B O Ğ A Z İ Ç İ U N İ V E R S İ T Y
E L E C T R I C A L & E L E C T R O N I C E N G I N E E R I N G D E P A R T M E N T

EE327-ELECTRICAL NETWORK LABORATORY REPORT

Number of The Experiment : 2 ....
Name of The Experiment : Frequency Response of Linear Circuits ....

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Delay

Grading

General		/20
Data		/30
Discussion		/20
Answers		/30
Total		/100
Delay		
SCORE		/100

1. THE EQUIPMENT USED IN THE LAB

1.1 DC Power Supply
1.2 AC Voltmeter
1.3 Signal Generator
1.4 1kΩ Resistors
1.5 10 nF Capacitor
1.6 Oscilloscope
1.7 Breadboard

2. THEORY AND METHOD

In this experiment we have applied our theoretical knowledge about the frequency response of circuits to real circuits formed of basically a resistor and a capacitor. For sinusoidal inputs, the capacitor in the circuit acts as a resistor with complex resistance which is equal to 1/jwC. This impedence, as seen, depends on the input frequency. Therefore changing the frequency of the input signal changes the voltage on the capacitor, and also the resistor. There are or may be some frequencies where the power of the input signal is halved. Such a frequency is called cut-off frequency. It corresponds to the frequency where $V_o/V_i = 0.707$ or 3 dB fall of the bode plot. In the following parts of the report, this phenomenon is represented by calculations, graphs and measured values for various types of circuits.

Low Pass Filter

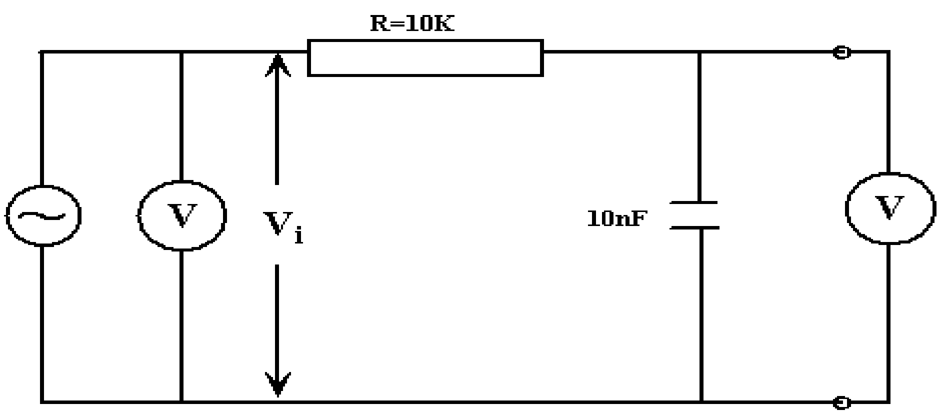

Figure: Low Pass Filter Circuit

$$V_i(s) = (R + 1/Cs) \cdot I(s)$$

$$V_o(s) = (1/Cs) \cdot I(s)$$

$$\frac{V\ (s)}{V_o(s)} = \frac{1/Cs}{R + 1/Cs}$$

If we put C = 10 nF and R = 10 kΩ, we obtain the following transfer function for the low pass filter circuit:

$$\frac{V_o(s)}{V_i(s)} = \frac{10^4}{s+10^4} \qquad f_c = \frac{10^4}{2p} = 1592Hz$$

High Pass Filter

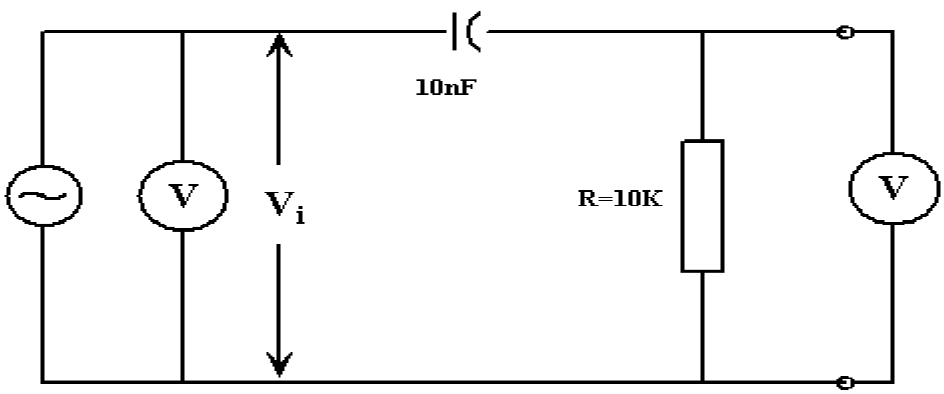

Figure: High Pass Filter Circuit

$$V_i(s) = (R + \tfrac{1}{Cs}) \cdot I(s)$$
$$V_o(s) = R \cdot I(s)$$
$$\frac{V_i(s)}{V_o(s)} = \frac{R}{R + \tfrac{1}{Cs}}$$

