EE 320 L ELECTRONICS I

LABORATORY 3: CIRCUIT FREQUENCY RESPONSE

DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING
UNIVERSITY OF NEVADA, LAS VEGAS

1. OBJECTIVE

Review the knowledge of time constant and frequency response of RC (or RLC) circuits and Op Amp applications.

2. COMPONENTS & EQUIPMENT

Power Supply
Function Generator
Multimeter
Oscilloscope
Breadboard
Jump wires
Resistors & Capacitors
Inductors (optional)
Op Amp chip (LM741)

3. BACKGROUND

RC circuits are the simplest circuits that are related to time-constants and frequency response, and are widely used in countless electrical and electronic applications.

In physics and engineering, the time constant, usually denoted by the Greek letter τ (tau), is the parameter characterizing the response to a step input of a first-order, linear time-invariant (LTI) system. Frequency response is the quantitative measure of the output spectrum of a system or device in response to a stimulus, and is used to characterize the dynamics of the system. It is a measure of magnitude and phase of the output as a function of frequency, in comparison to the input.

Key knowledges and formulas regarding to RC circuits and frequency response.

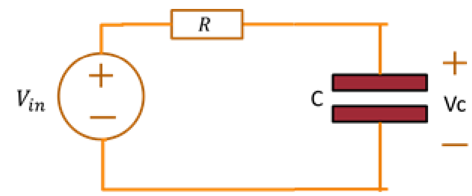
V_{in} is a step input:

$$V_C = V_{in}(1 - e^{-\frac{t}{RC}})$$

$$V_R = V_{in}e^{-\frac{t}{RC}}$$

Time constant $\tau = RC$

An RC Circuit:



V_{in} is an AC input with frequency f :

$$V_C = V_{in}\left(\frac{1}{1 + j(2\pi f)RC}\right) = V_{in}\left(\frac{1}{1 + j\omega RC}\right)$$

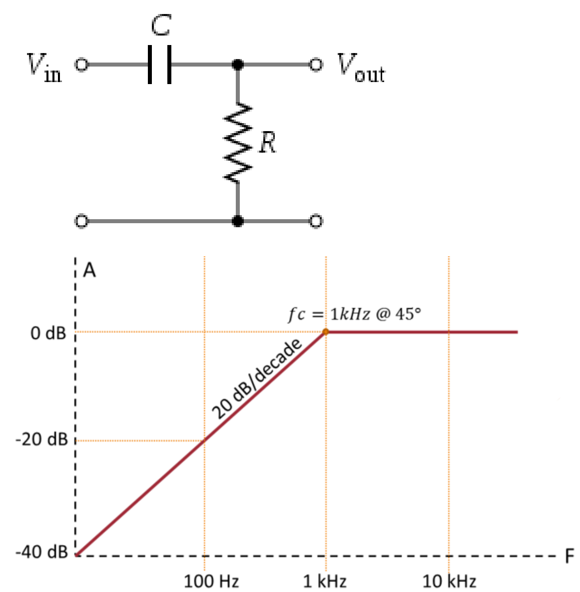
$$V_R = V_{in}\left(\frac{j(2\pi f)RC}{1 + j(2\pi f)RC}\right) = V_{in}\left(\frac{j\omega RC}{1 + j\omega RC}\right)$$

