Roll No: 20PH20014
Name: Jessica John Britto
Date: 01/09/2021

Basic Electronics Laboratory

Name:	Jessica John Britto
Roll Number:	20PH20014

EXPERIMENT-2

Title: Familiarisation with signal generator, oscilloscope and studies on RC, CR and RL circuits

Aim:

1. Explain RC Circuit as a Low Pass Filter
2. Explain RC Circuit as a High Pass Filter
3. Explain RL circuit as a High Pass Filter
4. Explain Square wave response of RC circuit
5. Explain RC circuit as Integrator
6. Explain RC circuit as Differentiator
7. Explain charging of RC circuit with DC source
8. Explain discharging of RC circuit with DC source
9. Voltage Divider

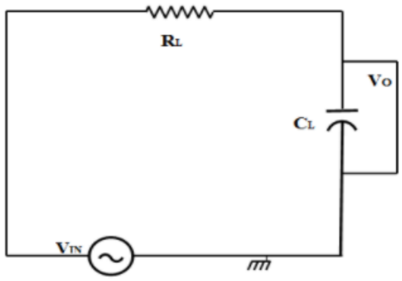
Ⅰ. Explain RC Circuit as Low Pass Filter

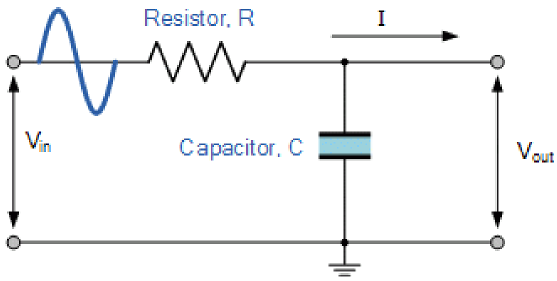
Tools Used: Circuit Simulator Applet (Falstad)

Background Knowledge (Brief):

1. A filter is a circuit that allows passing a specified range of frequency components, while blocking or "attenuating" the rest according to the frequency range of signals.
2. The most commonly used filter designs are as follows:
    1. The Low Pass Filter- Filter passes low frequencies and blocks high frequencies.It only allows low frequency signals from 0Hz to its cut-off frequency, (f_c) point to pass while blocking those any higher.
    2. The High Pass Filter-Filter passes high frequencies and blocks low frequencies. It only allows high frequency signals from its cut-off frequency, (f_C) point and higher to infinity to pass through while blocking those any lower.
    3. The Band Pass Filter- Filter passes only a relatively narrow range of frequencies. It allows signals falling within a certain frequency band setup between two points to pass through while blocking both the lower and higher frequencies either side of this frequency band.
3. Filters can also be classified according to the types of components that are used to implement the circuit. Passive filters are made up of passive components such as resistors, capacitors and inductors and have no amplifying elements (transistors, op-amps, etc) so have no signal gain, therefore their output level is always less than the input.

4. RC as Low Pass Filter: A simple passive RC Low Pass Filter or LPF, can be easily made by connecting together in series a single Resistor with a single Capacitor as shown below.





In this type of filter arrangement the input signal (V_{in}) is applied to the series combination (both the Resistor and Capacitor together) but the output signal (V_{out}) is taken across the capacitor only. The reactance of a capacitor varies inversely with frequency, while the value of the resistor remains constant as the frequency changes. At low frequencies the capacitive reactance, (X_C) of the capacitor will be very large compared to the resistive value of the resistor,R. Voltage across the capacitor will be much larger than the voltage drop developed across the resistor. At high frequencies the reverse is true with (V_C) being small and (V_R) being large due to the change in the capacitive reactance value. Thus, low frequencies are passed and high frequencies are blocked.

5. Low-Pass Filter Phase Shift

Each reactive element in a circuit introduces 90° of phase shift, but this phase shift does not happen all at once. The phase of the output signal, just like the magnitude of the output signal, changes gradually as the input frequency increases. In an RC low-pass filter, we have one reactive element i.e. the capacitor, and consequently the circuit will eventually introduce 90° of phase shift.

$$\phi = -arctan(2 \times 3.14 \times f \times C_L \times R_L)$$

6. Capacitive Reactance:

The reactance of a capacitor indicates the amount of opposition to current flow, but unlike resistance, the amount of opposition depends on the frequency of the signal passing through the capacitor. Thus, to calculate reactance at a specific frequency, following equation is used:

$$X_C = \frac{1}{2 \times \pi \times f \times C_L}$$

$$Z = \sqrt{R_L^2 + X_C^2}$$

$$Magnitude = 20 \times \log\left(\frac{X_C}{Z}\right)$$

$$V_{out} = V_{in} \times \left(\frac{X_C}{Z}\right)$$

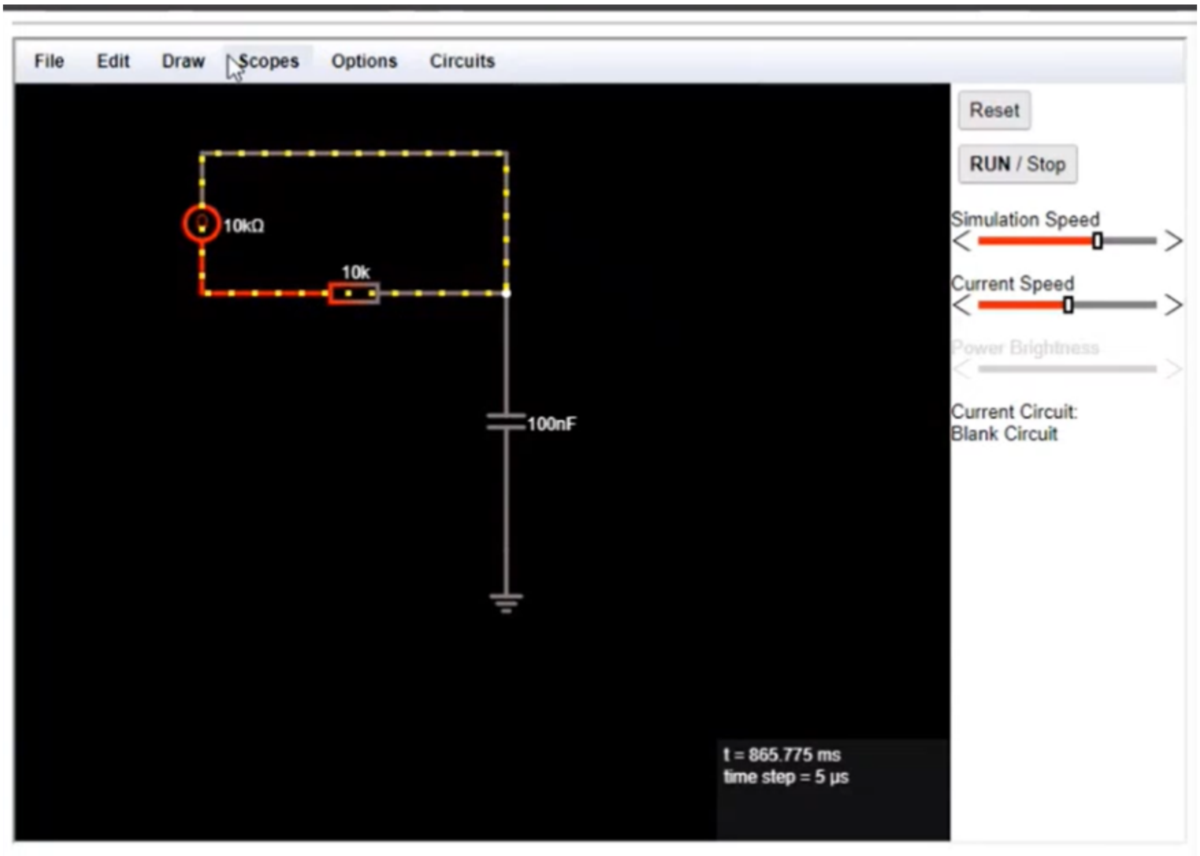
7. Cut-off Frequency:

   The cutoff frequency of an RC low-pass filter is the frequency at which the amplitude of the input signal is reduced by 3 dB (this value was chosen because a 3 dB reduction in amplitude corresponds to a 50% reduction in power). Thus, the cutoff frequency is also called the –3 dB frequency. The term bandwidth refers to the width of a filter's passband, and in the case of a low-pass filter, the bandwidth is equal to the –3 dB frequency The cutoff frequency (fc) of an RC low-pass filter is calculated as follows:

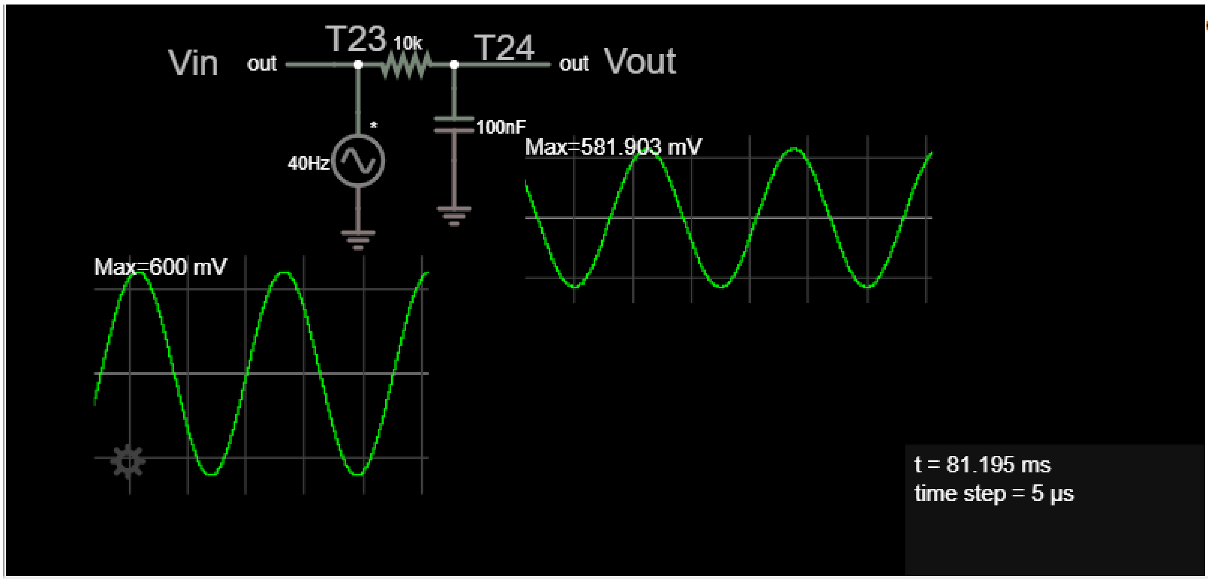
$$f_c = \frac{1}{2 \times \pi \times R_L \times C_L}$$

Circuit (hand drawn/image):

