Department of Electronics and Telecommunication Engineering
University of Moratuwa

B.Sc. (Eng) Semester 4
EN 2111-Electronic Circuit Design
Laboratory Experiment 01

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Lab: Analog Lab
Group: 07
Field: EN/~~BM~~

Marks:

First Order Filter Circuits

Objectives

To learn the frequency response of the first order active and passive filter circuits by experimental work.

Equipment

- Multimeter
- Function Generator
- Dual Power Supply
- Digital Oscilloscope (or CRO)
- Breadboard

Components

- OP-Amp (741)
- Resistors (180Ω, 330 Ω, 1.5KΩ)
- Capacitors (0.1uF ,10nF)
- Wires

Theory

Filters alter the amplitude and/or phase characteristics of an electrical signal with respect to its frequency. A low-pass filter passes signals with a frequency lower than a cutoff frequency and attenuates signals with frequencies higher than the cutoff frequency. A high-pass filter passes signals with a frequency higher than a cutoff frequency and attenuates signals with frequencies lower than the cutoff frequency.

Types of Filters:

- Low pass Filter
- High pass Filter
- Band pass Filter
- Band stop Filter

Procedure

1.0 First Order Low-pass Filter Design

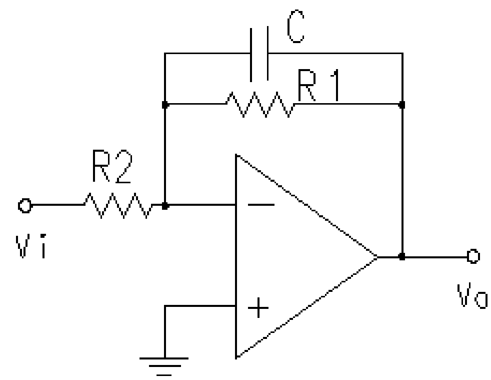


Figure 1: First Order Filter

1.1 Derive the transfer function of the circuit & and determine the mid- band gain and the cutoff frequency. Identify the type of filter.

1.2 Calculate the values for R1, R2 and C to design a filter with 10 KHz cutoff frequency and a mid-band gain of 5. Select the components R1, R2, and C which are close to the claculated values.

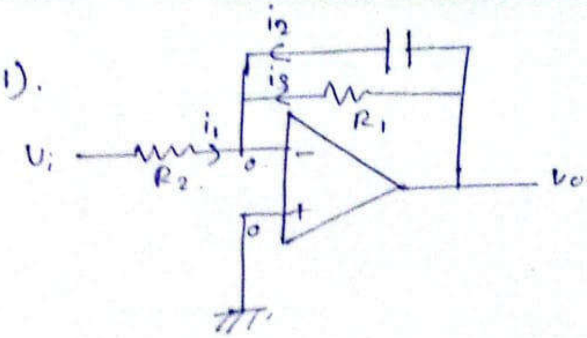
1.3 Connect the circuit shown in Figure 1 with your selected components.

1.4 Connect a 200mV p-p sine wave to the input 'Vi' and change the frequency of the input signal as shown in Table 1. Measure the output voltage amplitude 'Vo p-p' and its phase shift introduced by the filter.

Frequency (KHz)	$V_{o\ p\text{-}p}$	Phase	Frequency (KHz)	$V_{o\ p\text{-}p}$	Phase
0.05	888mV	179^0	8.0	696mV	133^0
0.10	888mV	178^0	10.0	632mV	130^0
0.50	880mV	176^0	15.0	472mV	122^0
0.75	880mV	171^0	20.0	408mV	119^0
1.00	880mV	169^0	30.0	344mV	112^0
3.00	848mV	160^0	50.0	332mV	97.2^0
5.00	792mV	148^0	100	286mV	88.4^0

Table 1

1) 1.1).



$$i_1(s) = \frac{V_i(s)}{R_2} \leftarrow ① \quad i_2(s) = \frac{V_o(s)}{\left(\frac{1}{Cs}\right)} \quad i_3(s) = \frac{V_o(s)}{R_1} \leftarrow ③$$

$$i_2(s) = CsV_o(s) \leftarrow ②$$

$$i_1(s) + i_2(s) + i_3(s) = 0$$

$$\frac{V_i(s)}{R_2} + CsV_o(s) + \frac{V_o(s)}{R_1} = 0$$

$$V_o(s)\frac{(1 + CR_1 s)}{R_1} = -\frac{V_i(s)}{R_2}$$

$$H(s) = \frac{V_o(s)}{V_i(s)} = -\frac{R_1}{R_2}\left(\frac{1}{1 + CR_1 s}\right).$$

$$H(j\omega) = -\frac{R_1}{R_2}\left(\frac{1}{1 + CR_1 j\omega}\right)$$

$$|H(j\omega)| = \frac{R_1}{R_2}\frac{1}{\sqrt{1 + (CR_1\omega)^2}} \Rightarrow \omega_c = \frac{1}{CR_1} \Rightarrow f_c = \frac{1}{2\pi R_1 C}.$$