$\omega = 2\pi f$

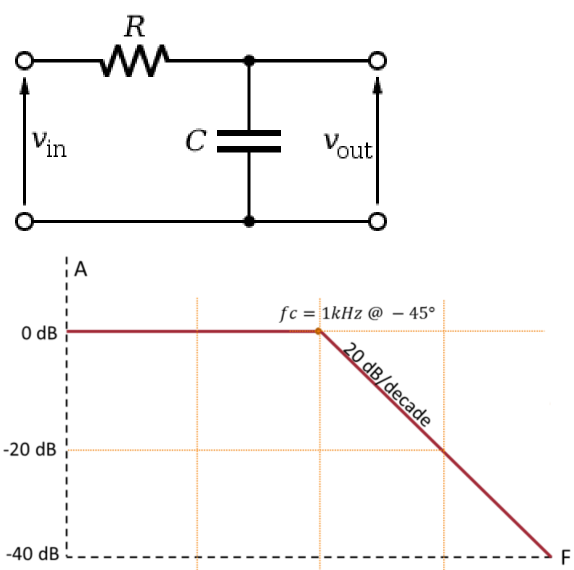
$\omega \to 0$: $V_C \to V_{in}$, $V_R \to 0$ (Open circuit in DC)

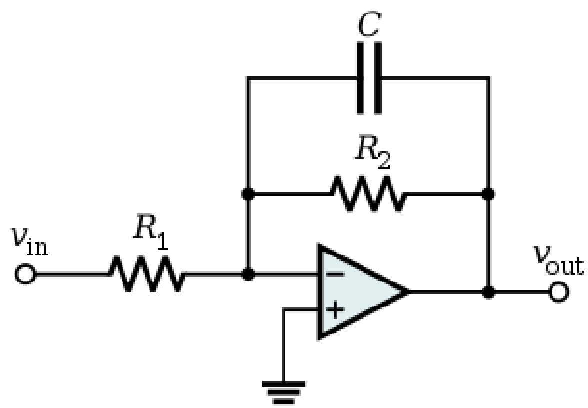
$\omega \to \infty$: $V_C \to 0$, $V_R \to V_{in}$

(Passive) High pass filter:



(Passive) Low pass filter:



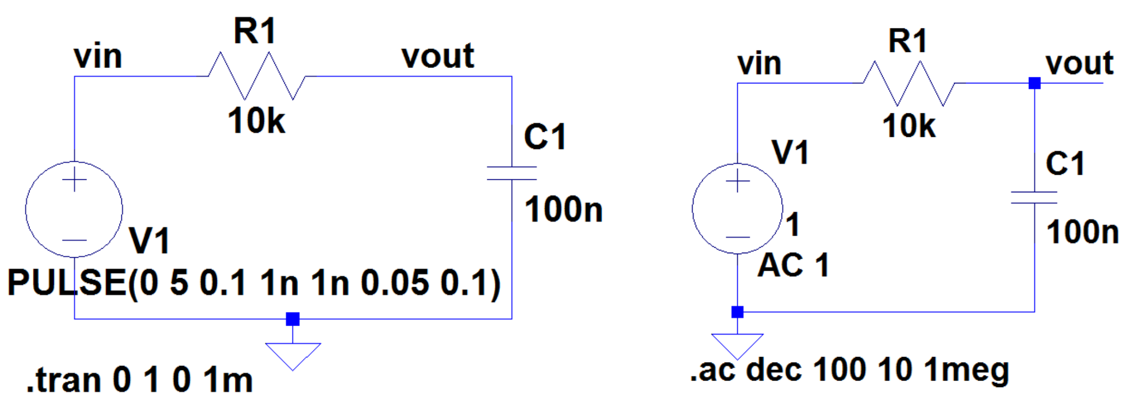
Op Amp Application:	(Active) Low pass filter, also an integrator?
$$\frac{V_{out}}{V_{in}} = -\frac{R_2}{R_1}\frac{1}{1+j\omega R_2 C}$$	

4. LAB DELIVERIES

PRELAB:

1. **Review the knowledge of RC circuits and frequency response, part of which are listed in the previous section.**