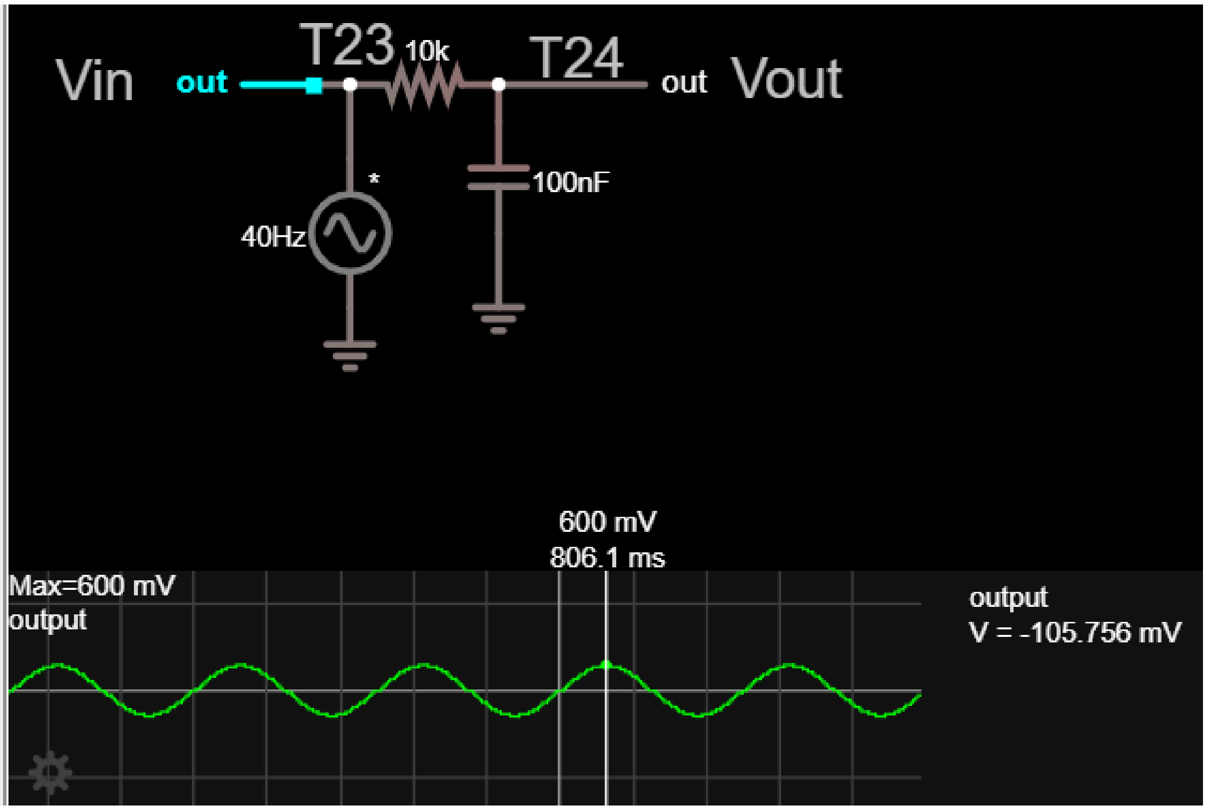
Circuit-1



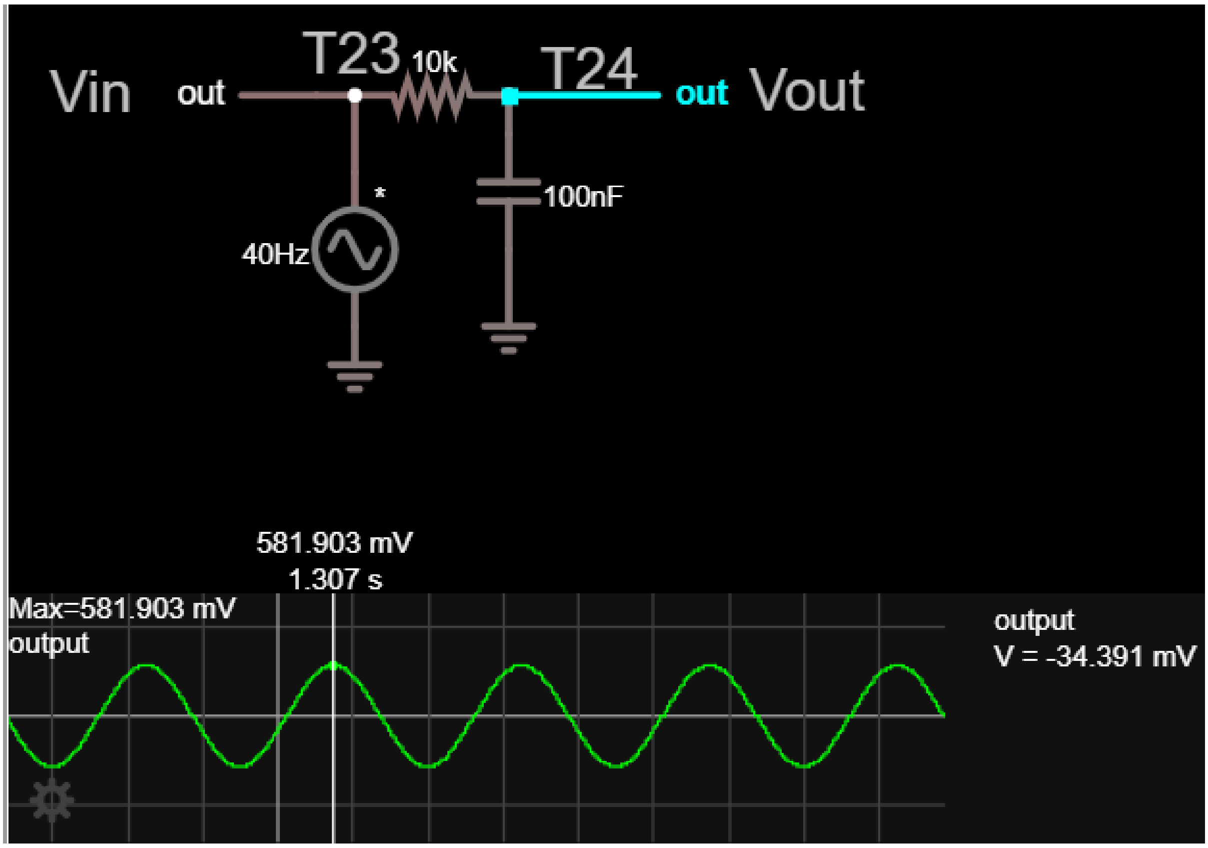
Circuit-2



Circuit-3



Circuit-4



Measurement Data(Tabular Form):

From Circuit-1, it can be noted that R=10k using ohmmetere attached parallely to the resistor, and C=100nF.

Observation Table-1 for Circuit-2:

The experiment is being performed on the Circuit Simulator Applet (Falstad). An AC voltage source of about 1.2 Vp-p has been used to power the circuit. Left-side waveform represents the waveform of V_{IN} and the right-side waveform graph is for V_{OUT}.

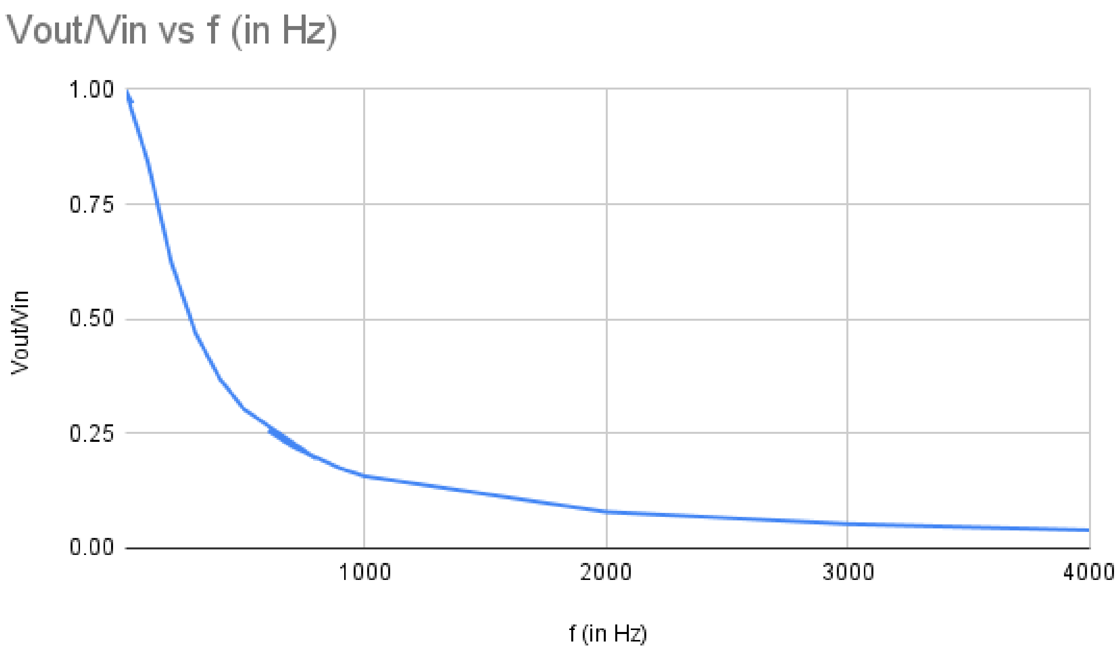
SI No.	V_{out} (in mV)	V_{in} (in mV)	f (in Hz)	V_{OUT}/V_{IN}	log(f)	log(V_{OUT}/V_{IN})
1	581.903	600	40	0.9698383333	1.602059991	-0.266013084
2	598.819	600	10	0.9980316667	1	-0.017113574
3	508.039	600	100	0.8467316667	2	-1.445083957
4	373.605	600	200	0.622675	2.301029996	-4.114771411
5	281.188	600	300	0.4686466667	2.477121255	-6.583089352

6	221.816	600	400	0.3696933333	2.602059991	-8.643167619
7	181.982	600	500	0.3033033333	2.698970004	-10.36245633
8	117.065	600	800	0.1951083333	2.903089987	-14.19448362
9	153.83	600	600	0.2563833333	2.77815125	-11.82220421
10	133.018	600	700	0.2216966667	2.84509804	-13.08481673
11	104.475	600	900	0.174125	2.954242509	-15.18277741
12	94.298	600	1000	0.1571633333	3	-16.07297537
13	47.574	600	2000	0.07929	3.301029996	-22.01563164
14	31.761	600	3000	0.052935	3.477121255	-25.52514165
15	23.804	600	4000	0.03967333333	3.602059991	-28.03002618
16	423.138	600	160	0.70523	2.204119983	-3.033384428

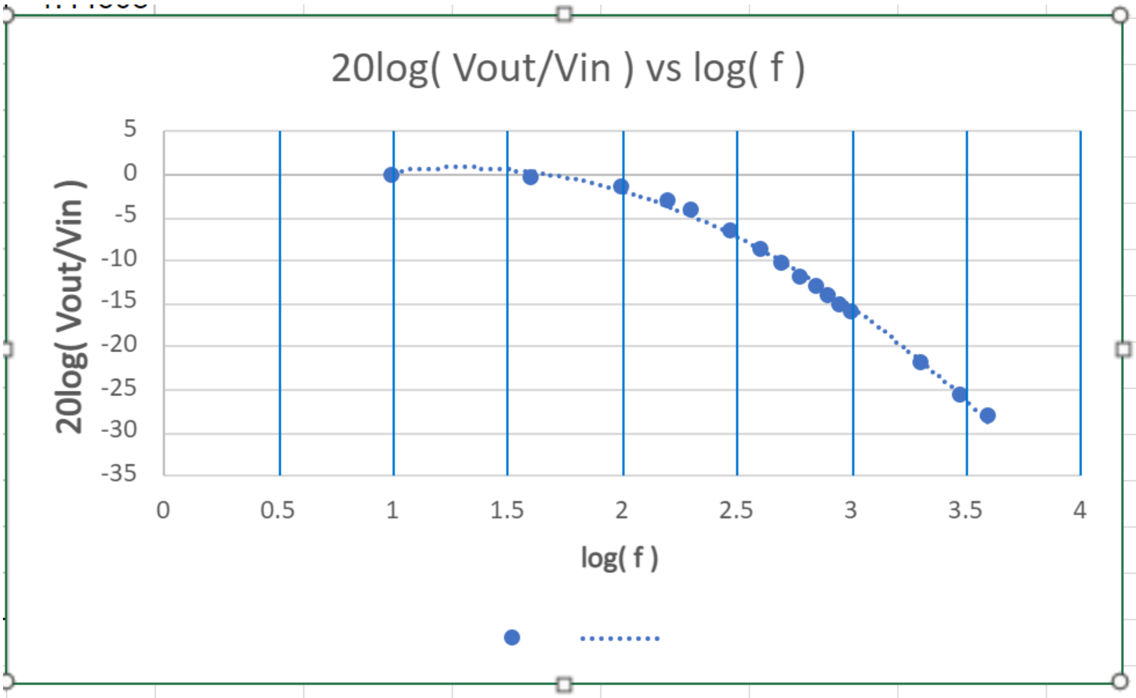
From circuits-3 and 4, maximum values of V_{IN} and V_{OUT} are recorded, and they are 600mV and 581.903mV when f = 40Hz.

Graphs (Image/Screenshots):

Graph-1: Graph of Table-1: V_{OUT}/V_{IN} vs f (in Hz):



Graph-2: Graph of Table-1: log(V_{OUT}/V_{IN}) vs log(f):



Calculation:

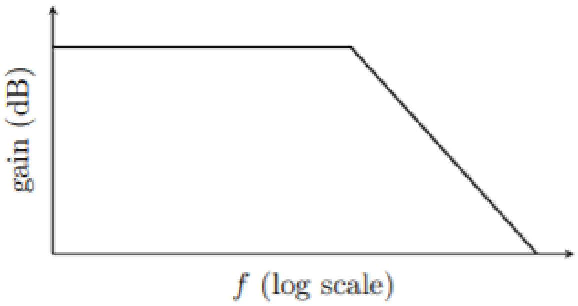
From the graph, using plotting tools of excel software, we can determine the value of log (f) is 2.20182, which is f_c = 159.1549 Hz.

Using the formula $f_c = 1/2\pi R_L C_L$, we, again obtain the value of f_c as 159.1549 Hz. Clearly, calculated value of f_c using the formula is same as the observed value of f_c from the graph, this is because, as the experiment is performed on virtual lab, errors due to heating effect, human error in measuring the readings, parallax error and instrumental error, are avoided. Hence calculated f_c is same as observed f_c hence, verified.

Conclusion:

During this experiment on the Circuit Simulator Applet (Falstad), value of V_{OUT} was varying as the frequency of the AC source was varied from 10Hz to 4k Hz. The basics of low pass filters, such as the construction of low pass filters, low-pass filter phase shift and its applications were studied thoroughly. The low pass filters are used in ECG, used in smoothing methods of images, to filter noise from a circuit and hence are named treble cut filters and are used in many more electronic devices such as loudspeakers.

From graph-2, we can say that the type of the given filter is a low pass filter as the graph obtained through the experiment, i.e, graph-2, resembles the theoretical graph of the low pass filter given below.