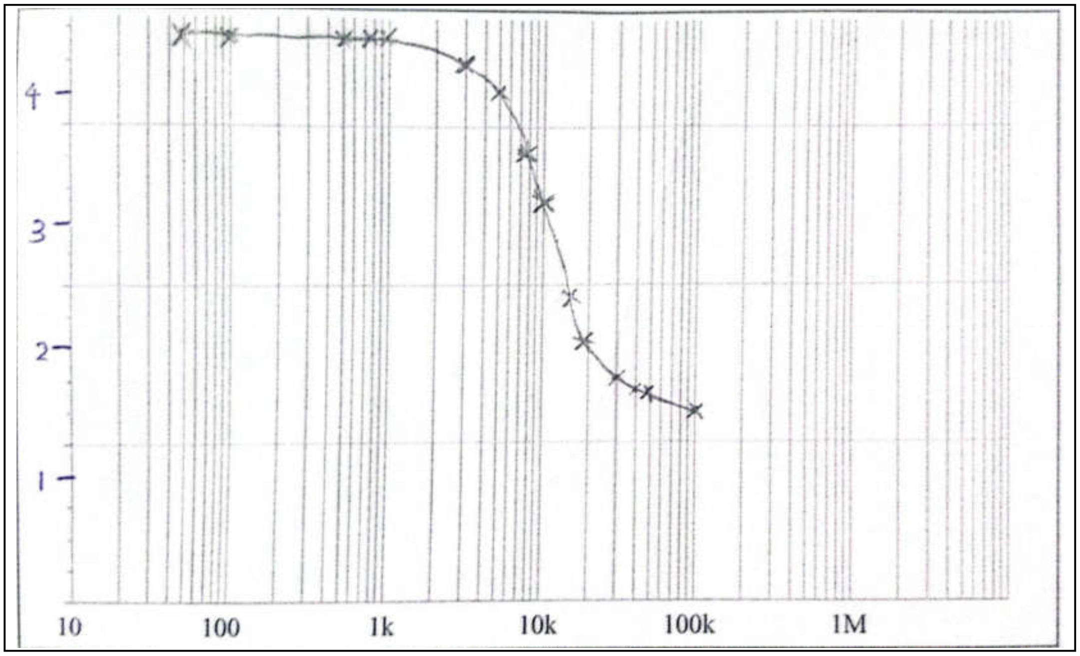
mid-band gain $= -\frac{R_1}{R_2}$. This is a low pass filter.

1.2). $\frac{R_1}{R_2} = 5 \Rightarrow R_1 = 1.5\,k\Omega$, $R_2 = 330\,\Omega$.

$$10\,kHz = \frac{1}{2\pi(1.5\,k\Omega)C} \Rightarrow C = 10.61\,nF \approx 10\,nF.$$

$$\boxed{R_1 = 1.5\,k\Omega,\ R_2 = 330\,\Omega,\ C = 10\,nF}$$

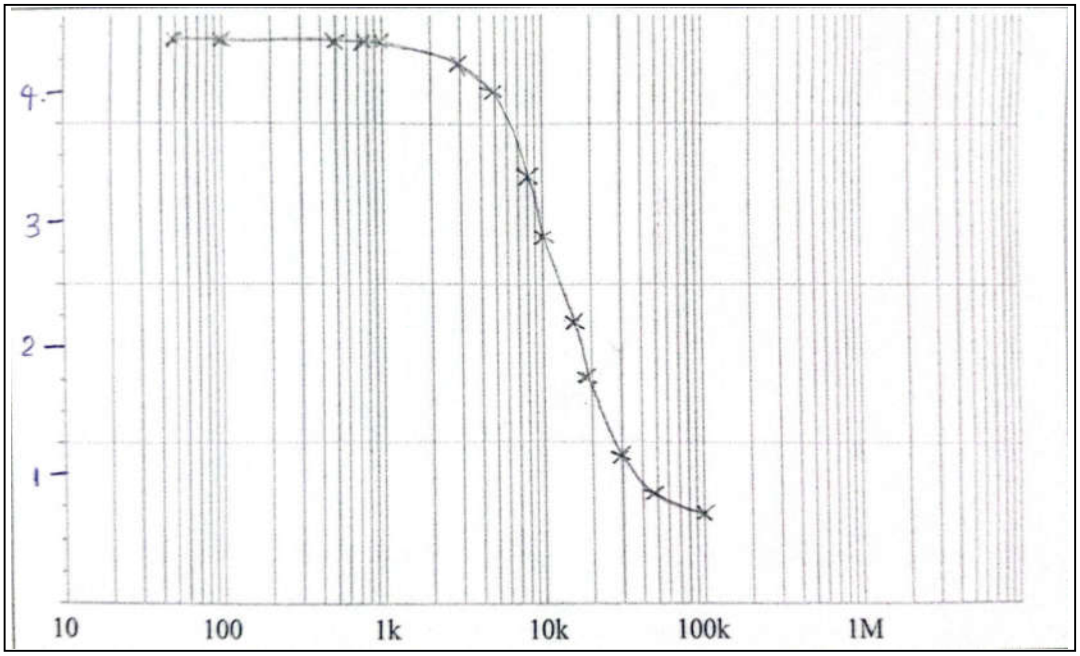
1.5 Plot the Gain vs Frequency.