If we put C = 10 nF and R = 10 kΩ, we obtain the following transfer function for the low pass filter circuit:

$$\frac{V_o(s)}{V_i(s)} = \frac{s}{s+10^4} \qquad f_c = \frac{10^4}{2p} = 1592Hz$$

3. DATA

Frequency (kHz)	0.2	0.5	1	2	5	10	20
Output(V)	0.494	0.475	0.422	0.309	0.134	0.080	0.023
Output(dB)	-0.10	-0.45	-1.47	-4.18	-11.4	-15.9	-26.7

Table: Voltage measurements for the low pass filter circuit

Measured value of cut-off frequency for low pass filter : $f_c = 1533Hz$

♦ This value is obtained by varying the frequency of the input in order to get –3dB at the output. Looking at the table above, it is obvious that cut-off frequency is between 1KHz and 2KHz.

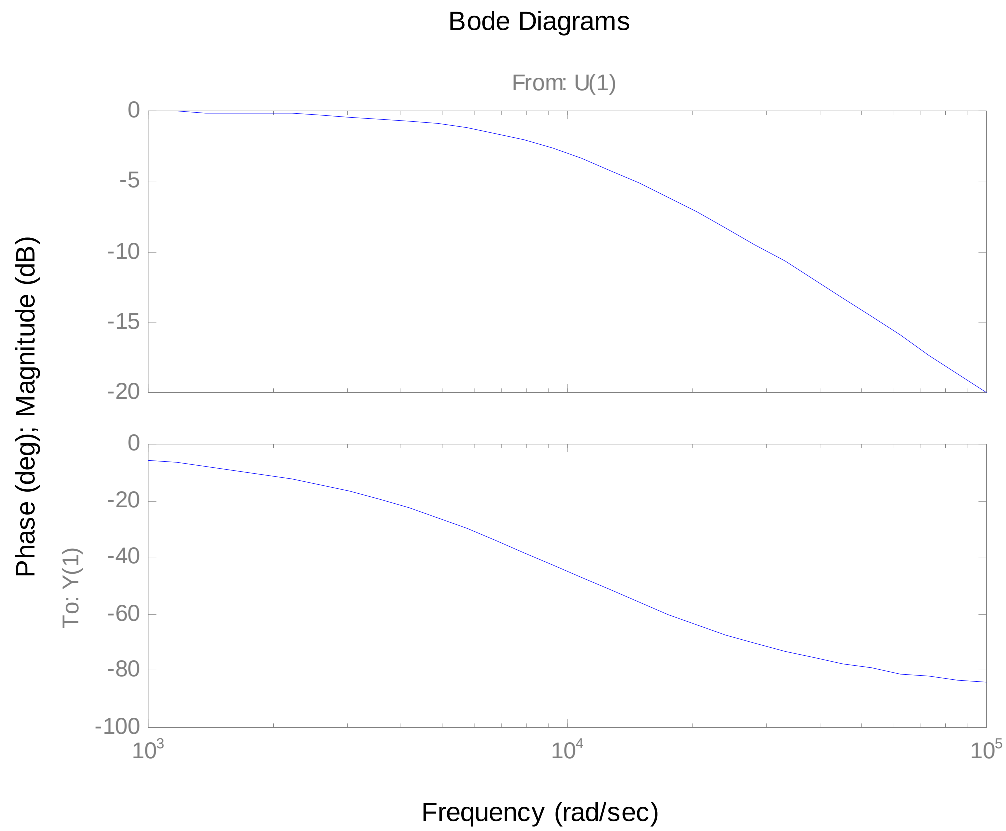

Figure: Bode pilot of the transfer function of the low pass filter circuit by MATLAB

Frequency (kHz)	0.2	0.5	1	2	5	10	20
Output(V)	0.061	0.146	0.263	0.388	0.473	0.490	0.496
Output(dB)	-18.2	-10.6	-5.5	-2.2	-0.43	-0.12	-0.02

Table: Voltage measurements for the high pass filter circuit

Measured value of cut-off frequency for low pass filter : $f_c = 1608 Hz$

♦ This value is obtained by varying the frequency of the input in order to get –3dB at the output. Looking at the table above, it is obvious that cut-off frequency is between 1KHz and 2KHz.

