

2.5 Resistances in parallel

Objective

Find the effective resistance of parallel combination of resistors, given by $\frac{1}{R} = \frac{1}{R1} + \frac{1}{R2} + \cdots$

Procedure



- Connect $1k\Omega$ resistor from CCS to Ground.
- Repeat the same with two resistors connected in parallel.

Observation

$R_{connected}(\Omega)$	$V_{measured}(V)$
1000	1.008
1000‖1000	0.503

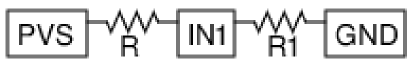
Since we know the current, we can calculate the resistance from the measured voltage. As per the measured voltage the resistance of the parallel combination is $\frac{0.503V}{0.001A} = 503\Omega$.

2.6 Measure resistance by comparison

Objective

Learn to apply Ohm's law to find the value of an unknown resistance by comparing it with a known one. Voltage across a resistor is given by $V = IR$. If same amount of current is flowing through two different resistors, the ratio of voltages will be the same as the ratio of resistances, $I = \frac{V1}{R1} = \frac{V2}{R2}$.

Procedure



- Connect the unknown resistor R from PVS to IN1.
- Connect $1k\Omega$ (R1) from IN1 to Ground.
- Set PVS to 4 volts.
- Measure voltage at IN1

Observation

Voltage at IN1 = 1.254, implies voltage across the unknown resistor is $4-1.254 = 2.746$

Current $I = \frac{1.254}{1000} = 1.254mA$. Unknown resistor value $= \frac{2.746}{1.254mA} = 2.19k\Omega$

What is the limitation of this method ? How do we choose the reference resistor ? suppose the unknown value is in Mega Ohms, what will be the voltage drop across a $1k\Omega$ reference resistor ? Our voltage measurement is having a resolution of $\frac{1}{4095}$.

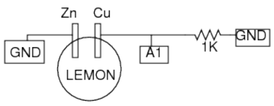
We will use this method later to measure the resistance of solutions, using AC.

2.7 Voltage of a lemon cell

Objective

Make a voltage source by inserting Zinc and Copper plates into a lemon. Explore the current driving capability and internal resistance.

Procedure



- Click on A1 to measure voltage
- Measure the voltage with and without the 1k resistor

Observation

Voltage across the Copper and Zinc terminals is nearly .9 volts. Connecting the resistor reduces it to 0.33 volts. When connected, current will start flowing through the resistor. But why is the voltage going down ?

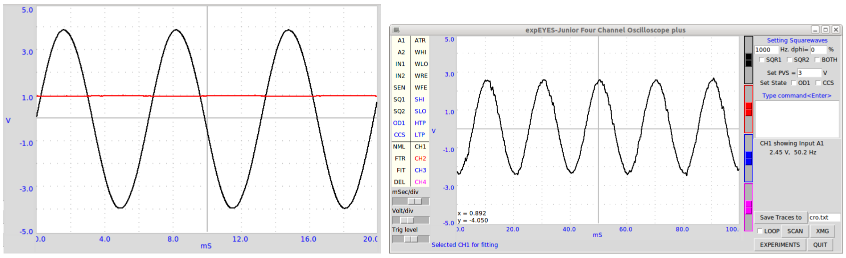
What is the internal resistance of the cell ?

Current is the flow of charges and it has to complete the path. That means, current has to flow through the cell also. Depending on the internal resistance of the cell, part of the voltage gets dropped inside the cell itself. Does the same happen with a new dry-cell ?

2.8 DC, AC and power line pickup

Objective

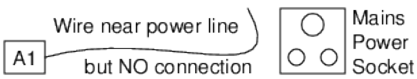
Introduce the concept of time dependent voltages, using a V(t) graph. Compare the graph of DC and AC. Learn about the AC mains supply. Explore the phenomenon of propagation of AC through free space.



Şekil 2.1: Plotting Voltage Vs Time. (a) graph of DC and AC (b) AC mains pickup

Procedure

- Assign A1 to CH1 and A2 to CH2
- Set PVS to 1 volt
- Assign CH1 to FIT, to measure AC parameters.
- Remove SINE and connect a long wire to A2



Observation

Figure 2.1(a) shows that the graph of DC is horizontal line and for AC it changes direction and magnitude with time. The voltage is changing with time. It goes to both negative and positive around 150 cycles per second. This voltage waveform is generated by using electronic circuits.