1.6 Connect a 100Ω ohm load to the output. Repeat the procedure given at section 1.4 and record the output 'Vo p-p' and its phase shift.

Frequency (KHz)	$V_{o\ p\text{-}p}$	Phase	Frequency (KHz)	$V_{o\ p\text{-}p}$	Phase
0.05	872mV	178^0	8.0	668mV	128^0
0.10	872mV	177^0	10.0	580mV	120^0
0.50	872mV	175^0	15.0	440mV	118.8^0
0.75	872mV	164^0	20.0	352mV	108^0
1.00	872mV	163^0	30.0	232mV	100^0
3.00	848mV	162^0	50.0	158mV	95.4^0
5.00	800mV	132^0	100	120mV	88.5^0

1.7 Plot the Gain vs Frequency.



2.0 Connect the circuit shown in Figure 2 using the same components. Repeat the procedure given in Section 1.4.

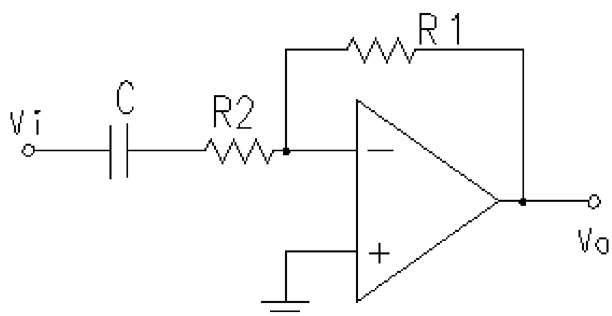
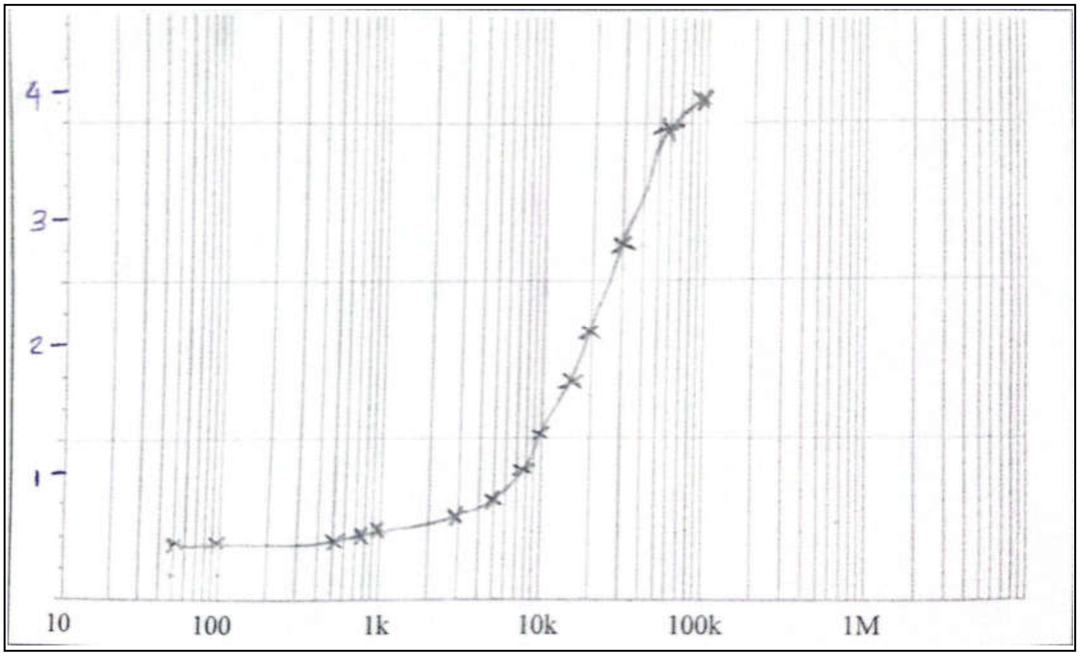


Figure 2

Frequency (KHz)	$V_{o\ p\text{-}p}$	Phase	Frequency (KHz)	$V_{o\ p\text{-}p}$	Phase
0.05	84mV	-	8.0	224mV	103.68^0
0.10	86mV	115.2^0	10.0	256mV	100.8^0
0.50	90mV	107.99^0	15.0	344mV	118.8^0
0.75	99.2mV	97.19^0	20.0	424mV	115.19^0
1.00	114mV	100.8^0	30.0	560mV	129.6^0
3.00	120mV	97.19^0	50.0	744mV	160.5^0
5.00	160mV	100.8^0	100	800mV	167.7^0

2.1 Plot the Gain vs Frequency.



2.2 Discuss your observation and identify the type of filter.

- The gain of the filter increases with frequency, showing high attenuation at low frequencies while allowing high-frequency signals to pass with a gain approximately equal to 4.

- At low frequencies, the phase takes values close to 90°, and as the frequency increases, it approaches values close to 180°, resulting in an effective phase shift of 90°.

Therefore this is a high pass filter.