Discussions:

1. Nearly all electronic circuits consist of various types of filters, so it is important to get a complete idea about them such as the construction of low pass filters and other types of filters based on a specific requirement and knowing the significance and use of different types of filters is essential in order to choose an appropriate type of filter for a specific requirement such as low pass filters are used when signals of lower frequencies are to be passed through in a circuit.
2. Low pass filters allow signals of low frequency to pass through and after a certain frequency, higher frequency signals are severely attenuated (Their magnitudes are severely decreased). The frequency at which the output power is reduced to half its input value is called the cut off frequency. It is calculated as fc = $1/2\pi R_L C_L$.
3. I learnt the basics of low pass filters such as the construction of low pass filters and also learnt that low pass filters have a wide range of applications. The low pass filters are used in ECG, used in smoothing methods of images, to filter noise from a circuit and hence are named treble cut filters and are used in many more electronic devices such as loudspeakers.
4. From the graph, using plotting tools of excel software, we can determine the value of log (f) is 2.20182, which is f_c = 159.1549 Hz. Using the formula fc = $1/2\pi RC$, we, again obtain the value of f_c as 159.1549 Hz. Clearly, calculated value of f_c using the formula is same as the observed value of f_c from the graph, this is because, as the experiment is performed on virtual lab, errors due to heating effect, human error in measuring the readings, parallax error and instrumental error, are avoided. Hence calculated f_c is same as observed f_c hence, verified.

5. The output signal for Low pass filters lags in phase, i.e, there's a negative phase shift.

Ⅰ Ⅰ. Explain RC Circuit as a High Pass Filter

Tools Used: Circuit Simulator Applet (Falstad)
Background Knowledge (Brief):

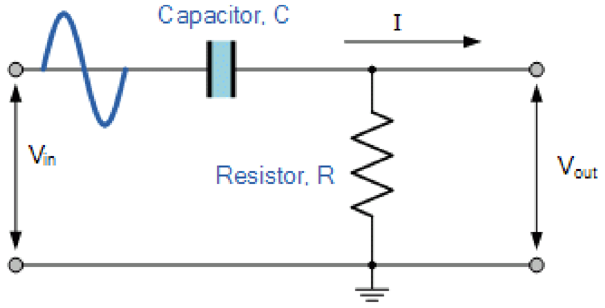
1. A filter is a circuit that allows to pass a specified range of frequency components, while blocking or "attenuating" the rest according to the frequency range of signals.
2. The most commonly used filter designs are as follows:

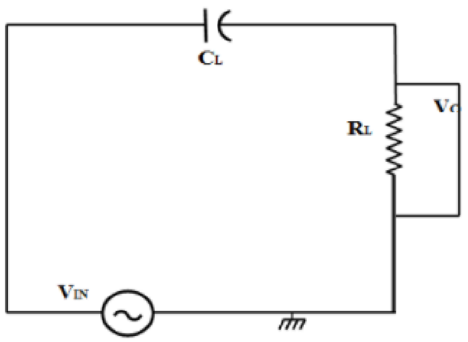
   1. The Low Pass Filter- Filter passes low frequencies and blocks high frequencies.It only allows low frequency signals from 0Hz to its cut-off frequency, (f_c) point to pass while blocking those any higher.

   2. The High Pass Filter-Filter passes high frequencies and blocks low frequencies. It only allows high frequency signals from its cut-off frequency, (f_C) point and higher to infinity to pass through while blocking those any lower.

   3. The Band Pass Filter- Filter passes only a relatively narrow range of frequencies. It allows signals falling within a certain frequency band setup between two points to pass through while blocking both the lower and higher frequencies either side of this frequency band.

3. Filters can also be classified according to the types of components that are used to implement the circuit. Passive filters are made up of passive components such as resistors, capacitors and inductors and have no amplifying elements (transistors, op-amps, etc) so have no signal gain, therefore their output level is always less than the input.
4. RC as a high pass filter: A simple passive RC High Pass Filter or HPF, can be easily made by connecting together in series a single Resistor with a single Capacitor as shown below. In this type of filter arrangement the input signal (V_{in}) is applied to the series combination (both the Resistor and Capacitor together) but the output signal (V_{out}) is taken across the resistor only.





5. In the above circuit, the reactance of the capacitor is very high at low frequencies so the capacitor acts like an open circuit and blocks any input signals at (V_{in}) until the

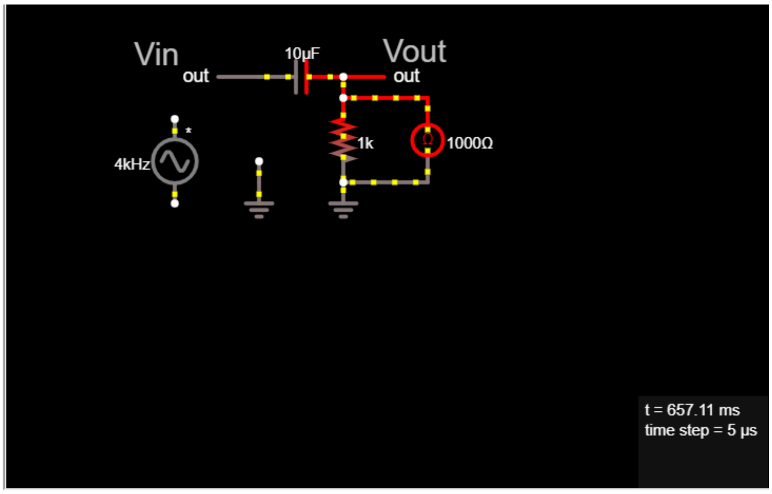
cut-off frequency point (f_C) is reached. Above this cut-off frequency point the reactance of the capacitor has reduced sufficiently as to now act more like a short circuit allowing all of the input signal to pass directly to the output as shown below in the filters response curve.

$$Magnitude = 20 \times \log\left(\frac{R}{Z}\right)$$

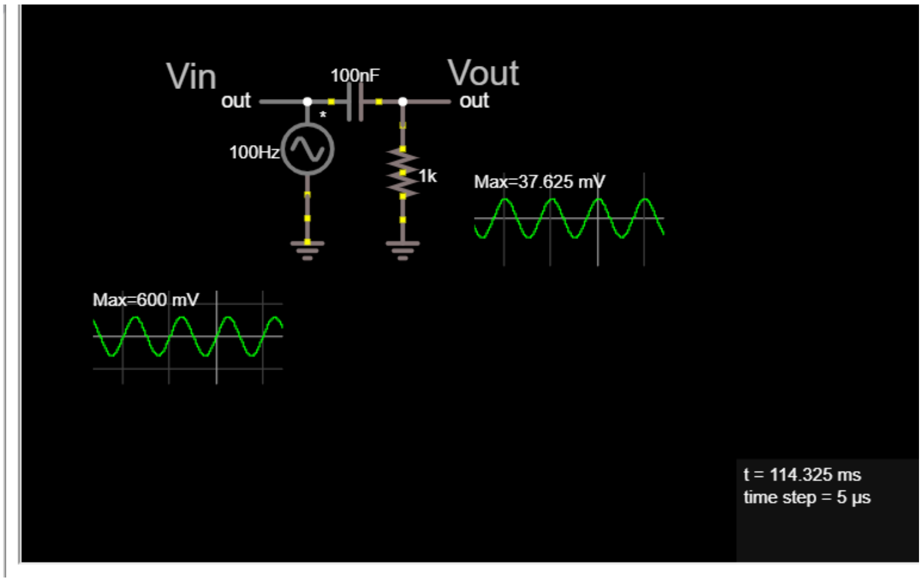
$$V_{out} = V_{in} \times \left(\frac{R}{Z}\right)$$

Circuit (hand drawn/image):

<u>Circuit-1</u>



<u>Circuit-2</u>



Measurement Data(Tabular Form):

From Circuit-1, it can be noted that R=10k using ohmmetere attached parallely to the resistor, and C=100nF.

Observation Table-1 for Circuit-2:

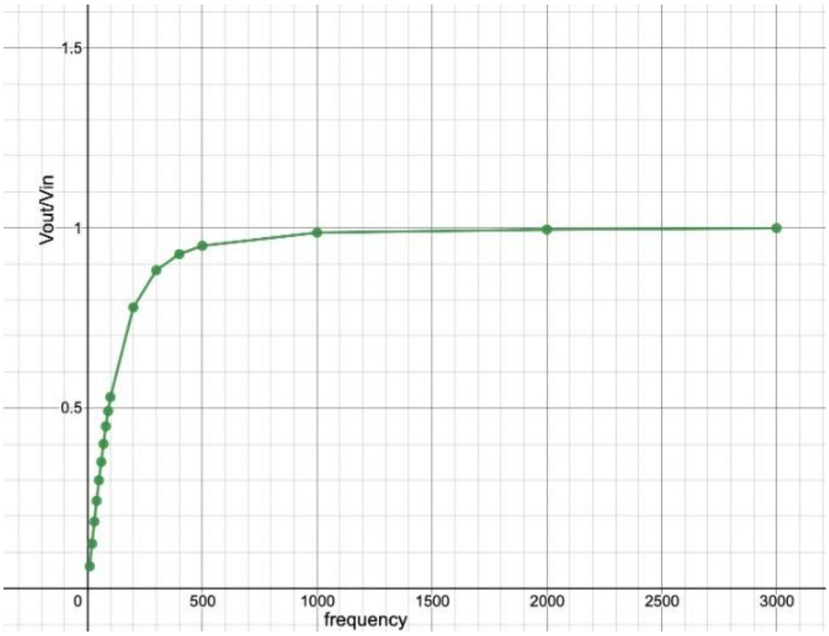
The experiment is being performed on the Circuit Simulator Applet (Falstad). An AC voltage source of about 1.2 Vp-p has been used to power the circuit. Left-side waveform represents the waveform of V_{IN} and the right-side waveform graph is for V_{OUT}.

SI No.	V_{out} (in mV)	V_{in} (in mV)	f (in Hz)	V_{OUT}/V_{IN}	log(f)	log(V_{OUT}/V_{IN})
1	18.84	600	50	0.0314	1.698970004	-30.06140704
2	37.625	600	100	0.0627	2	-24.05464918
3	74.81	600	200	0.1246	2.301029996	-18.08963915
4	179.81	600	500	0.2996	2.698970004	-10.46916382
5	269.466	600	800	0.4491	2.903089987	-6.953138899
6	319.211	600	1000	0.532	3	-5.481767354
7	411.52	600	1500	0.6858	3.176091259	-3.276050384
8	469.487	600	2000	0.7824	3.301029996	-2.131423164
9	530.03	600	3000	0.8833	3.477121255	-1.077835391
10	571.733	600	5000	0.9528	3.698970004	-0.4199650305
11	592.542	600	10000	0.9875	4	-0.109257914
12	596.643	600	15000	0.9944	4.176091259	-0.04877768733
13	598.09	600	20000	0.9968	4.301029996	-0.0278394137
14	599.436	600	50000	0.999	4.698970004	-0.00869023548
15	599.31	600	100000	0.9988	5	-0.01042932641
16	598.023	600	150000	0.9983	5.176091259	-0.01477857774
17	595.846	600	200000	0.9997	5.301029996	-0.002606157835
18	599.987	600	250000	0.99994	5.397940009	-0.0005211690135

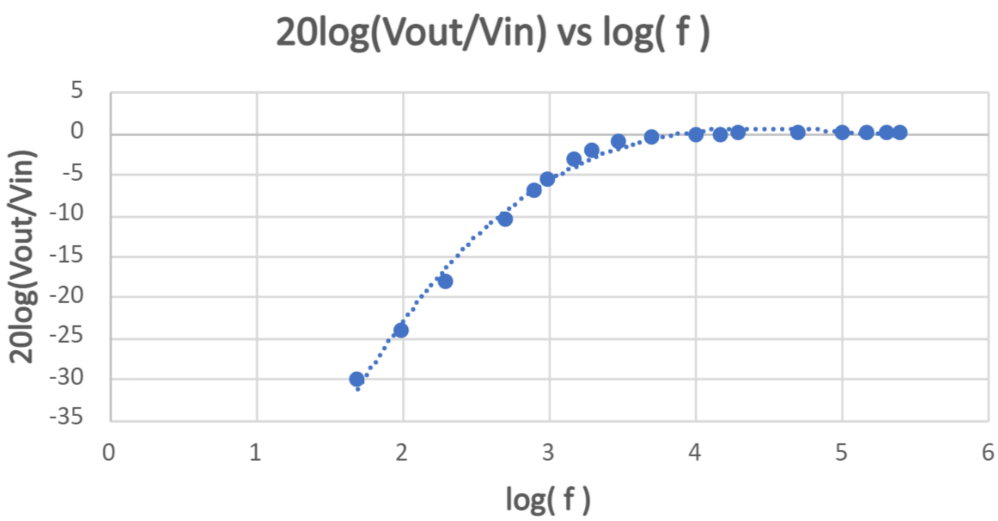
From circuit-1, maximum values of V_{IN} and V_{OUT} are recorded, and they are 600mV and 37.625 mV when f = 100 Hz.