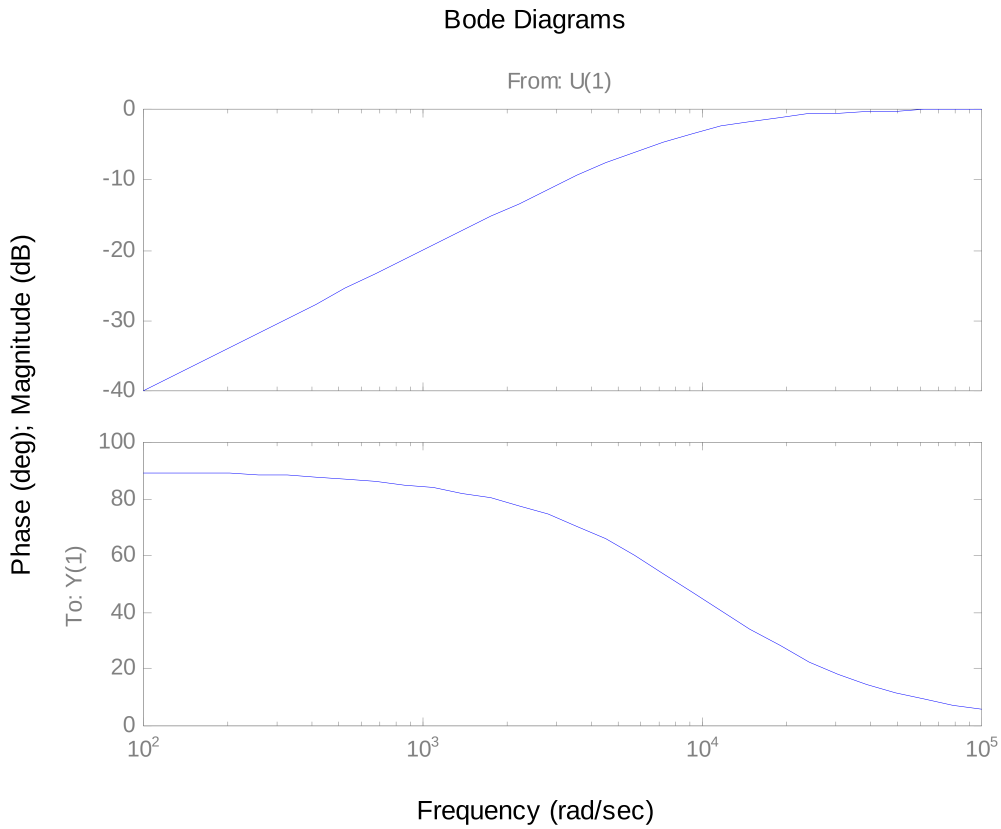

Figure: Bode pilot of the transfer function of the high pass filter circuit by MATLAB

4. ANALYSIS AND DISCUSSION

In this experiment, our experimental values showed small deviations from the theoretically calculated values. Certainly there are several reasons for that. First, as in all experiments, there are the ignored resistance and capacitance in the wires. Secondly, the signal generator we had used was some sort of unreliable. To test the reliability of it, we measured the frequency of the signal by oscilloscope and saw the inconsistency between what the signal generator said and what oscilloscope said. Since we had a limited time, we didn't check for all the frequencies to match the values in the tables. Instead we used the frequency measurement tool of the multimeter to check the frequency of the signal produced by the signal generator. To my opinion, this experiment was a successful one, because we had the graphs correctly and obtained the cut-off frequency close to its theoretical value. During the experiment, I fell into conflict with the lab instructor in the way the dB values of the output voltages are calculated which also reflected to the time we had finished the experiment, but later I realized that it was unimportant from the cut-off frequency point of view, because what we are concerned is the calculation of cut-off frequency, and it is the 3 dB below the assumed 0 dB value.

5. ANSWERS TO THE QUESTIONS

1.