Enabling FIT option calculates the amplitude and frequency by fitting the data with the equation $V = V_0 \sin(2\pi f t + \theta)$, where V_0 is the amplitude and f is the frequency. What is the significance of θ in this equation ?

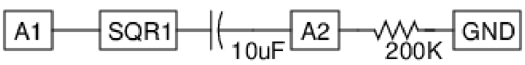
The power line pickup is shown in figure 2.1(b). The frequency is obtained by fitting the data. Without making any connection, how are we getting the AC voltage from the mains supply ?

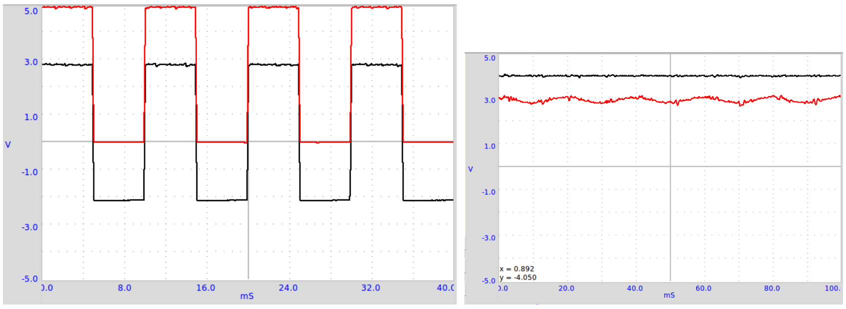
2.9 DC & AC components of a voltage

Objective

Separating AC and DC components of a voltage waveform using a capacitor.

Procedure





Şekil 2.2: (a) A 0 to 5V square wave, with DC component blocked (b) Resuming electrical resistance of human body

- Set SQR1 to 500 Hz
- Assign SQR1 to CH1 and A2 to CH2
- Adjust the horizontal scale to see several cycles.

Observation

The observed waveforms with and without the series capacitor are shown in figure 2.2. The voltage is swinging between 0 and 5 volts. After passing through the capacitor the voltage swings from -2.5 volts to +2.5 volts.

What will you get if you subtract a 2.5 from the y-coordinate of every point of the first graph? That is what the capacitor did. It did not allow the DC part to pass through. This original square wave can be considered as a 2.5V AC superimposed on a 2.5V DC.

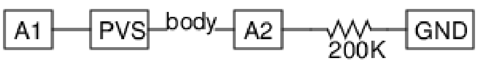
You may need to connect a resistor from A2 to GND to see a waveform swinging between -2.5 to +2.5 volts. Remove the resistor and observe the result.

2.10 Resistance of human body

Objective

Get some idea about the resistance of the skin and how it varies.

Procedure



- Assign A1 to CH1 and A2 to CH2
- Join PVS and A2, through your body and measure voltage at CH2
- Calculate your body's resistance, as given in section 2.6
- Repeat using SINE instead of PVS. Enable FIT to measure voltage.

Observation

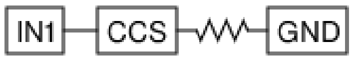
The observed waveform is shown in figure 2.2(b). Voltage at A2 is 3V, the variation is due to the 50Hz AC pickup.

2.11 Temperature dependent resistors

Objective

Show the dependence of resistance on temperature, using a thermistor,$1k\Omega@25^0C$, with negative temperature coefficient. Introduce temperature sensor.

Procedure



- Click on IN1 to measure the voltage
- Repeat at different temperatures

Observation

Setup	V=IR	$R = \frac{V}{I}$
In cold water	1.2	1200
Room Temperature	0.935	935

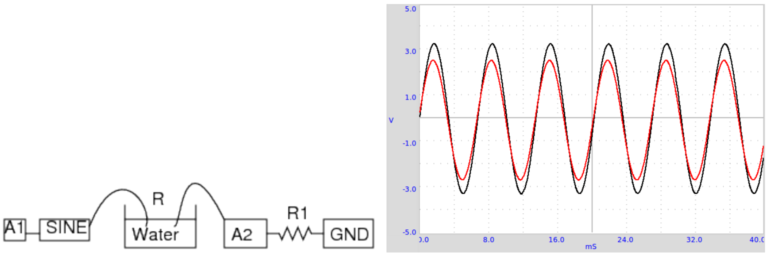
2.12 Light dependent resistors

Objective

Learn about LDR. Measure intensity of light and its variation with distance from the source. Use the comparison method to find out the resistance.