Graphs (Image/Screenshots):

Graph-1: Graph of Table-1: V_{OUT}/V_{IN} vs f (in Hz):



Graph-2: Graph of Table-1: log(V_{OUT}/V_{IN}) vs log(f):



Calculation:

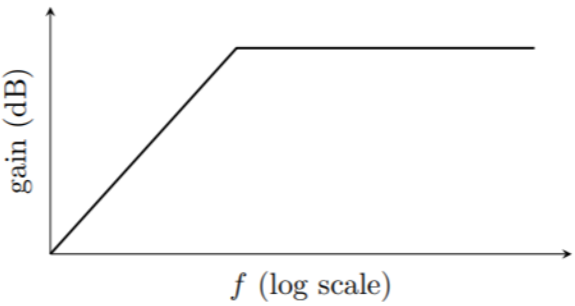
From the graph, using plotting tools of excel software, we can determine the value of log (f) is 2.20182, which is f_c = 159.1549 Hz.

Using the formula $f_c = 1/2\pi RC$, we, again obtain the value of f_c as 159.1549 Hz. Clearly, calculated value of f_c using the formula is same as the observed value of f_c from the graph, this is because, as the experiment is performed on virtual lab, errors due to heating effect, human error in measuring the readings, parallax error and instrumental error, are avoided. Hence calculated f_c is same as observed f_c hence, verified.

Conclusion:

During this experiment on the Circuit Simulator Applet (Falstad), value of V_{OUT} was varying as the frequency of the AC source was varied from 50Hz to 250k Hz. The basics of high pass filters, such as the construction of high pass filters, high-pass filter phase shift and their applications were studied thoroughly. The high pass filters are used in blocking DC from circuitry sensitive to non-zero average voltages or radio frequency devices, can also be used in conjunction with a low-pass filter to produce a bandpass filter, can be used to make images appear sharper.

From graph-2, we can say that the type of the given filter is a high pass filter as the graph obtained through the experiment, i.e, graph-2, resembles the theoretical graph of the high pass filter given below.



Discussions:

1. Nearly all electronic circuits consist of various types of filters, so it is important to get a complete idea about them such as the construction of high pass filters and other types of filters based on a specific requirement and knowing the significance and use of different types of filters is essential in order to choose an appropriate type of filter for a specific requirement such as high pass filters are used when signals of higher frequencies are to be passed through in a circuit as output.
2. High Pass filters allow signals of high frequency to pass through. Signals of lower frequency are reduced in magnitude. Below a certain frequency, the input signals are severely attenuated. Like low pass filters, the frequency at which the output power of the high pass filter is reduced to half its input value is calculated as fc = $1/2\pi$RC.
3. I learnt the basics of high pass filters such as the construction of high pass filters and also learnt that high pass filters have a wide range of applications. The high pass filters are used in blocking DC from circuitry sensitive to non-zero average voltages or radio frequency devices, can also be used in conjunction with a low-pass filter to produce a bandpass filter, can be used to make images appear sharper.
4. From the graph, using plotting tools of excel software, we can determine the value of log (f), i.e, log (f) is 2.20182, which is f_c = 159.1549 Hz. Using the formula fc = $1/2\pi RC$, we, again obtain the value of f_c as 159.1549 Hz. Clearly, calculated value of f_c using the formula is same as the observed value of f_c from the graph, this is because,

as the experiment is performed on virtual lab, errors due to heating effect, human error in measuring the readings, parallax error and instrumental error, are avoided. Hence calculated f_c is same as observed f_c hence, verified.

5. The output signal of the high pass filter leads the input, i.e, there's a positive phase shift.

ＩＩＩ. Explain RL as High Pass filter

Tools Used: Circuit Simulator Applet (Falstad)

Background Knowledge (Brief):

1. A filter is a circuit that allows to pass a specified range of frequency components, while blocking or "attenuating" the rest according to the frequency range of signals.
2. The most commonly used filter designs are as follows:

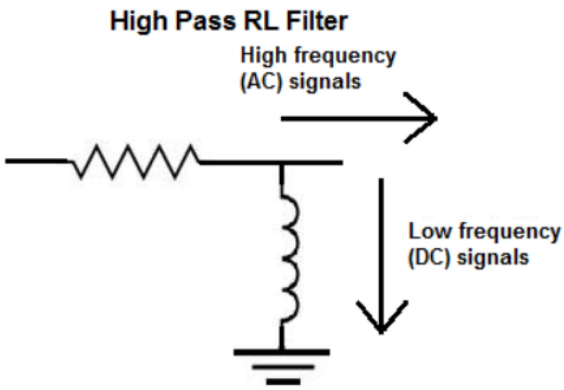
   1. The Low Pass Filter- Filter passes low frequencies and blocks high frequencies.It only allows low frequency signals from 0Hz to its cut-off frequency, (f_c) point to pass while blocking those any higher.

   2. The High Pass Filter-Filter passes high frequencies and blocks low frequencies. It only allows high frequency signals from its cut-off frequency, (f_C) point and higher to infinity to pass through while blocking those any lower.

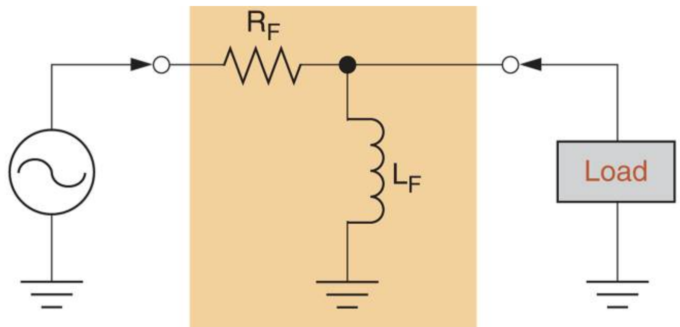
   3. The Band Pass Filter- Filter passes only a relatively narrow range of frequencies. It allows signals falling within a certain frequency band setup between two points to pass through while blocking both the lower and higher frequencies either side of this frequency band.

3. Filters can also be classified according to the types of components that are used to implement the circuit. Passive filters are made up of passive components such as resistors, capacitors and inductors and have no amplifying elements (transistors, op-amps, etc) so have no signal gain, therefore their output level is always less than the input.
4. RL as a high pass filter: A high pass RL filter is a filter composed of a resistor and inductor which passes through high-frequency signals.

   To build a high pass RL filter, the inductor is placed in parallel to the power source signals entering the circuit, as shown below in the following circuit:



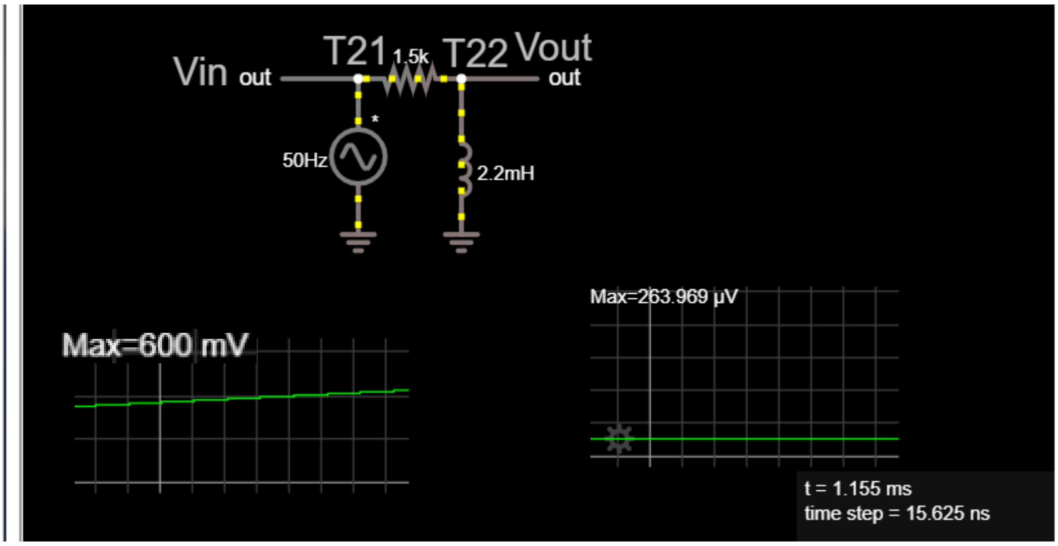
5. The above circuit is an RL high pass filter. It passes through high frequency signals. An inductor, like a capacitor, is a reactive device. Inductors offer different resistances to signals input into them of different frequencies. Inductors pass low-frequency signals with very little resistance, while offering great resistance to signals of high frequency. Thus, low-frequency signals pass through very easily without any attenuation and high frequency signals are either completely blocked or greatly attenuated as output.
6. Off of this principle described, which is inductive reactance is how the above circuit operates. Since inductors offer such high resistance to high frequency signals, current signals of high frequency will not go through the inductor of this circuit. They will take an alternate path and go through another part of the circuit which offers lesser resistance. In this circuit, instead of the high-frequency signals going through the inductor and down to ground, they go through to output. And this is why this circuit is a high-pass filter circuit. Low frequency signals, however, will go through the inductor, because inductors offer very low resistance to low-frequency, or Dc, signals. Therefore, low-frequency current will take the path of going through the inductor to ground.
7. In this type of filter arrangement the input signal (V_{in}) is applied to the series combination (both the Resistor and Inductor together) but the output signal (V_{out}) is taken across the inductor only.
8. The lower cutoff frequency for an RL high pass filter is determined by the inductor and the parallel combination of R_F and R_L . By the formula:



$$f_C = \frac{R_{EQ}}{2\pi L}$$ Where $R_{EQ} = R_F \parallel R_L$.

Circuit (hand drawn/image):

Circuit-1



Measurement Data(Tabular Form):

From Circuit-1, it can be noted that R=1.5k and L=2.2mH.

Observation Table-1 for Circuit-1:

The experiment is being performed on the Circuit Simulator Applet (Falstad). An AC voltage source of about 1.2 Vp-p has been used to power the circuit. Left-side waveform represents the waveform of V_{IN} and the right-side waveform graph is for V_{OUT}.

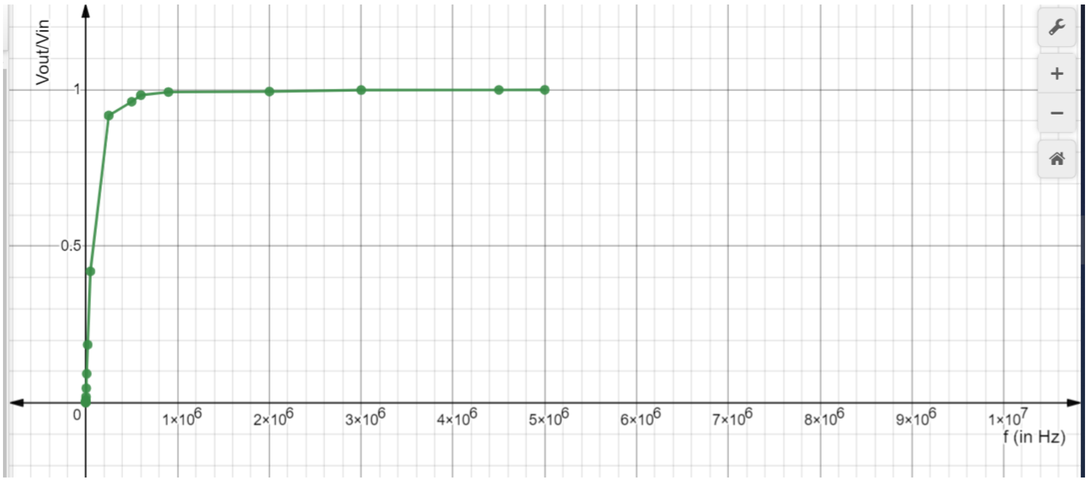
SI No.	V_{out} (in mV)	V_{in} (in mV)	f (in Hz)	V_{OUT}/V_{IN}	log(f)	$\log(V_{OUT}/V_{IN})$
1	0.0553	600	10	0.0001	1	-80
2	0.2765	600	50	0.00045	1.698970004	-66.93574972
3	0.5529	600	100	0.00092	2	-60.72424345
4	0.8294	600	150	0.00138	2.176091259	-57.20241827
5	1.106	600	200	0.00184	2.301029996	-54.70364354
6	2.765	600	500	0.00461	2.698970004	-46.72598149
7	5.529	600	1000	0.00922	3	-40.70538158
8	11.06	600	2000	0.01843	3.301029996	-34.6894933
9	27.67	600	5000	0.04612	3.698970004	-26.72221403