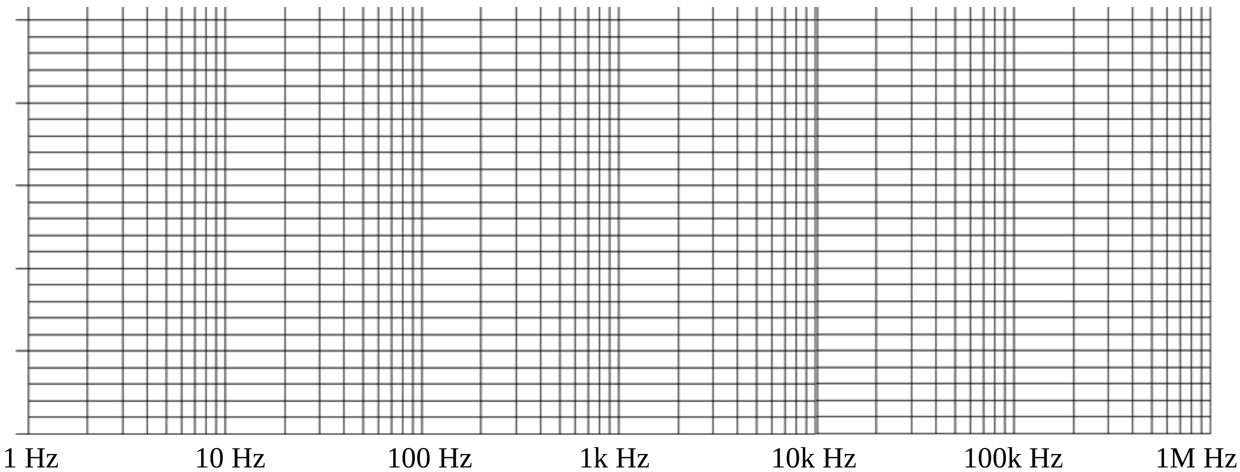
2. **Use LTspice to simulate the circuit below.**



Circuit 1 transient (left) and ac (right) analysis.

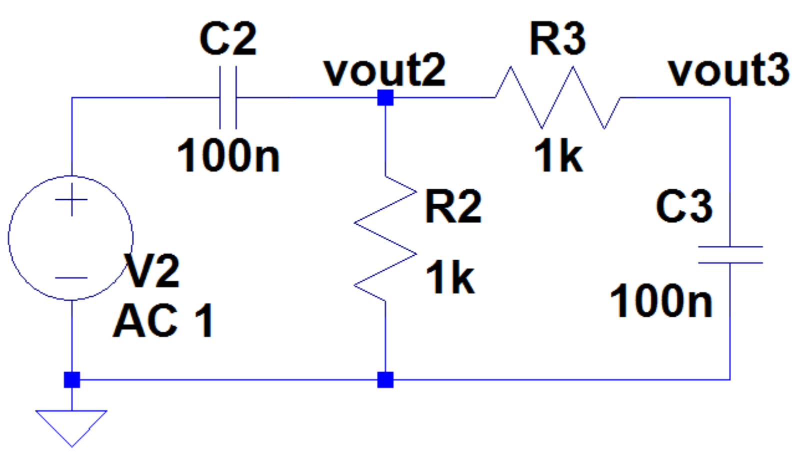
1) Calculate the time constant (τ) of Circuit 1.
2) Run the simulation and observe the differences between vin and vout.
3) Can you measure an approximate τ through simulation? Compare with your calculation.
4) Run LTspice and .ac analysis (.ac dec 100 10 1MEG) to obtain the Bode plot of the circuit.

