Basics of Electrical and Electronic Circuits

Experiment 5 **Spring2025**

Transients in Capacitors and Common RC Filter Circuits

Filters are used very widely in communication systems to separate different frequencies, and so their behavior is studied in terms of their **Frequency Response**, which reflects how the ***Gain***, defined to be the ratio of the amplitude of the output signal to that of the input signal, varies with frequency.

In this experiment, we will study very common RC circuits:

A. **Transients in capacitors:** Observe the Transient behavior in capacitor using square wave
B. **Lowpass** filter – Gain is maximum at low frequencies, and falls off beyond a Cut-off frequency,
C. **Bandpass** filter – Gain falls off on either side of a Centre frequency

Lowpass filters are widely used to get rid of unwanted high-frequency disturbances generally referred to as **noise.** Bandpass filters are employed to selectively permit only a narrow band of frequencies to pass through, their most common use being in radio receivers for selecting a chosen radio station. These circuits may in general consist of various circuit elements, but we will study circuits consisting of resistors and capacitors only.

A. **Transients in RC circuits:** Implement the given circuit with R= 20 K-Ohm and C=0.001 µF. Generate square wave voltage (at 1 kHz) v_s= 4 V with Min. 0 to Max. 4V using desired offset through function generator (**WaveGen**).

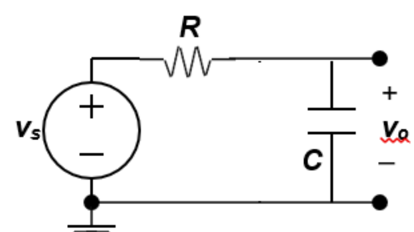


Fig.1 RC circuit to observe Transient behavior

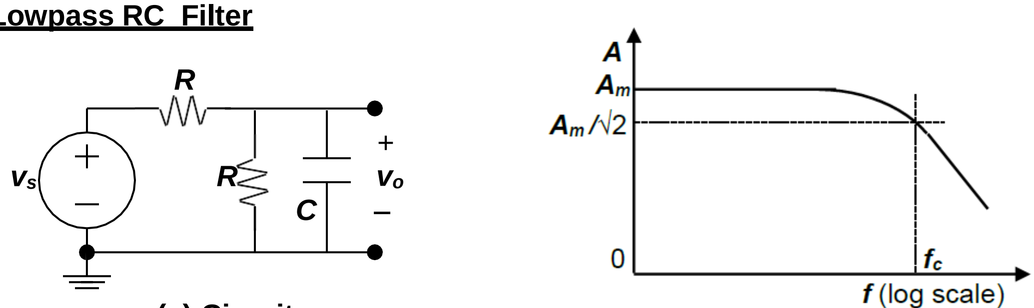
Table: 1: Charging and Discharging observations:

Charging	Time constant τ=RxC	Applied frequency of Square wave	Voltage Amplitude v_s	v_o at t=0	v_o at t=τ (…s)	v_o at t= 2xτ (……..s)	v_o at t= 5xτ (…..s)
Discharging	Time constant τ=RxC	Applied frequency of Square wave	Voltage Amplitude v_s	v_o at t=0	v_o at t=τ	v_o at t= 2xτ	v_o at t= 5xτ

- Repeat Table-1 with R= 10 K-Ohm [by adding another R=20 k-Ohm in parallel to existing resistor R=20 k-Ohm].

- Now increase the frequency of the input square wave till the maximum output v_o (of charging cycle) is comparable to the input voltage. Increase the frequency further and observe the effect of it on the level of maximum voltage of v_o across capacitor.

B. Lowpass RC Filter



(a) Circuit diagram

(b) Frequency Response

Fig. 2 Lowpass RC Filter

Fig. 2(a) shows the circuit of a simple Lowpass RC Filter, where $\boldsymbol{R}$ = 20 kΩ and $\boldsymbol{C}$ = 0.001 μF**.** The Voltage Gain $\boldsymbol{A} = \boldsymbol{V_{om}} / \boldsymbol{V_{sm}}$, where $\boldsymbol{V_{sm}}$ and $\boldsymbol{V_{om}}$ are the amplitudes of the voltages $\boldsymbol{v_s}$ and $\boldsymbol{v_o}$ respectively. The Frequency Response given in **Fig. 2(b)** indicates that $\boldsymbol{A}$ remains constant at a value $\boldsymbol{A_m}$ at low frequencies, and falls off as frequency increases. The frequency $\boldsymbol{f_c}$, at which $\boldsymbol{A} = \boldsymbol{A_m} /\sqrt{2}$ is called the **Cut-off Frequency**. The theoretically expected values are: $\boldsymbol{A_m} = 0.5$ and $\boldsymbol{f_c} = 1 / (\pi \boldsymbol{RC})$.

1. Set up the circuit given in **Fig.2(a)**, with the input voltage $\boldsymbol{v_s}$ applied from the WAVEGEN, and connect $\boldsymbol{v_s}$ and the output voltage $\boldsymbol{v_o}$ to channels 1 and 2 of the DSO. Set the WAVEGEN for 100Hz **sinusoidal** wave output with peak-to-peak value 4.0V and zero offset. Choosing WAVEGEN as the **trigger** source, display 2-3 cycles of the waveforms by adjusting the **time base**.