10	55.4	600	10000	0.09233	4	-20.69314329
11	111.001	600	20000	0.185	4.301029996	-14.65656543
12	251.708	600	50000	0.4195133333	4.698970004	-7.54508463
13	550.6	600	250000	0.9176666667	5.397940009	-0.7463008665
14	406.42	600	100000	0.6773666667	5	-3.383523577
15	577.034	600	500000	0.9617233333	5.698970004	-0.3389969395
16	589.705	600	600000	0.9828416667	5.77815125	-0.1503288057
17	617.974	600	1000000	1.029956667	6	0.2563790606
18	595.641	600	900000	0.992735	5.954242509	-0.06333332611
19	596.519	600	2000000	0.9941983333	6.301029996	-0.05053938489
20	599.455	600	3000000	0.9990916667	6.477121255	-0.00789326849
21	599.663	600	4500000	0.9994383333	6.653212514	-0.00487994526
20	599.729	600	5000000	0.9995483333	6.698970004	-0.00392401306

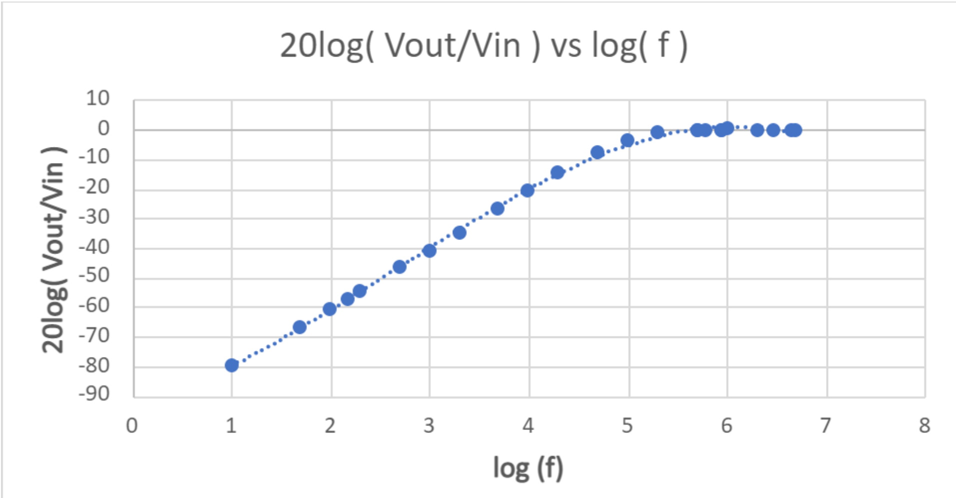
From circuit-1, maximum values of V_{IN} and V_{OUT} are recorded, and they are 600mV and 0.2765 mV when f = 50 Hz.

Graphs (Image/Screenshots):

Graph-1: Graph of Table-1: V_{OUT}/V_{IN} vs f (in Hz):



Graph-2: Graph of Table-1: log(V_{OUT}/V_{IN}) vs log(f):



Calculation:

From the graph, using the plotting tools of excel software, we can determine the value of log(f_C) is 5.15, which is f_c = 141253.7545 Hz.

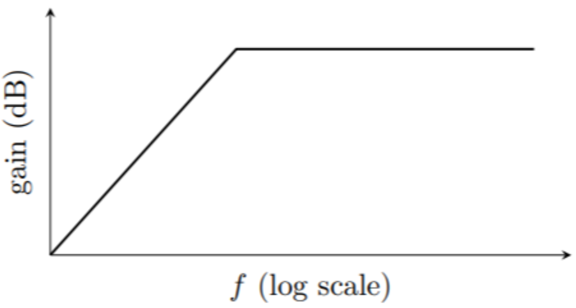
Using the formula $f_c = R/2\pi L$, we obtain the value of f_c as 108514.7339 Hz, and

log(f_C) =5.04. Clearly, the calculated value of log(f_c) using the formula is nearly the same as the observed value of log(f_c) from the graph. Hence calculated log(f_c) is the same as observed log(f_c), hence, verified.

Conclusion:

During this experiment on the Circuit Simulator Applet (Falstad), the value of V_{OUT} was varying as the frequency of the AC source was varied from 10Hz to 5000k Hz. The basics of high pass filters, such as the construction of high pass filters, high-pass filter phase shift and their applications were studied thoroughly. The high pass filters are used in blocking DC from circuitry sensitive to non-zero average voltages or radio frequency devices, can also be used in conjunction with a low-pass filter to produce a bandpass filter, and can be used to make images appear sharper.

From graph-2, we can say that the type of the given filter is a high pass filter as the graph obtained through the experiment, i.e, graph-2, resembles the theoretical graph of the high pass filter given below.



Discussions:

1. Nearly all electronic circuits consist of various types of filters, so it is important to get a complete idea about them such as the construction of high pass filters and other types of filters based on a specific requirement and knowing the significance and use of different types of filters is essential in order to choose an appropriate type of filter for a specific requirement such as high pass filters are used when signals of higher frequencies are to be passed through in a circuit as output.
2. High Pass filters allow signals of high frequency to pass through. Signals of lower frequency are reduced in magnitude. Below a certain frequency, the input signals are severely attenuated. Like low pass filters, the frequency at which the output power of the high pass filter is reduced to half its input value is calculated as $f_c = R/2\pi L$.
3. I learnt the basics of high pass filters such as the construction of high pass filters and also learnt that high pass filters have a wide range of applications. The high pass filters are used in blocking DC from circuitry sensitive to non-zero average voltages or radio frequency devices, can also be used in conjunction with a low-pass filter to produce a bandpass filter, and can be used to make images appear sharper.
4. From the graph, using the plotting tools of excel software, we can determine the value of $\log(f_C)$ is 5.15, which is f_c = 141253.7545 Hz.

   Using the formula $f_c = R/2\pi L$, we obtain the value of f_c as 108514.7339 Hz, and

   $\log(f_C)$ =5.04. Clearly, the calculated value of $\log(f_c)$ using the formula is nearly the same as the observed value of $\log(f_c)$ from the graph. Hence calculated $\log(f_c)$ is the same as observed $\log(f_c)$, hence, verified.

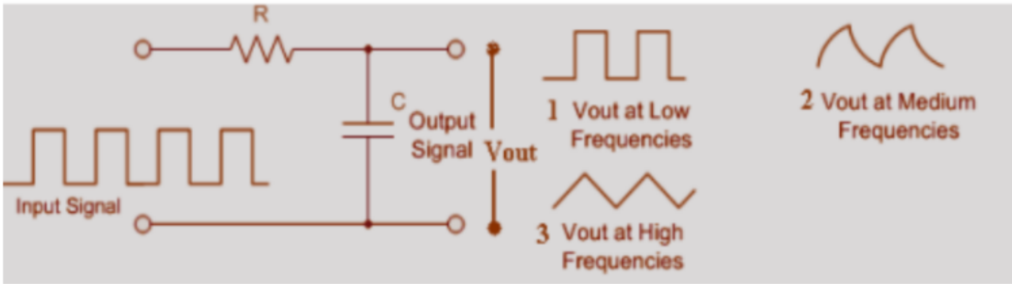
6. The output signal of the high pass filter leads the input, i.e, there's a positive phase shift.

Ⅳ**. Explain Square wave response of RC circuit**

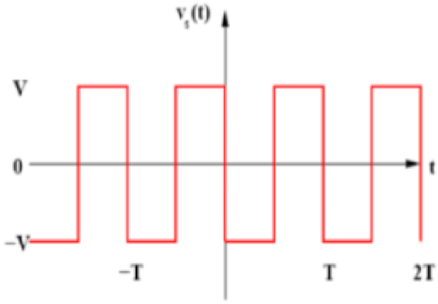
Tools Used: Basic Electronics Virtual Lab

Background Knowledge (Brief):

1. A square wave is a non-sinusoidal periodic waveform in which the amplitude alternates at a steady frequency between fixed minimum and maximum values, with the same duration at minimum and maximum.



2. Characteristics of a square wave: The pulse goes from - V to +V and has a period T.



3. On taking a time of 5T where T=R*C is needed for the capacitor to change fully, time period of square wave >> RC, then this square wave is changing slowly.
4. These experiments are done in the time domain. However, in this frequency domain a signal which changes fast would mean it's a high frequency signal (or it has frequency components), a signal which changes slowly would mean it has low frequency components and a signal which does not change very fast has medium frequency components.

Conclusion and Discussion:

I have learnt that square waves are used in all kinds of digital equipment because they are ideal for representing the ones and zeros of digital. They are also used for clock and other data signals as well as certain types of audio signals.

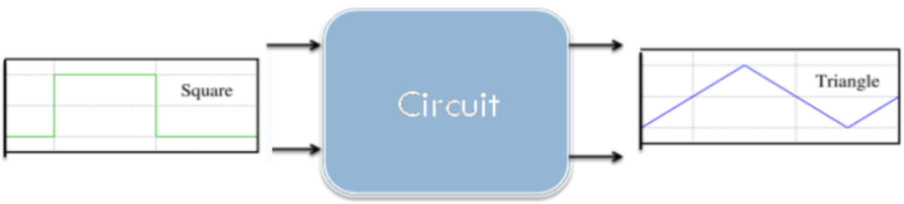
I have understood their significance in electronic circuits and their application in low pass and high pass filters.

Ⅴ. Explain RC circuit as Integrator

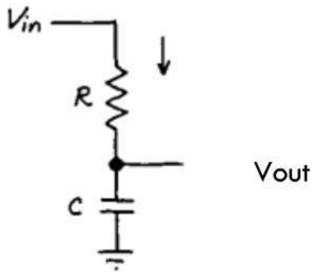
Tools Used: Basic Electronics Virtual Lab

Background Knowledge (Brief):

1. The Integrator is a circuit that converts or ‘integrates' a square wave input signal into triangular waveform output.



2. An RC Integrator performs integration on the input signal and converts a square wave input into a triangular waveform.

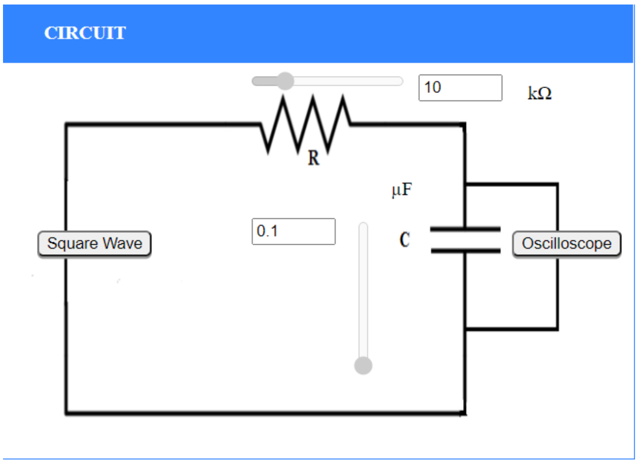


3. As shown in the circuit ,a capacitor and a resistor is joined in series and a voltmeter is attached to the ends of the capacitor.

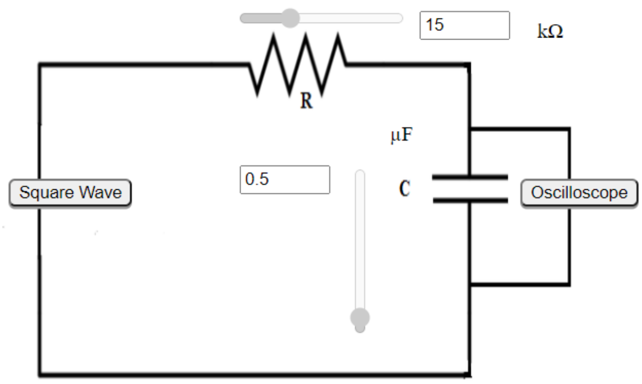
4. So, we put a resistor such that we can control the current and ideally try to have dVout/dt to be a constant. Since the current does not change much during the initial part of the charging and discharging of the capacitor , the value of RC must be chosen such that it is large compared to the time period of the square wave.