τ (s)	f (Hz)	10	100	1k	10k	100k	1M
	V_{pp}						

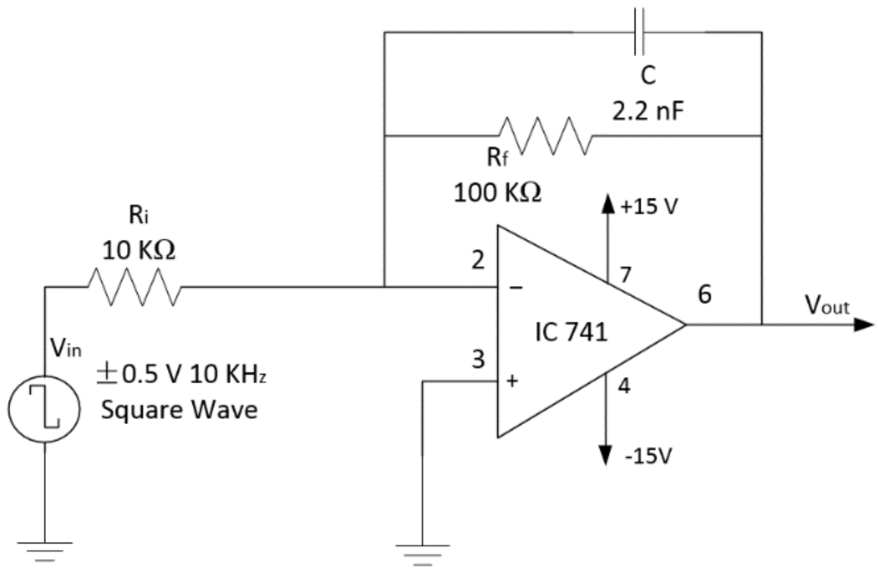


3. Use both hand calculation and LTspice simulation to determine the voltage gain $A_v = v_o/v_i$ of the following op amp circuits.

1) Use sine wave for Circuit 2 input.
2) Use sine wave for Circuit 3 input, and use AD795 for OpAmp in LTspice.
3) Draw the Bode plot of output for input frequency ranging from 10Hz to 10^6Hz, for both circuits with sine inputs, respectively.
4) Repeat 1~3), but with triangular wave input for Circuit 2 and square wave input for Circuit 3, respectively. Explain what you observe.



Circuit 2



Circuit 3

LTspice simulations:

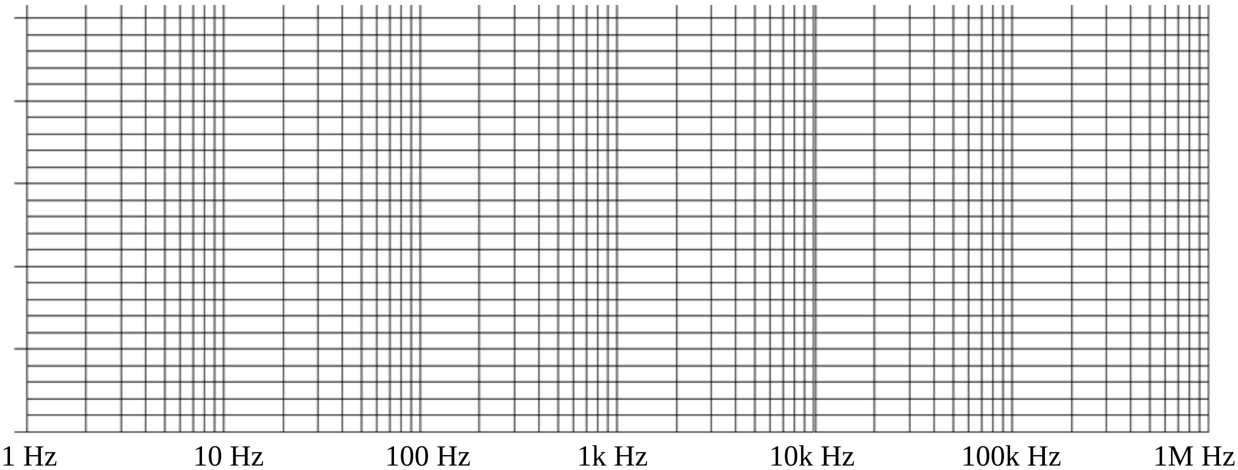
Circuit 1 (sine input): $V_{o,pp}$ = ________V, A_v = ________	Waveform:
Circuit 1 (triangular input): $V_{o,pp}$ = ________V, A_v = ________	Waveform:
Circuit 2 (sine input): $V_{o,pp}$ = ________V, A_v = ________	Waveform:
Circuit 2 (square input): $V_{o,pp}$ = ________V, A_v = ________	Waveform:

Bode plot for Circuit 2 (sine input):	Bode plot for Circuit 3 (sine input):
Bode plot for Circuit 2 (triangle input):	Bode plot for Circuit 3 (square input):

LAB EXPERIMENTS:

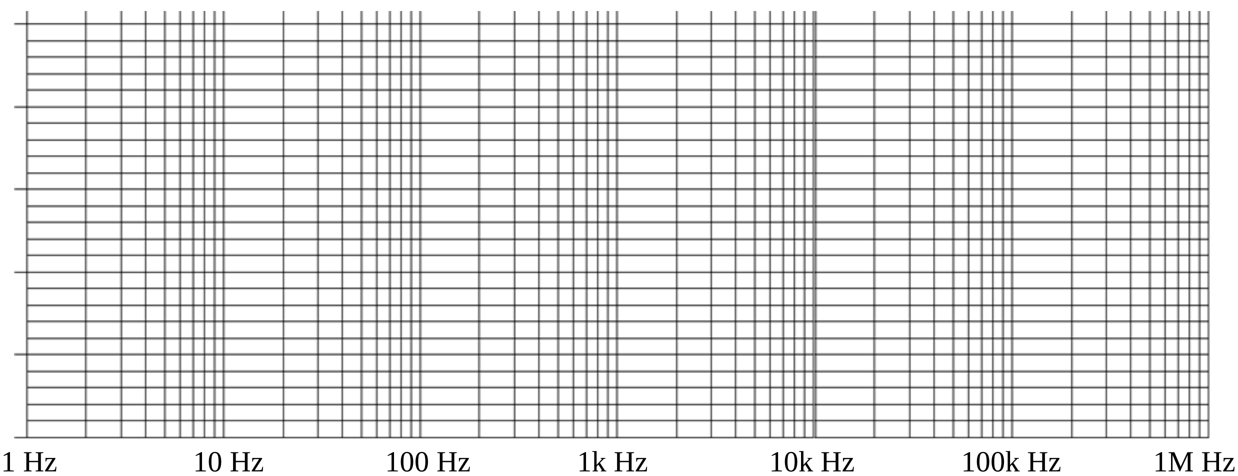
1. **Implement Circuit 1 in Prelab 2 on breadboard with following steps, and compare the hand-calculation and LTspice results.**
   1) Use the function generator to setup V_{in} as a square signal with $V_{pp} = 1$V and $f = 10$Hz.
   2) Use oscilloscope to read the voltage at V_{out}. Zoom in and look into the rising/falling edge of the achieved waveform. Measure rising, falling time (T_r, T_f), and time constant. Compare the measured results to the ones in hand calculations and LTspice simulations.
   3) Change the input signal frequency from 10Hz to 100Hz, 1kHz, … 1 MHz, respectively. Observe the V_{out} waveform on the oscilloscope, and write down the amplitude at each frequency. Draw the Bode plot for Circuit 1.
   4) Repeat 1) and 2) with R = 20kΩ, C = 50nF and $f = 500$Hz. Repeat to calculate the time constant and observe the input/output waveform and rising/falling time.