Procedure

- Set PVS to 4V and note down the value set
- Click on IN1 to measure it, Assign IN1 to CH1.
- Calculate the LDR's resistance, as explained in2.6
- Repeat by changing intensity of light falling on LDR
- Connect an LED from SQR1 to GND. Set SQR1 to 10 Hz
- Show the LED above LDR and watch waveform at IN1



Şekil 2.3: Conductivity of water. (b)Total voltage applied and the voltage across the 10k resistor.

Observation

The resistance vary from 1kΩ to around 100 kΩ depending on the intensity of light falling on it. The voltage is proportional to the resistance. The resistance decreases with intensity of light. If you use a point source of light, the resistance should increase as the square of the distance.

Illuminate the LDR using a fluorescent tube and watch the waveform at CH1. The frequency of the ripple is related to the mains frequency.

2.13 Conductivity of water, using DC & AC

Objective

Measure the resistance of ionic solutions, using both DC and AC voltages. We have used normal tap water.

Procedure

- R1 should be comparable to R, start with 10k.
- Assign A1 to CH1 and A2 to CH2, enable FIT on both
- Calculate the resistance as explained in section 2.6
- Repeat using a DC voltage, PVS instead of SINE

Observation

	V_{total}	$V_{10k\Omega}$	V_{liq}	$I = \frac{V_{10k\Omega}}{1000}$	$R_{liq} = \frac{V_{liq}}{I}$
SINE	3.25	2.6	0.65	.26 mA	2.5 kΩ
PVS	4	2.3	1.7	.23 mA	7.4 kΩ

Observed values are shown in the table. The DC and AC resistances seems to be very different. With DC, the resistance of the liquid changes with time, due to electrolysis and bubble formation. The resistance does not depend much on the distance between the electrodes, the area of the electrode is having some effect. The resistance depends on the ion concentration and presence of impurities in the water used.

Try changing the distance between electrodes. Try adding some common salt and repeat the measurements. Why is the behavior different for AC and

DC ? What are the charge carriers responsible for the flow of electricity through solutions ? Is there any chemical reaction taking place ?

2.14 Measuring Capacitance

Objective

expEYES Junior has an internal programmable current source, that can be enabled on IN1. Connect a capacitance C and switch on current (5.5 μA) for a fixed time interval. The accumulated charge $Q = It = CV$. By measuring V , the value of C is calculated. For better results the stray capacitance need to be subtracted. Measure C without connecting anything to IN1, and subtract that value from the C measured with capacitor. This method can be used for values upto 10000 pF.[1] Touching the capacitor during the measurement will corrupt the result.

Procedure

- Measure C without anything connected, to get the stray capacitance.
- connect the capacitor from IN1 to ground.
- Click on the Button***Measure C on IN1***
- Repeat with different capacitors

Observation

The empty socket measures 34 pF. Several capacitors were measured.

Value	Measured value (pF) - 34pF
10	11
20	19
680	664
180	176
3000	2900

2.15 Measuring Dielectric Constant

Objective

Measure the dielectric constant of materials like glass, paper, polyester etc., by making a capacitor. Capacitance $C = \epsilon_0 k \frac{A}{d}$, where ϵ_0 is the permittivity of free space, k the dielectric constant , A the overlapping area of plates and d the separation between them. We have used a 13 cm x 10.6 cm piece of window glass having 4 mm thickness to make a capacitor by pasting metal foil on both sides.

[1]Beyond that you need to use the Python function that can specify the charging current, duration of charging etc.

Procedure

- connect the capacitor from IN1 to ground.
- Click on the Button ***Measure C on IN1***
- Repeat without connecting anything to IN1

Observation

The measured capacitance is 225 pF. The stray capacitance is measured after removing the wire from IN1 and it is 30pF, means C = 195pF. $k = \frac{Cd}{\epsilon_0 A} = \frac{195e-12 \times 0.004}{8.854e-12 \times .13 \times .106} = 6.37$. Touching the capacitor during the measurement gives wrong results.

Using two parallel plates, the dielectric constant of liquids also can be measured.

2.16 AC Phase shift in RC circuits

Objective

Explore the effect of a series capacitor in AC circuits, under steady state conditions. Impedance of a Capacitor $X_c = \frac{1}{2\pi f C}$, where f is the frequency in Hertz and C is the capacitance in Farads.

Procedure

- Assign A1 to CH1 and A2 to CH2
- Adjust the horizontal scale to view more than 4 cycles.
- Right click on CH1 to calculate the phase shift.