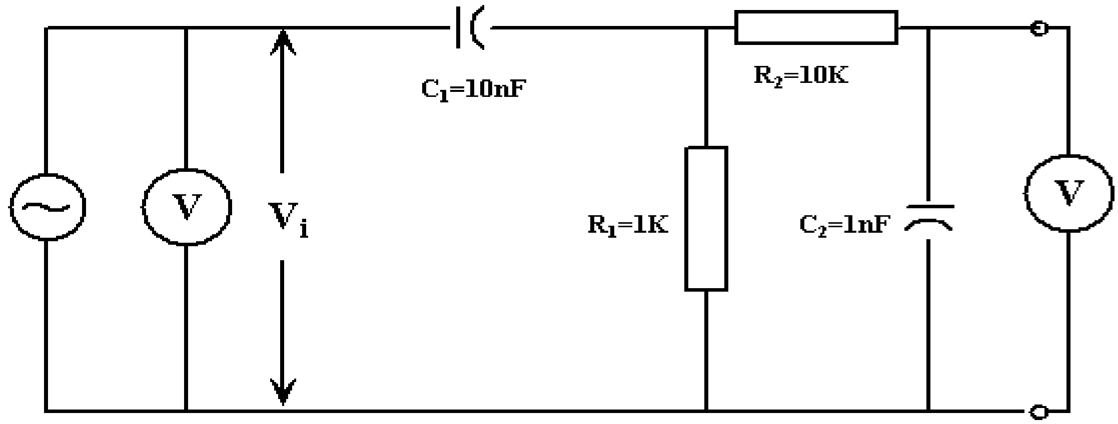

Figure: Band Pass RC Circuit

We write the output voltage and input voltage ratios applying the voltage division principles twice. After doing long calculations, I obtained the following transfer function.

$$\frac{V_o(s)}{V_i(s)} = \frac{R_1C_1s}{R_1C_1R_2C_2s^2 + (R_1C_1 + R_1C_2 + R_2C_2)s + 1}$$

Replacing R_1 = 1K R_2 = 10K C_1 = 100nF C_2 = 1nF, we obtain,

$$\frac{V_o(s)}{V_i(s)} = \frac{10^5 s}{s^2 + 111000s + 10^9}$$

Poles of this Transfer Function are s_1 = 101110 s_1 = 9890 (rad/sec) We can see this cut-off frequencies from the graph given below.