	τ, T_r, T_f (μs)	Output Waveforms:
$f = 10$Hz R = 10kΩ C = 100nF	$\tau =$ $T_r =$ $T_f =$	
$f = 500$Hz R = 20kΩ C = 50nF	$\tau =$ $T_r =$ $T_f =$	

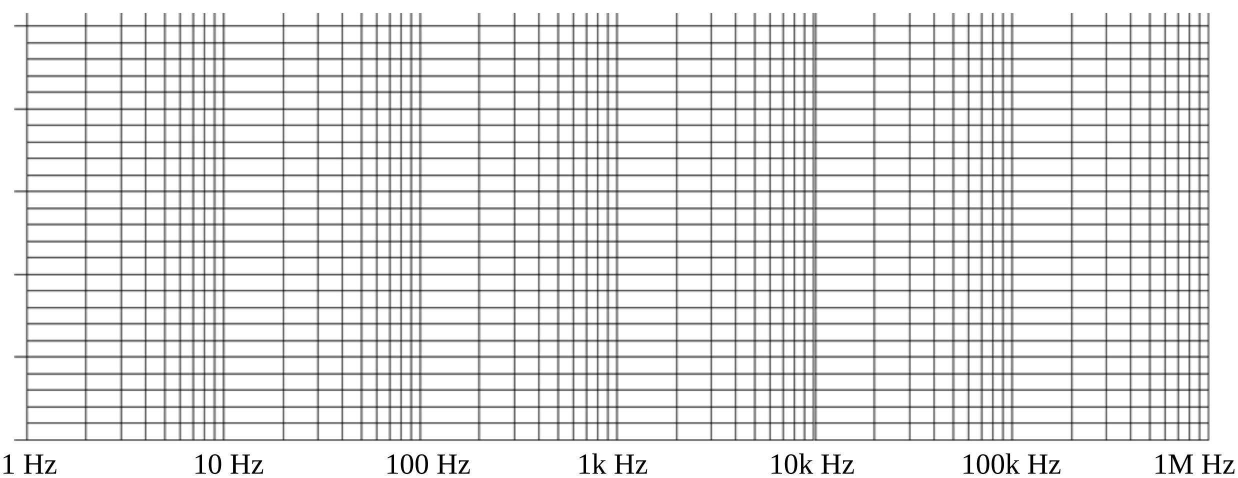


2. Implement Circuit 2 and 3 in Prelab 3 on breadboard, respectively.

1) Bode plot of Circuit 2 with sine waveform input.



2) Bode plot of Circuit 3 with sine waveform input.



POSTLAB REPORT:

Include the following elements in the report document:

<table>
<tr><th>Section</th><th colspan="2">Element</th></tr>
<tr><td>1</td><td colspan="2">Theory of operation
Include a brief description of every element and phenomenon that appear during the experiments.</td></tr>
<tr><td>2</td><td colspan="2">Prelab report
1. Hand calculation results of prelab Circuit 1~3.
2. LTspice schematics and simulation results of all circuits.</td></tr>
<tr><td rowspan="3">3</td><td colspan="2">Results of the experiments</td></tr>
<tr><th>Experiments</th><th>Experiment Results</th></tr>
<tr><td>1</td><td>Complete the forms and Bode plots in Experiment 1~3.</td></tr>
<tr><td rowspan="3">4</td><td colspan="2">Answer the questions</td></tr>
<tr><th>Questions</th><th>Questions</th></tr>
<tr><td>1</td><td>What can you conclude about Op Amp?</td></tr>
<tr><td>5</td><td colspan="2">Conclusions
Write down your conclusions, things learned, problems encountered during the lab and how they were solved, etc.</td></tr>
<tr><td>6</td><td colspan="2">Images
Paste images (e.g. scratches, drafts, screenshots, photos, etc.) in Postlab report document (only .docx, .doc or .pdf format is accepted). If the sizes of images are too large, convert them to jpg/jpeg format first, and then paste them in the document.

Attachments (If needed)
Zip your projects. Send through WebCampus as attachments, or provide link to the zip file on Google Drive / Dropbox, etc.</td></tr>
</table>

5. REFERENCES & ACKNOWLEDGEMENT

1. C. K. Alexander and M. Sadiku, "Fundamentals of Electric Circuits", 4th Ed.

I appreciate the help from faculty members and TAs during the composing of this instruction manual. I would also thank students who provide valuable feedback so that we can offer better higher education to the students.