For a detailed study select **Study of AC Circuits** from **EXPERIMENTS**.

Observation

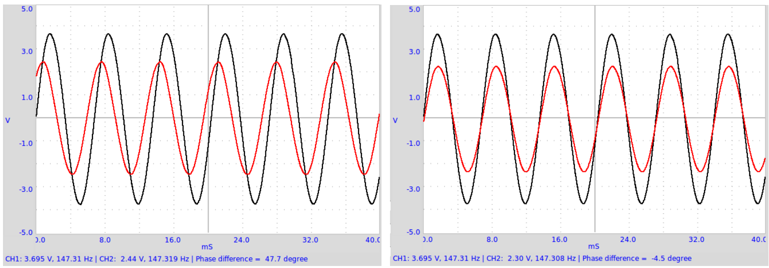
The voltage waveform before and after the capacitor are shown in figure 2.4(a),and the calculations are shown in the table.

C(uF)	R(Ω)	Freq (Hz)	$\triangle\Phi$	$\arctan\left(\frac{X_c}{X_R}\right)$
1	1000	147.3	47.7	47.2

where $X_c = \frac{1}{2\pi f C}$ is the impedance of the capacitor, Frequency is 147.3 Hz. X_R is the resistance.

Current through a capacitor leads the voltage across it by 90^0. Why ?

Why does the phase of the voltage advance? Assume we have connected the AC to plate A and at an instant $t = t_0$ the input voltage is at zero volts. We can see that the slope of the curve is maximum there, i.e. the rate of change of voltage is maximum. The capacitor gets charged very fast at this point. The plate B also gathers the same charge as plate A , that is how a capacitor works.



Şekil 2.4: Phase shift of AC in an (a) RC circuit (b) RL circuit

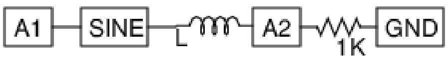
The current to plate B is flowing from ground through the resistor and we are measuring the IR drop across the resistor, it will be already positive when plate A is at zero. This results in the phase advance.

2.17 AC phase shift in RL circuits

Objective

Measure the AC voltage phase shift in an RL circuit. Impedance of an Inductor $X_L = 2\pi f L$, where f is the frequency in Hertz and L is the inductance in Henry. In an LC circuit, the phase lag across the inductor is given by the equation $\triangle\Phi = \arctan\left(\frac{X_L}{X_R}\right)$, where R is the resistance in Ohms.

Procedure



- Assign A1 to CH1 and A2 to CH2
- Adjust the horizontal scale to view more than 4 cycles.
- Right Click on A1 to view voltage, frequency and phase difference.

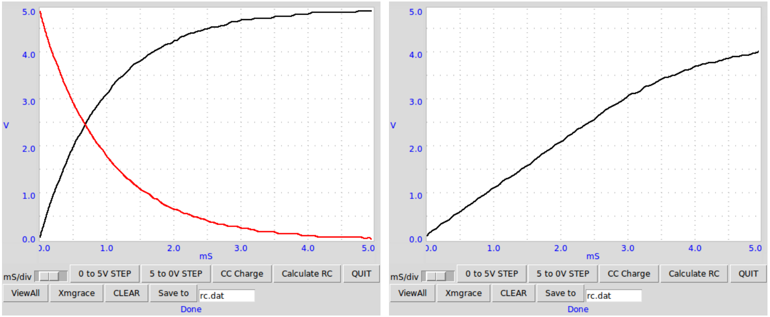
Observation

The measured phase shifts are shown below. Waveforms for the 125 mH inductor is shown in figure 2.4(b). The resistance of the inductor also should be included while calculating the phase shift.[2].

L(mH)	$R = R_{coil} + R_{ext}(\Omega)$	$\triangle\Phi = \arctan\left(\frac{X_L}{X_R}\right)$	$\triangle\Phi_{measured}$
125	565 + 560	3.71	-3.8

Insert an iron or ferrite core to the coil and observe the effect of ferromagnetic materials. Self Inductance of a solenoid is given by $L = \frac{\mu N^2 A}{l}$, where N is the number of turns, A is the cross sectional area, μ is the permeability of the surrounding media and l is the length.

[2]http://www.play-hookey.com/ac_theory/ac_inductors.html



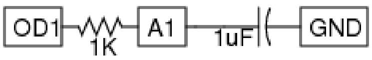
Şekil 2.5: (a)Transient response of RC circuit. (b) Charging of capacitor with constant current.