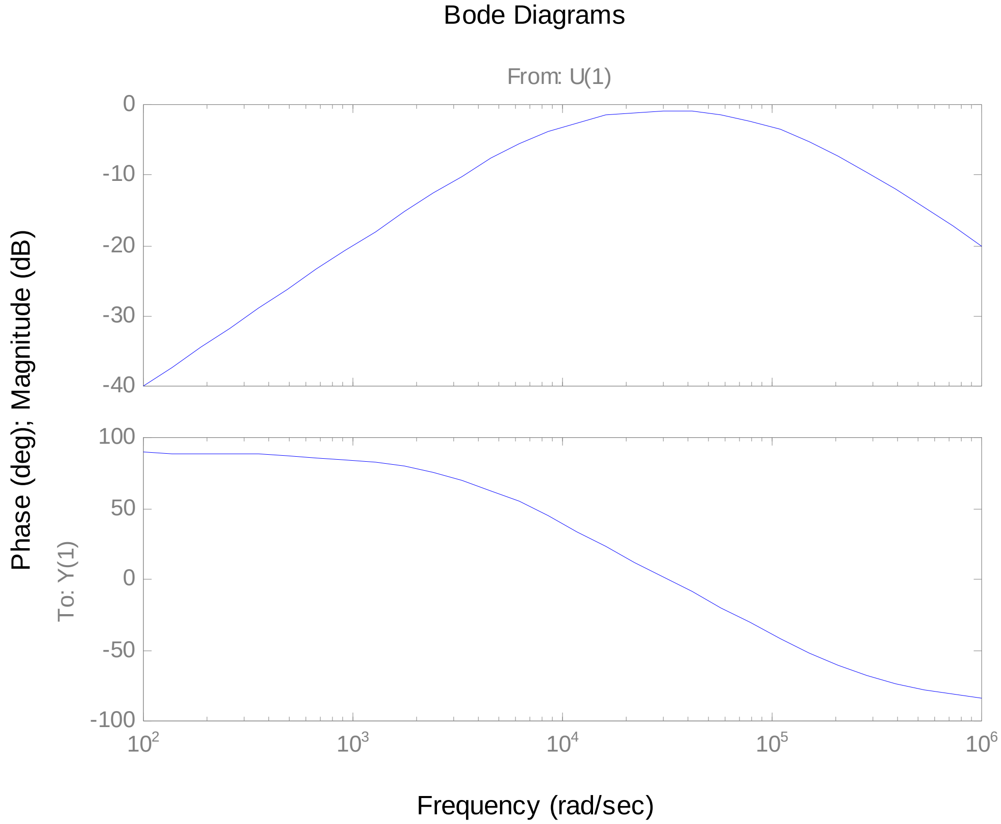

Figure: Bode pilot of the transfer function of the band pass filter circuit by MATLAB

2.

h(t) is known as the impulse response of circuits and given as;

$$h(t) = L^{-1}\{H(s)\}$$

h(t) for the low pass circuit;

$$h(t) = L^{-1}\left\{\frac{10^4}{s+10^4}\right\} = 10^4 e^{-10^4 t} \quad t \geq 0$$

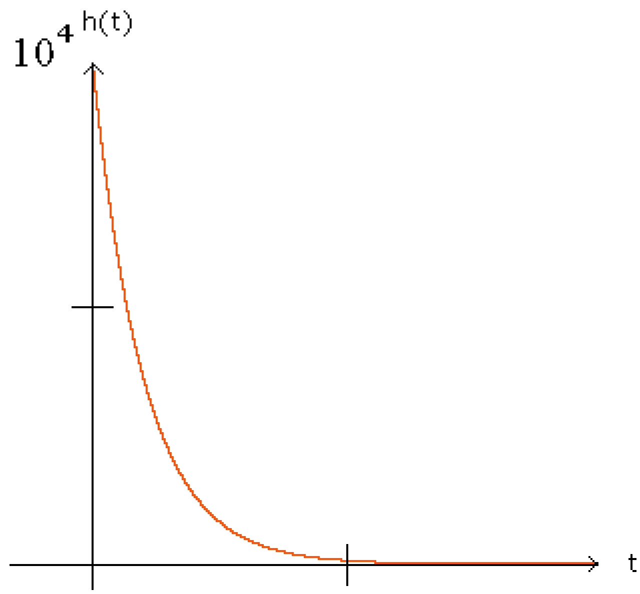

Figure: h(t) vs t for low pass filter circuit in the experiment

h(t) for the high pass circuit;

$$h(t) = L^{-1}\left\{\frac{s}{s+10^4}\right\} = d(t) - 10^4 e^{-10^4 t} \qquad t \geq 0$$

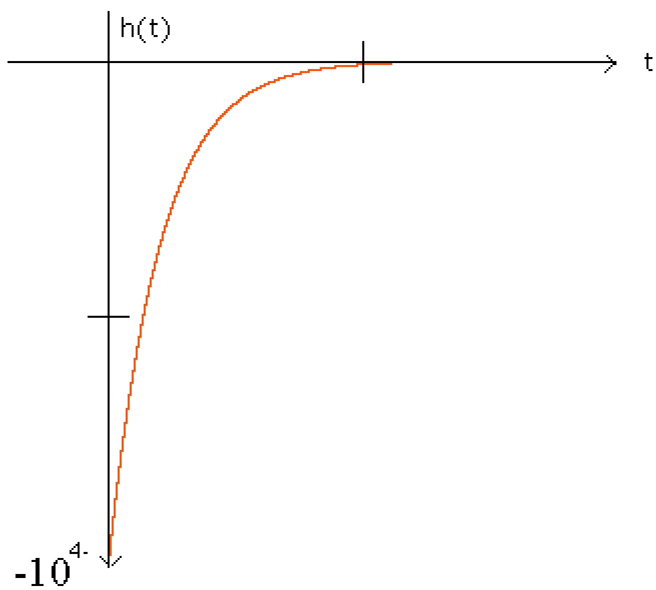

Figure: h(t) vs t for high pass filter circuit in the experiment

3.

h(t) is what we need to characterize a linear time invariant circuit. The amplitude-frequency response is not enough to characterize h(t). As MATLAB bode plots also shows us, we also need phase-frequency response of the circuit. That is to say, two circuits may have the same amplitude-frequency response but different phase-frequency responses, which is to say that these circuits have different unit impulse responses.