Circuit (hand drawn/image):

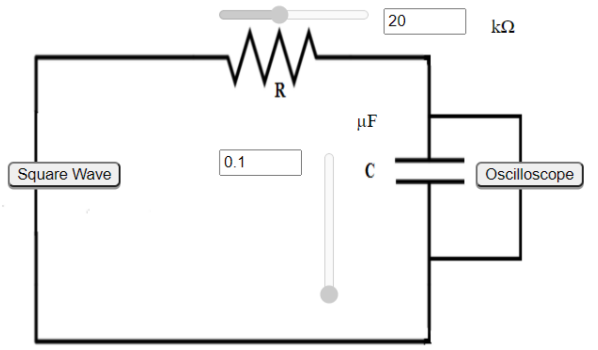
Circuit-1



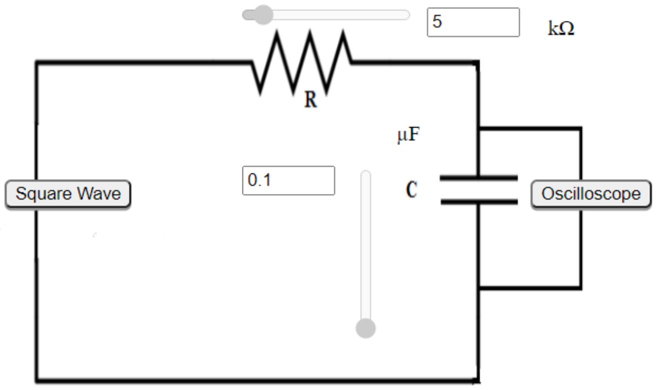
Circuit-2



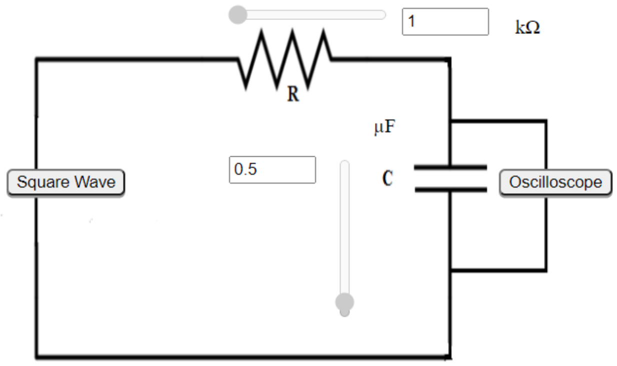
Circuit-3



Circuit-4



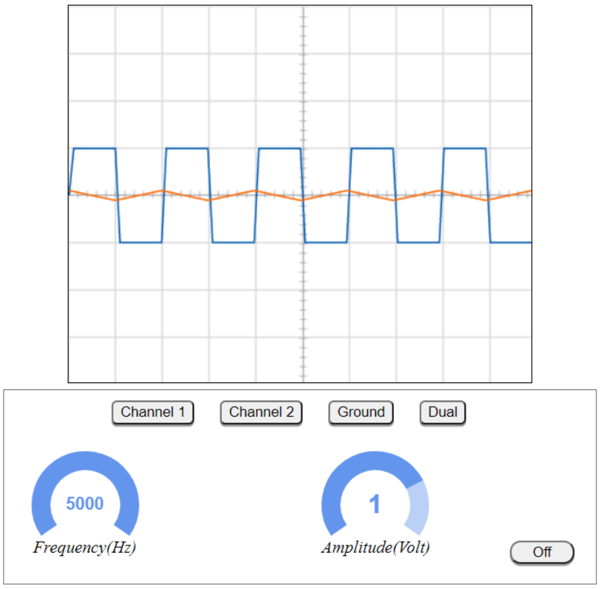
Circuit-5



Graphs (Image/Screenshots):

<u>Graph-1 of Circuit-1:</u>

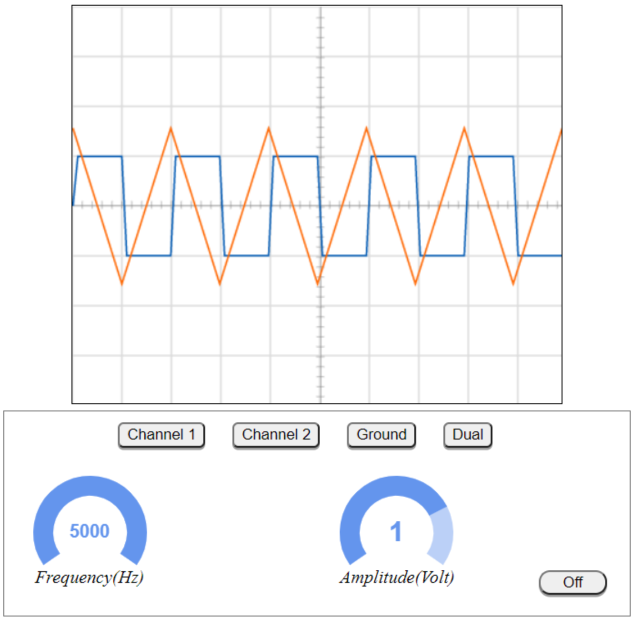
<u>Graph-2 of Circuit-2:</u>



Graph-3 of Circuit-3:

Graph-4 of Circuit-4:

Graph-5 of Circuit-5:



Conclusion and Discussion:

1.1. We have seen here that the RC integrator is basically a series RC low-pass filter circuit which when a step voltage pulse is applied to its input produces an output that is proportional to the integral of its input.

1.2. The integration of the input step function produces an output that resembles a triangular ramp function with amplitude smaller than that of the original pulse input with the amount of attenuation being determined by the time constant.

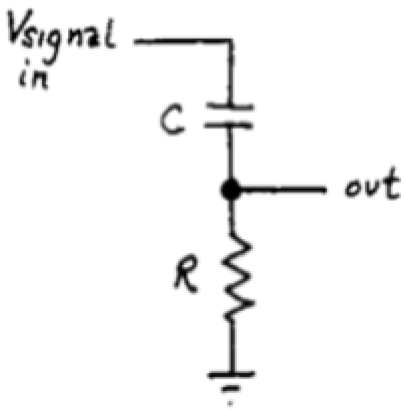
1.3. An RC integrator's time constant is always compared to the period, a long RC time constant will produce a triangular wave shape with low amplitude compared to the input signal as the capacitor has less time to fully charge or discharge. A short time constant allows the capacitor more time to charge and discharge producing a more typical rounded shape.

VI. Explain RC circuit as Differentiator

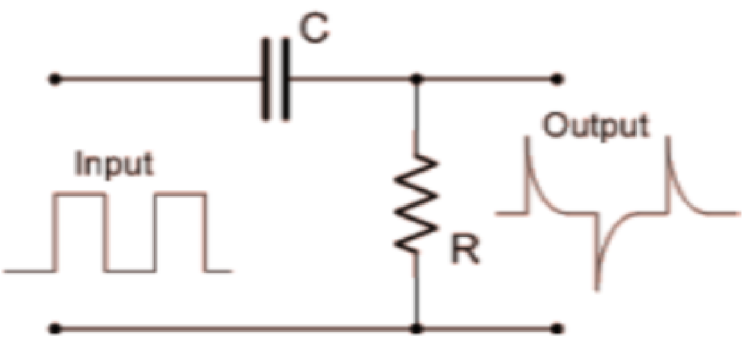
Tools Used: Basic Electronics Virtual Lab

Background Knowledge (Brief):

1. The Differentiator circuit converts or 'differentiates' a square wave input signal into high frequency spikes at its output.

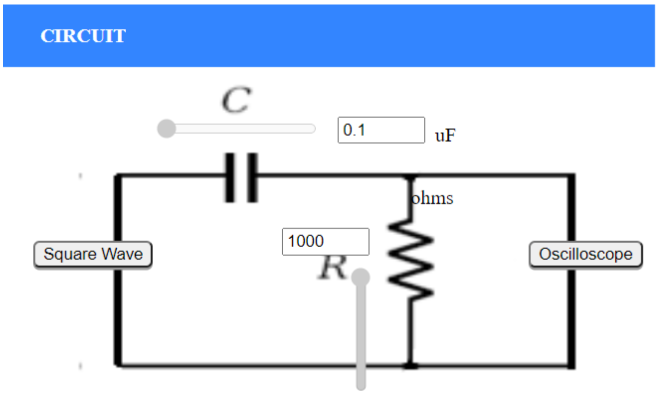


2. As shown in the circuit ,a capacitor and a resistor is joined in series and a voltmeter is attached to the ends of the resistor.
3. In an RC circuit if we take the voltage drop across R, and if we keep RC time constant is very short compared to the time period of the input waveform we will be differentiating the square wave.

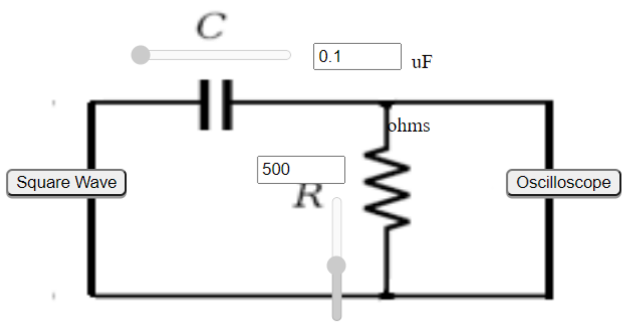


Circuit (hand drawn/image):

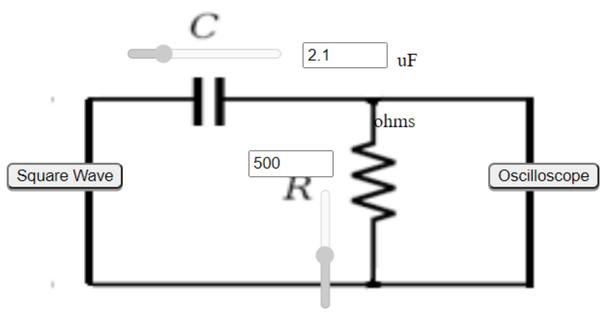
<u>Circuit-1</u>



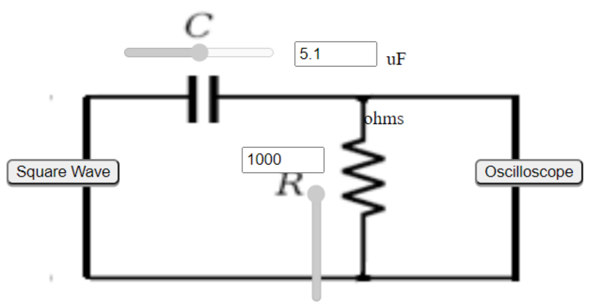
Circuit-2



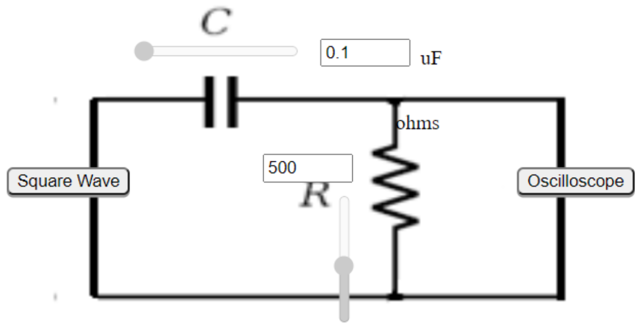
Circuit-3



Circuit-4

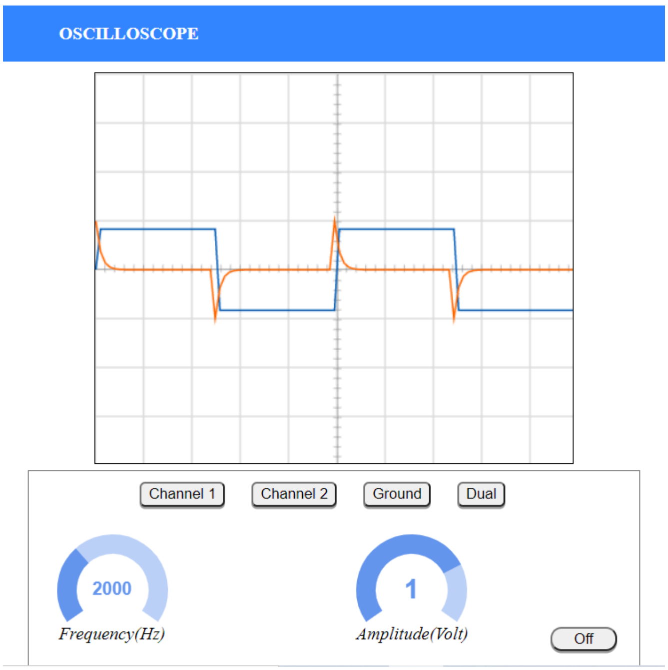


Circuit-5

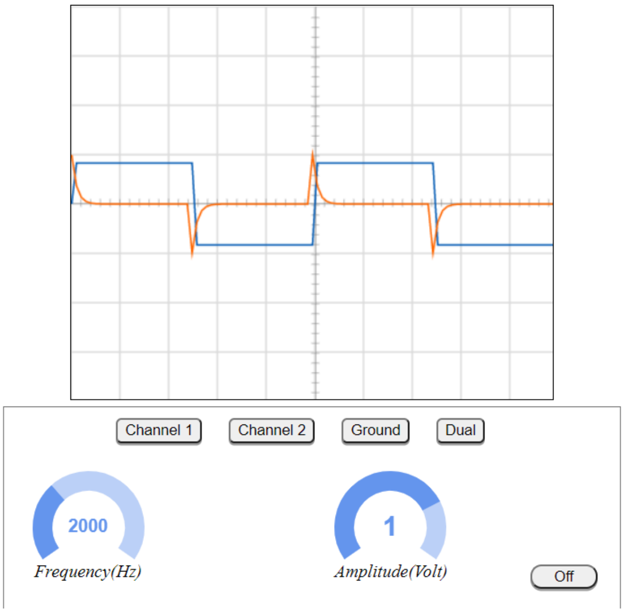


Graphs (Image/Screenshots):