2.18 Transient Response of RC circuits

Objective

Plot the voltage across a capacitor, when it is charged by applying a voltage step through a resistor. Calculate the value of the capacitance from the graph.

Procedure



- From **EXPERIMENTS** , select **RC Circuit**
- Click on *0->5V STEP* and *5->0V step* Buttons to plot the graphs
- Adjust the horizontal scale, if required, and repeat.
- Calculate RC time constant.
- Use CCS instead of OD1 to charge capacitor with constant current.

Observation

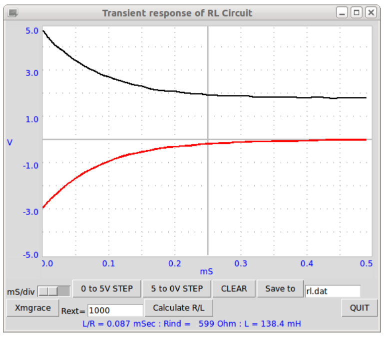
Applying a 0 to 5V step makes the voltage across the capacitor to rise exponentially as shown in the figure2.5(a). By fitting the discharge curve with $V(t) = V_0 e^{-\frac{t}{RC}}$,we can extract the RC time constant and find the values of capacitance from it.

The voltage across a capacitor is exponential only when it is charged trough a linear element, a resistor for example. When charged from a constant current source, the voltage shows linear increase, as shown in figure 2.5(b), because $Q = It = CV$, and voltage increases linearly with time as $V = \left(\frac{I}{C}\right) t$.

2.19 Transient Response of RL circuits

Objective

Explore 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

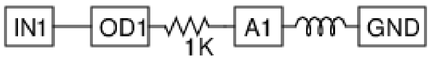


Şekil 2.6: Transient response of RL circuit

a function of time, we can calculate its inductance.

In an RL circuit $V = IR + L\frac{dI}{dt}$ and solving this will give $I = I_0 e^{-\frac{R}{L}t}$. The coefficient of the exponential term R/L can be extracted from the graph of voltage across the inductor. The resistance of the inductor coil should be included in the calculations, $R = R_{ext} + R_L$. [3]

Procedure



- Inductor is the 3000 Turn coil
- From **EXPERIMENTS** select **RL Circuit**
- Click on *0->5V STEP* and *5->0V step* Buttons to plot the graphs
- Adjust the horizontal scale, if required, and repeat.
- Calculate the value of inductance
- Insert an iron core into the inductor and repeat

Observation

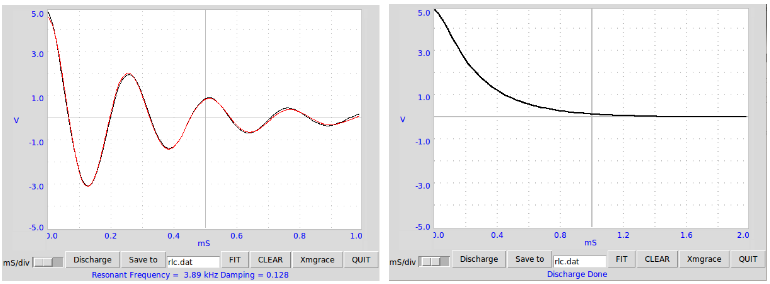
The transient response of the inductor is shown in figure 2.5. The exponential curve is fitted to extract the L/R value. The resistance of the coil is measured by comparing it with the known external resistance under DC conditions. IN1 is connected to OD1 for a more accurate measurement of the coil resistance.

The applied voltages are above zero, but the graph went to negative voltages. Why ?

What was the current before doing the 5->0 step ? What is back EMF ?

Repeat with two coils in series, by (a) placing them far away (b) placing one over the other and (c) after changing the orientation. The effect of mutual inductance can be seen.

[3] http://nptel.iitm.ac.in/courses/Webcourse-contents/IIT-KANPUR/esc102/node14.html



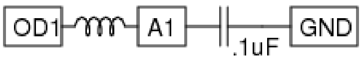
Şekil 2.7: Transient response of LCR circuit,(a)Under-damped (b)Over-damped.

2.20 Transient response of LCR circuits

Objective

Explore the oscillatory nature of L and C in series. Resonant frequency of series LC circuit is given by $\omega_0 = \frac{1}{2\pi\sqrt{LC}}$. The damping factor is $\frac{R}{2}\sqrt{\frac{C}{L}}$, and it is equal to 1 for critical damping.[4] Depending upon the value of C/L and R, the response could be under-damped, critically-damped or over-damped.