2. Change the mode of the DSO to ***x-y*** and note that the graph displayed on the screen is a straight line, and hence the slope of the line will give the value of the Gain $\boldsymbol{A}$. Verify that the straight line remains unchanged if the frequency is **decreased** gradually, indicating that the Gain $\boldsymbol{A}$ is constant and thus equal to $\boldsymbol{A_m}$. Find the value of $\boldsymbol{A_m}$ by measuring the slope of the straight line.

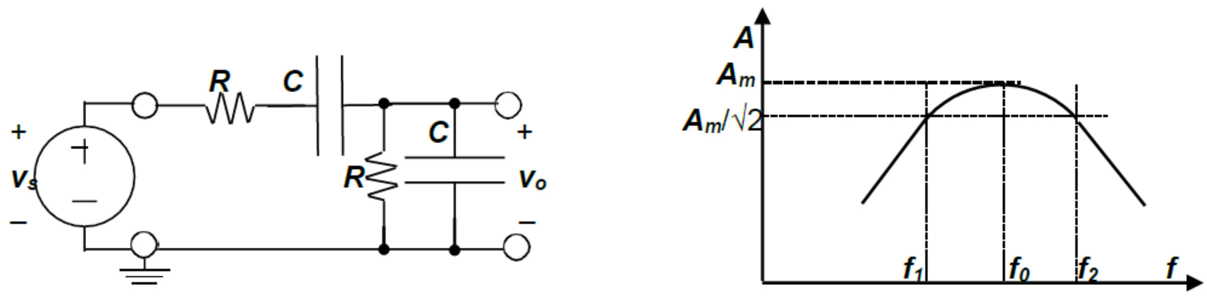
3. **Increase** the frequency gradually until the display starts becoming elliptical in shape, indicating that $\boldsymbol{v_o}$ is no longer in phase with $\boldsymbol{v_s}$. Change the display mode of the DSO to ***y-t*** and set up the **Measurement** option of the DSO to measure the peak-to-peak values of $\boldsymbol{v_o}$ and $\boldsymbol{v_s}$. Observe that the amplitude of $\boldsymbol{v_o}$ and hence the value of Gain $\boldsymbol{A}$ decreases as the frequency is increased. Note that as long as the peak-to-peak value of the input voltage $\boldsymbol{v_i}$ remains 4.0V, $\boldsymbol{A}$ is given by half the amplitude of the output voltage $\boldsymbol{v_o}$. Determine the cut-off frequency $\boldsymbol{f_c}$ where $\boldsymbol{A} = \boldsymbol{A_m} /\sqrt{2}$ ($\approx 0.7\boldsymbol{A_m}$). Calculate the theoretically expected value of $\boldsymbol{f_c}$ and compare it with the measured value.

Table:2: LPF

Voltage Amplitude v_s	Gain A_m	f_0	f_c	Bandwidth

C. Bandpass RC Filter

The circuit diagram of a simple Band-pass RC Filter and its frequency response are shown in **Fig. 3**. The Frequency Response shown in **Fig. 3(b)** indicates that the Voltage Gain $\boldsymbol{A}$ has a maximum value $\boldsymbol{A_m}$ at a Centre Frequency $\boldsymbol{f_0}$, and falls off both at lower and at higher frequencies. The theoreticalvalues of $\boldsymbol{f_0}$ and the Voltage Gain $\boldsymbol{A_m}$ at $\boldsymbol{f_0}$ are given by: $f_0 = 1 / (2\pi RC)$ and $A_m = 1/3$.



(a) Circuit diagram **(b) Frequency Response**

Fig. 3 Bandpass RC Filter

1. Set up the circuit given in **Fig. 3(a)**, with R = 20 kΩ, C = 0.001μF.
2. Repeat the WAVEGEN and DSO settings used in step **B.1**.
3. Change the mode of the DSO to ***x-y*** and note that the graph displayed on the screen is elliptical in shape, indicating that there is a phase difference between v_s and v_o. Increase the frequency gradually until the display becomes a straight line, indicating that v_o is in phase with v_s. Note the frequency and find the value of the Voltage Gain by measuring the slope of the straight line.
4. Change the display mode of the DSO to ***y-t*** and set up the **Measurement** option of the DSO to measure the peak-to-peak values of v_o and v_s. Note that the amplitude of v_o and hence the Gain $\boldsymbol{A}$ decreases if frequency is changed either way. The frequency and the Voltage Gain found out in the previous step therefore give the Centre Frequency $\boldsymbol{f_0}$ and the Centre-frequency Gain $\boldsymbol{A_m}$.
5. Vary the frequency and determine the lower cut-off frequency f_{C1} and the upper cut-off frequency f_{C2} of the Bandpass filter, where $A = A_m/\sqrt{2}$ ($\approx 0.7A_m$). Verify that $f_{C1}f_{C2} \approx f^2$.
6. Set the WAVEGEN for a triangular waveform having frequency $\boldsymbol{f_0}$ as found in step **4**, and sketch thewaveform of the output voltage v_o. Is the waveform more like a triangular waveform or more like a sinusoidal waveform?

Table:3: BPF

Voltage Amplitude v_s	Gain A_m	f_0	f_{c1}	f_{c2}	Bandwidth

Results:

Conclusion: It must be in your words and be based on your understanding/ learning in the experiment.