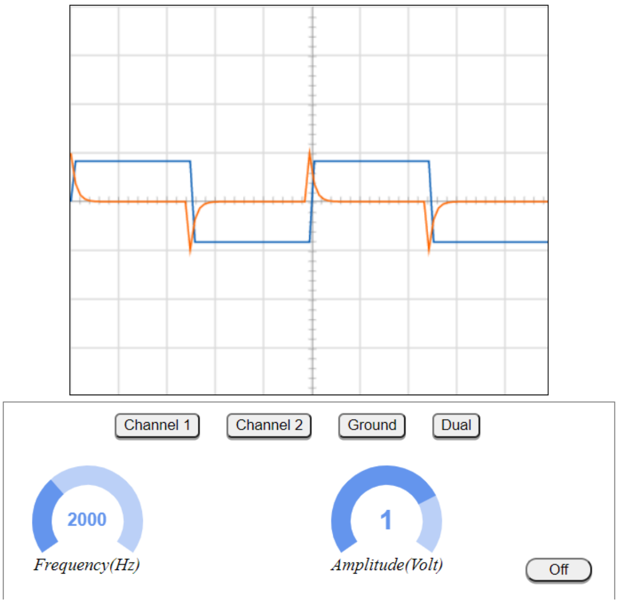
Graph-1 of Circuit-1:



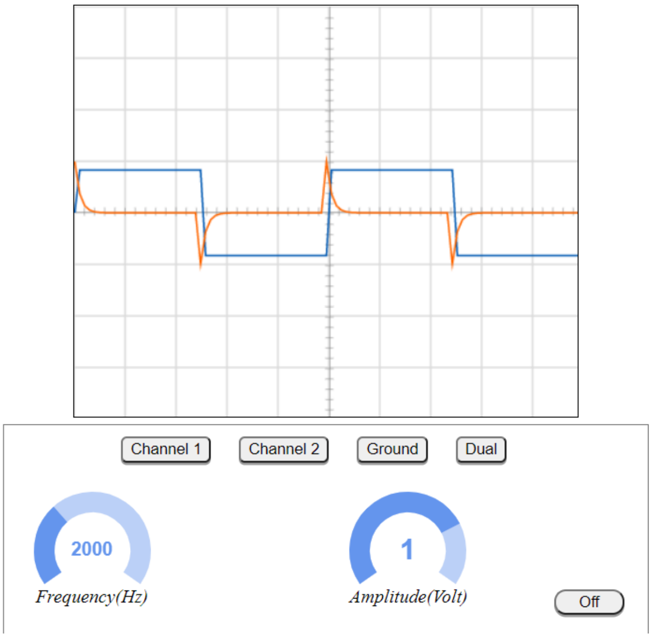
Graph-2 of Circuit-2:



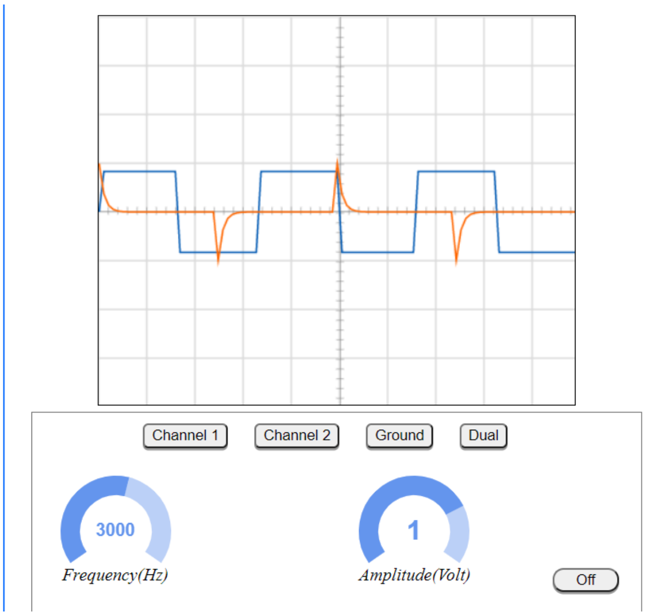
Graph-3 of Circuit-3:



Graph-4 of Circuit-4:



Graph-5 of Circuit-5:



Conclusion and Discussion:

1.1. When a square wave step input is applied to this RC circuit, it produces a completely different wave shape at the output.

1.2. When the periodic time of the input waveform is similar too, or shorter than, (higher frequency) the circuits RC time constant, the output waveform resembles the input waveform, that is a square wave profile. When the periodic time of the input waveform is much longer than, (lower frequency) the circuits RC time constant, the output waveform resembles narrow positive and negative spikes.

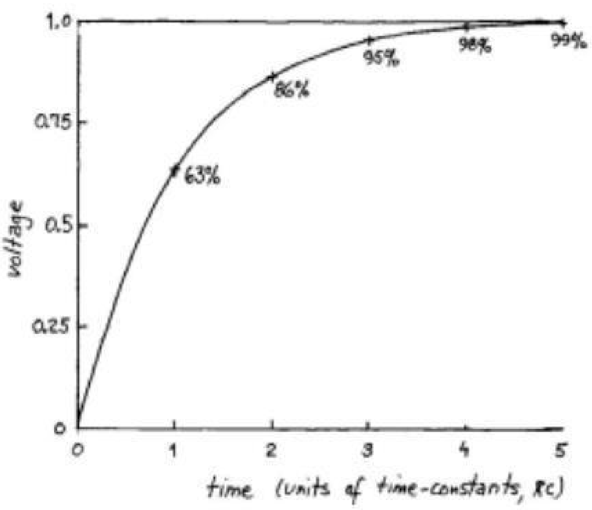
1.3. The positive spike at the output is produced by the leading-edge of the input square wave, while the negative spike at the output is produced by the falling-edge of the input square wave. Then the output of an RC differentiator circuit depends on the rate of change of the input voltage as the effect is very similar to the mathematical function of differentiation.

Ⅶ.Explain charging of RC circuit with DC source

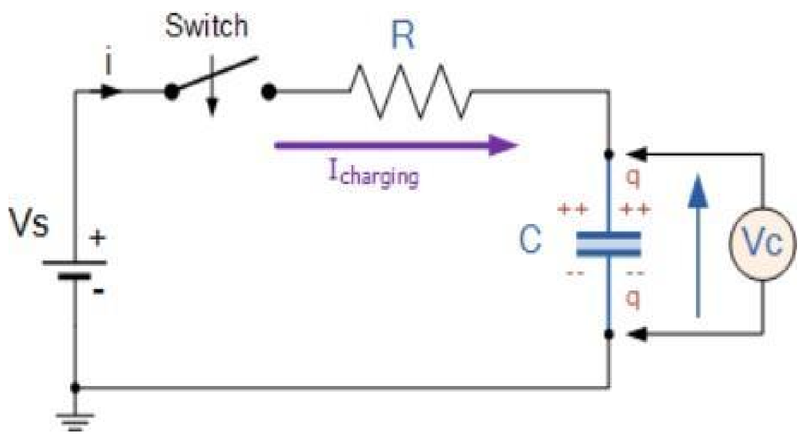
Tools Used: Basic Electronics Virtual Lab

Conclusion and Discussion:

1. A capacitor (discharged) in series with a resistor forms a RC Charging Circuit connected across a DC battery supply via a mechanical switch. The capacitor gradually charges up through the resistor until the voltage across it reaches the supply voltage of the battery.



2. In this circuit ,a battery is supplying energy to the capacitor in the form of charge carried in the form of current from the battery.



Kirchoff’s Equation for charging the capacitor:

$$V_S - R \times i(t) - V_C(t) = 0$$

3. Using this formula ,we can find the potential difference across the capacitor as (keeping i(t)=dq/dt and Vc(t) as q/C,where q is charge on capacitor and C is capacitance of the capacitor) :

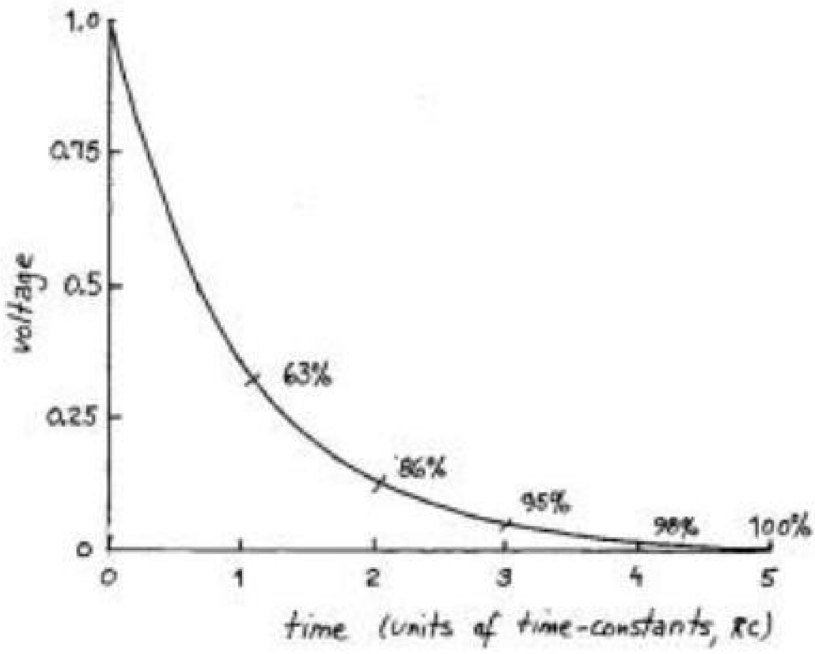
$$V_C = V_S\,(1 - e^{(-t/RC)})$$

4. Here as we can see from the equation, Voltage increases ,and thus charge increases, with time (t) making it a charging circuit. Here RC is the time constant for the circuit. In one time constant = RC , the capacitor charges 63% of the maximum charge that can come in this circuit.

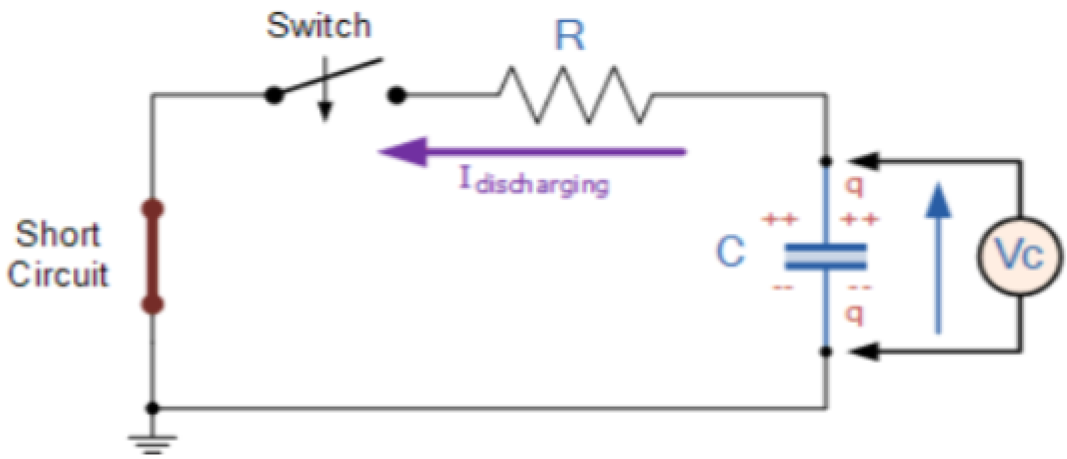
Ⅷ.Explain discharging of RC circuit with DC source

Tools Used: Basic Electronics Virtual Lab
Conclusion and Discussion:

1. A capacitor (discharged) in series with a resistor forms a RC Charging Circuit connected across a DC battery supply via a mechanical switch. The capacitor gradually charges up through the resistor until the voltage across it reaches the supply voltage of the battery. If we remove the DC Source from a fully charged RC Circuit the capacitor will discharge through the resistor till voltage across it becomes zero.



2. In this circuit, the capacitor is supplying energy to the resistor in the form of current and heat energy is produced, thus discharging the capacitor.



Kirchoff's Equation for charging the capacitor: $V_C(t)=i(t)xR$

3. Using this formula ,we can find the potential difference across the capacitor as (keeping i(t)=dq/dt and Vc(t) as q/C,where q is charge on capacitor and C is capacitance of the capacitor) :

$$V_C = V_S \times e^{-t/RC}$$

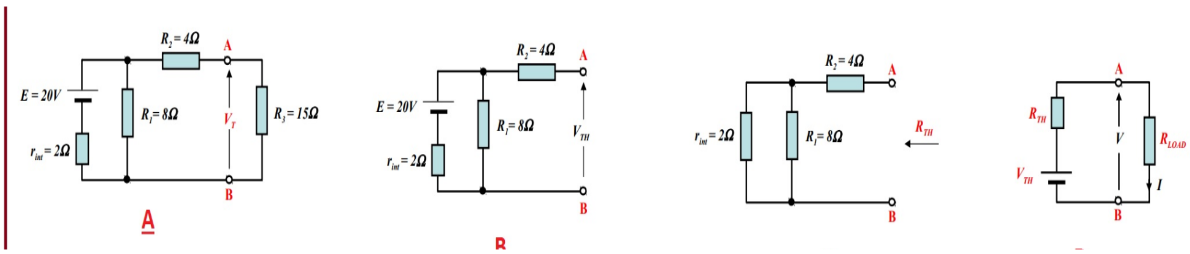
4. Here as we can see from the equation, Voltage decreases ,and thus charge decreases, with time (t) making it a discharging circuit. Here also RC is the time constant for the circuit. In one time constant = RC , the capacitor charges 63% of the charge it had at starting.