Procedure



- From **EXPERIMENTS** select **RLC Discharge**
- Click on 5->0V STEP. Adjust x-axis and repeat if required.
- FIT the graph to find the resonant frequency & Damping.
- Repeat the experiment with different values of L, C and R
- Repeat with a resistor in series.

Observation

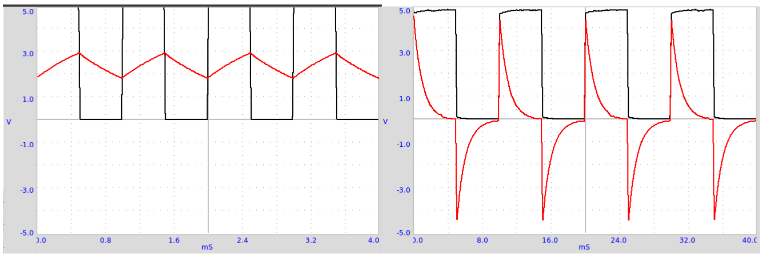
We have used the 3000 turn coil and a 0.1uF capacitor, added a 2.2k series resistor in the second case. The voltage across the capacitor after a 5 to 0V step is shown in figure 2.7 .The measured resonant frequency tallies with $f = \frac{1}{2\pi}\sqrt{\frac{1}{LC}}$, within the component tolerance values.

2.21 RC Integration & Differentiation

Objective

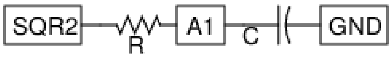
RC circuits can integrate or differentiate a voltage waveform with respect to time. A square wave is integrated to get a triangular wave and differentiated to get spikes at the transitions.

[4]http://en.wikiversity.org/wiki/RLC_circuit

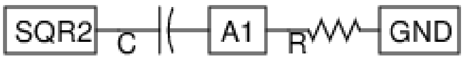


Şekil 2.8: (a)1kHz Squarewave after RC Integrator (b) 100Hz after RC Differentiator

Procedure



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



Observation

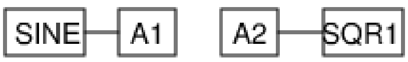
Integration observed at 1kHz and differentiation at 100Hz are shown in figure 2.8, using an RC value of 1 milliseconds. When the time period becomes comparable with the RC value, the output waveform is triangular. The differentiation can only be shown at lower frequency since capturing the narrow spike requires a fast oscilloscope.

2.22 Fourier Analysis

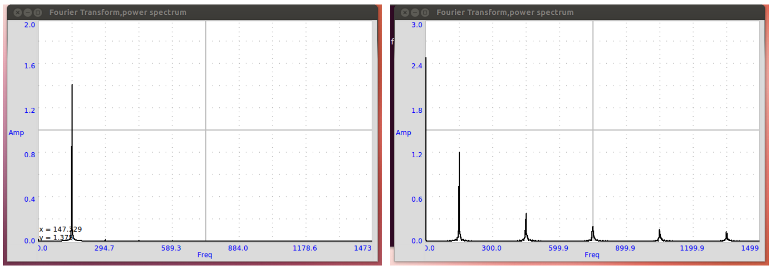
Objective

Learn about Fourier Transform of a signal. Time and Frequency domain representations.

Procedure



- Set SQR1 to 150Hz
- Assign A1 to CH1 and SQR1 to CH2
- Assign CH1 & CH2 to FT to view the Fourier transform



Şekil 2.9: Frequency spectrum of (a)Sine wave. (b) Squarewave

Observation

In the Fourier transform plot, frequency is on the x-axis and the y-axis shows the relative strength of each frequency components of the signal. This is called the frequency domain representation[5]. For the sine wave there is only one dominant peak, the smaller ones are a measure of distortion of the sine wave.

A square wave function can be represented as $f(\theta) = sin(\theta) + \frac{sin(3\theta)}{3} + \frac{sin(5\theta)}{5} + \cdots$. In the Fourier transform of a square wave of frequency f , there will be a $3f$ component (having an amplitude of one third of f), $5f$ component (amplitude one fifth) etc. as shown in the figure 2.9(b). Note the peak at 0 Hz, due to the DC component.

[5] http://en.wikipedia.org/wiki/Fourier_transform