Ⅸ. Voltage Divider

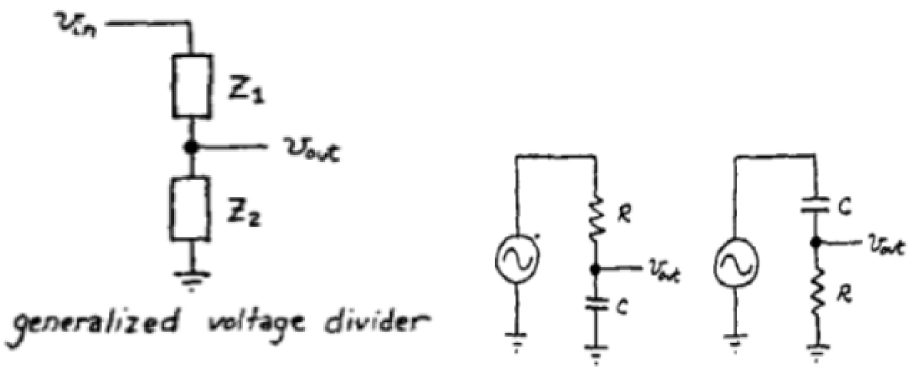
Tools Used: Circuit Simulator Applet (Falstad)

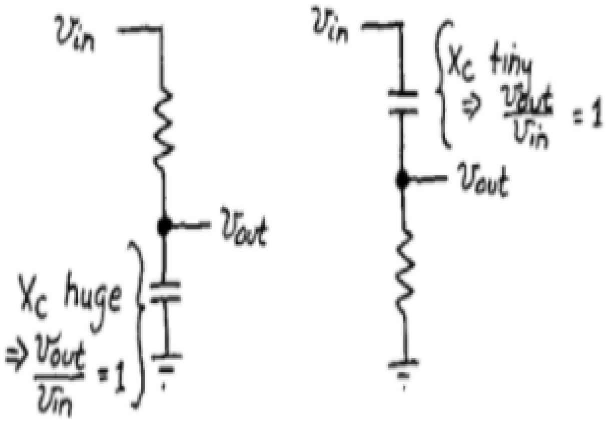
Background Knowledge (Brief):

1. A voltage divider in its simplest form consists of a pair of resistors connected in series, whereby the total voltage across the two of them is divided into two parts.
2. The current and voltage in each part of the circuit are calculated as in any other series or parallel circuit using Kirchhoff's laws.
3. When there is no load on the divider, the portions of the voltage can vary between 0 volts and the total voltage, depending on the individual resistors. There is a marked difference, however, when the circuit is loaded with very small loads. Then the voltage across the part of the circuit including the load will be very small regardless of the resistors in the divider.
4. Thevenin's Theorem-
   Any linear circuit containing several voltages and resistances can be replaced by just one single voltage in series with a single resistance connected across the load.

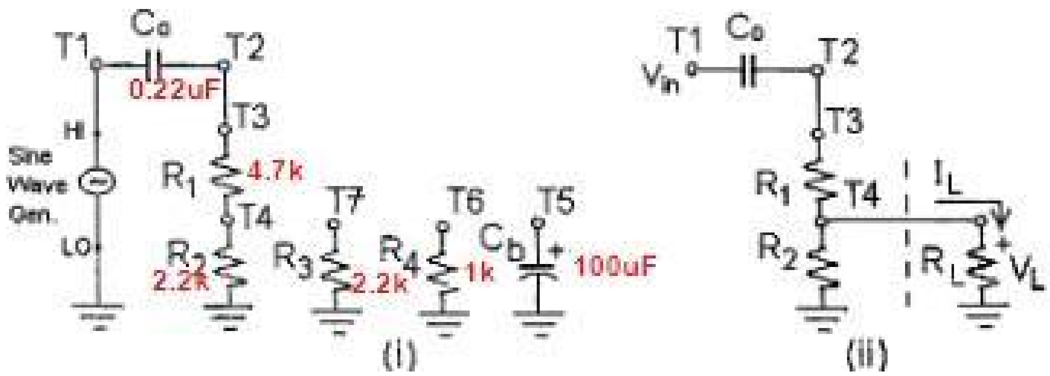


   Any linear two-terminal network can be replaced by an equivalent network consisting of a voltage source Vth in series with a resistance (Rth).
   Vth = Open circuit voltage at load terminals.
   Rth = Equivalent resistance at load terminals when sources are made inoperative.
5. Let us consider RC circuits as voltage dividers to understand how they would perform as 'filters'. Note that $V_{out} = (Z_2/ (Z_1 + Z_2)) \times V_{in}$. In this case – Since Z_1 or Z_2 is dependent upon frequency, the output is dependent upon the frequency of the input waveform.

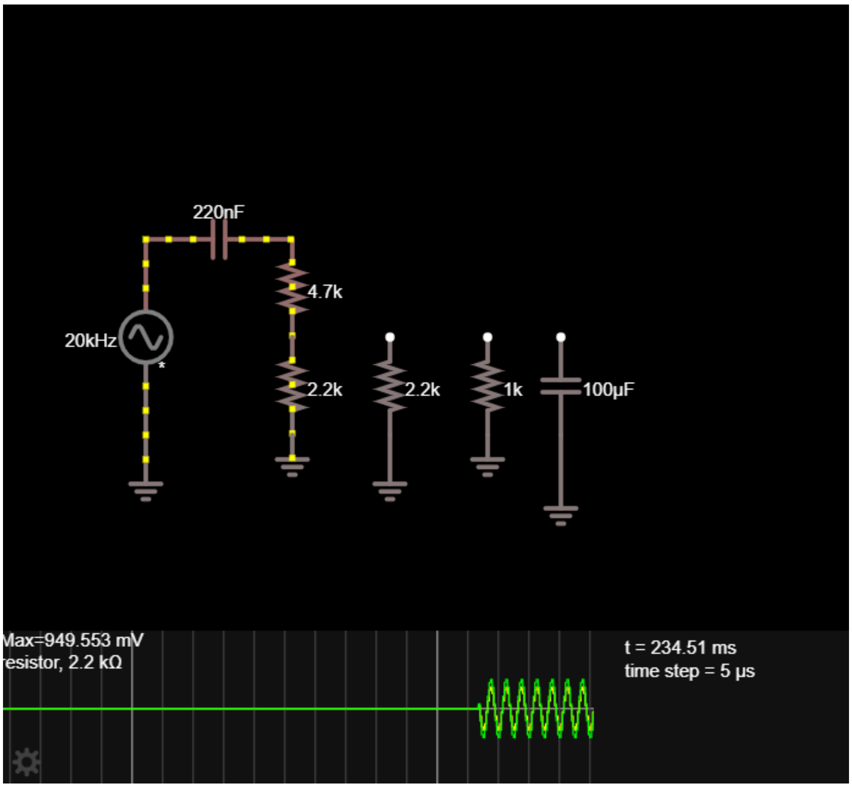




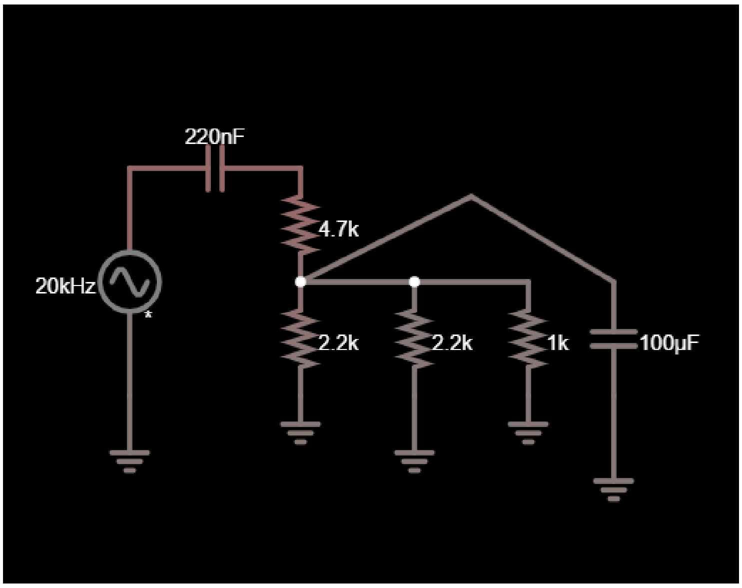
Circuit (hand drawn/image):



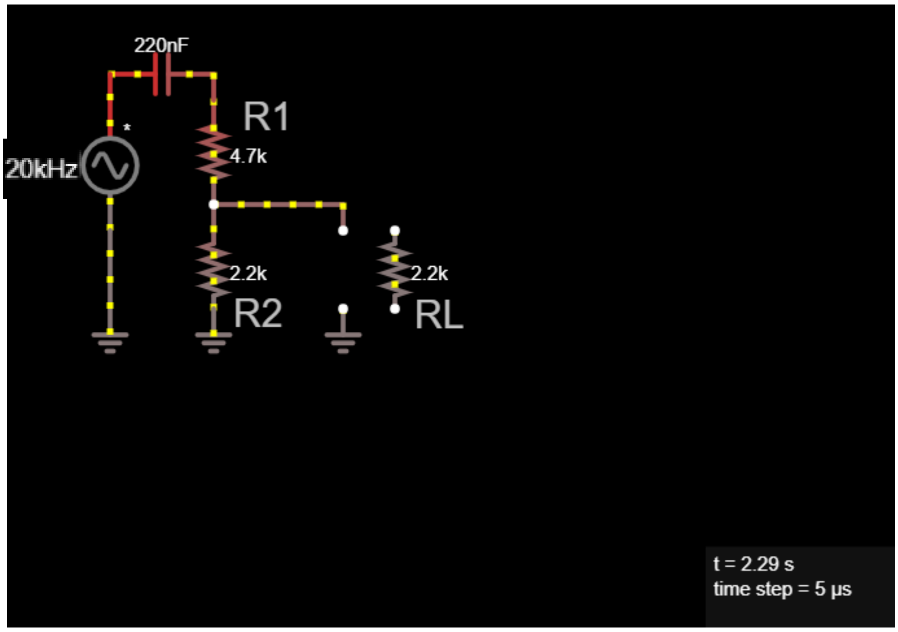
Circuit-1



Circuit-2:



Circuit-3: Making the load resistance inoperative to find Thevenin voltage and resistance



Measurement Data(Tabular Form):

Observation Table for Circuit-1:

Since the experiment is being performed on the Circuit Simulator Applet (Falstad), observed V_L and V_L (thevenin) calculated are the same due to the absence of heating effect, human error in measuring the readings, parallax error and instrumental error.

When C_o = 0.22uF -

Sl no.	**V_{in}(V)**	**C_o(uF)**	**R_1 (in Ω)**	**R_2 (in Ω)**	**R_L (in Ω)**	**V_L (in V)**	**V_L (Thevenin) in Volts**
1.	3	0.22	4700	2200	No load	0.956	0.956
2.	3	0.22	4700	2200	2200	0.569	0.569
3.	3	0.22	4700	2200	1000	0.383	0.383
4.	3	0.22	4700	2200	2200 ||1000	0.301	0.301

When C_b = 100uF is connected in parallel to R_L -

Sl no.	**V_{in}(V)**	**C_o(uF)**	**R_1 (in Ω)**	**R_2 (in Ω)**	**C_b(uF)**	**R_L (in Ω)**	**V_L (in V)**	**V_L (Thevenin) in Volts**
1.	3	0.22	4700	2200	100	No load	0.010623	0.010623
2.	3	0.22	4700	2200	100	2200	0.010617	0.010617
3.	3	0.22	4700	2200	100	1000	0.010606	0.010606
4.	3	0.22	4700	2200	100	2200 ||1000	0.010594	0.010594

Conclusion:

Clearly, Thevenin's theorem is verified. Any linear circuit, irrespective of its complexity can be reduced to an equivalent circuit with just a single voltage source and series resistance connected to the load. By observing the values from the Circuit Simulator Applet (Falstad), we get **V_L=V_{th}** , i.e, **V_L (Thevenin).** The basics of how a voltage is dropped across a resistor/impedance due to a component like inductor, capacitor were studied. By performing the experiment, I can observe that the greater is the resistance, the greater will be the voltage drop across it.

Discussions:

1. Nearly all electronic circuits make use of the concept of the voltage divider and Thevenin's theorem, so it is important to get a complete idea about them such as determining resistance while using a multimeter and using the voltage drop concept and with an ammeter, Ohm's Law verification can be done.
2. I have learnt to use Circuit Simulator Applet (Falstad).