ESC201 Introduction to Electronics Lab 3 Handout for Lab Experiments
Time and Frequency Domain Analysis of First Order RC and RL Circuits

Aim: The aim of this lab is to study the time and frequency response of first order RC and RL circuits.
To analyse the time domain behaviour, you will study the steady state response of RC and RL circuits to pulse as well as sinusoidal inputs. The pulse response is of great importance in the design of digital circuits. In order to get the steady state pulse response, periodic square-wave signals are applied to the input and the output is measured as a function of time. You will also observe the steady state response of these circuits for sinusoidal input to study the amplitude and phase relation between the input and output in the Lissajous figure. To analyse the frequency domain behaviour, you will apply sinusoidal input and specify the frequency range for the input to obtain the Bode magnitude and phase plots using the Analyze functionality of the DSO.

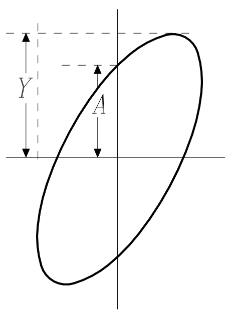
Note: For all experiments in this lab: **Do not use the external FG, use the Gen-Out of the DSO**.

Observing the Pulse Response:
Connect signal from the Gen-Out of the DSO to the input of the circuit. Connect CH-1 of the DSO to the input of the circuit to observe the input waveform. Observe the Gen-Out waveform on the DSO to set the amplitude and frequency of the input signal using the function keys on the DSO. Choose square wave signal from the menu and set the peak-to-peak amplitude to be 2 V with zero offset. Connect the CH-2 of the DSO to the output of the circuit to observe the output waveform. Be sure to choose the DC mode for both the CH-1and CH-2 of the DSO so as to observe the DC levels of the signals.

Note: *Because of parasitic L and C from the coaxial cables and DSO input sockets, there will be ringing effect in the output just after a sharp transition of the input. Avoid that part of the output to take measurement.*
If you zoom out by adjusting the horizontal knob and observe 2 to 3 full time periods, you will not see ringing.

Observing the Sinusoidal Response:
Connect signal from the Gen-Out of the DSO to the input of the circuit. Connect CH-1 of the DSO to the input of the circuit to observe the input waveform. Observe the Gen-Out waveform on the DSO to set the amplitude and frequency of the input signal using the function keys on the DSO. Choose sine wave signal from the menu and set the peak-to-peak amplitude to be 2 V with zero offset. Connect the CH-2 of the DSO to the output of the circuit to observe the output waveform. Be sure to choose the AC mode for both the CH-1and CH-2 of the DSO. Observe both the input and output waveforms in Normal mode and measure the amplitude of the output waveform and the phase difference between the input and output waveforms.

Observing the Lissajous Figure:



Set the display of the DSO in XY mode and observe the output vs input characteristic. You should see a figure as shown which is called a Lissajous diagram. Look at the appearance of the Lissajous diagram and understand how the amplitude ratio and phase angle between the input and output affects the shape. Measure the values of Y and A as shown in the figure for each frequency as mentioned in the experiment. The amplitude of the output signal will be Y and phase difference (δ) between the input and output will be $\delta = sin^{-1}(A/Y)$.

Observing the Bode Magnitude and Phase Plots:
Connect signal from the Gen-Out of the DSO to the input of the circuit and choose sine wave signal from the menu. Connect CH-1 of the DSO to the input of the circuit and CH-2 of the DSO to the output of the circuit. For the frequency response measurement, press the Analysis key on the DSO, then press the function key corresponding to Features in the menu displayed on the DSO. In Features, select Frequency Response Analysis (FRA) using the entry knob. To set the frequency range, press the function key corresponding to Setup in the

menu, then select the Start Freq or Stop Freq using the corresponding function key and enter the value mentioned in each experiment using the entry knob. For all experiments, set the peak-to-peak amplitude to be 2 V and use 100 points for measurement. Then, press the back button to return to the original menu of the FRA and press the function key corresponding to Run Analysis. The DSO will perform the measurement for you and show both the Bode magnitude and phase plot in different colors. Once the plot is displayed, you can read any data point by moving the orange pointer using the entry knob and reading the value from the DSO.

Experiment 1: RC Integrator or Low Pass Filter of Figure E1 (*4 + 3 + 3 = 10 marks*)

A. Pulse Response: For a 2 V pp square wave input with zero offset (–1 V to +1 V), obtain the time response of this circuit for frequency *f* = ***500 Hz***, ***5 kHz***, and ***25 kHz***.

1. For each frequency, observe and sketch V_i and V_0 with respect to time.
2. Mention the frequency at which the circuit is performing the integration operation and explain the reason. For that frequency, measure V_o and verify the integration. Show your calculation and result.
3. For *f = 5 kHz*, choose any two convenient points on either the rising or falling parts of V_0 and measure the corresponding voltages and time intervals. From these readings, obtain the time constant τ of the circuit.
4. Choose *f = 5 kHz*, and observe both V_i and V_o. Now, apply an offset voltage to the input and observe how the output V_o is changing. Note down your observation and explain.

B. Lissajous Figure: Apply 2 V pp sine wave (with 0 offset) of frequency *f* = ***500 Hz***, ***5 kHz***, and ***25 kHz***. In each case, observe both V_i and V_o with respect to time, and measure the amplitude ratio and the phase angle. Now, observe and plot the Lissajous figure, and calculate the amplitude ratio and the phase angle from the Lissajous Figure, and match these with your prior observations.

C. Bode Plot: Using starting frequency of 100 Hz, stopping frequency of 200 kHz and a 2 V pp sine wave, obtain the Bode magnitude and phase plots. Find out the 3dB cut-off frequency from the plot. Plot both the Bode magnitude and phase plots. Measure the phase at frequency *f* = ***500 Hz***, ***5 kHz***, and ***25 kHz***, from the Bode phase plot and match these with your prior observations.

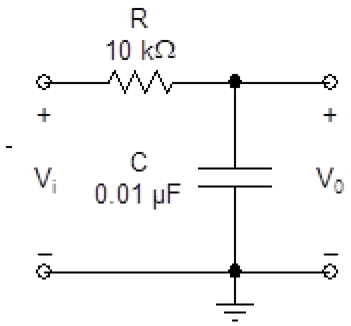


Fig. E1

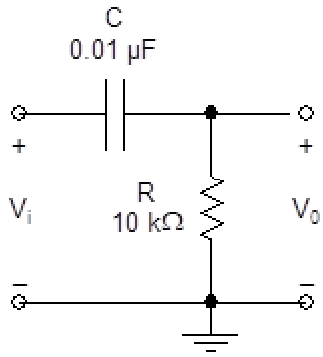


Fig. E2

Experiment 2: RC Differentiator or High Pass Filter of Figure E2 (*4 + 3 + 3 = 10 marks*)

A. Pulse Response: For a 2 V pp square wave input with zero offset (–1 V to +1 V), obtain the time response of this circuit for frequency *f* = ***500 Hz***, ***5 kHz***, and ***25 kHz***.

1. For each frequency, observe and sketch V_i and V_0 with respect to time.
2. Mention the frequency at which the circuit is performing the differentiation operation and explain the reason. For that frequency, measure V_o and verify the differentiation. Show your calculation and result.
3. Choose *f = 5 kHz*, and observe both V_i and V_o. Now, apply an offset voltage to the input and observe how the output V_o is changing. Note down your observation and explain.

4. Increase the input signal frequency beyond 25 kHz and note down the minimum frequency at which the linear tilt seen in the V_0 waveform is negligible. Explain the reason.

B. Lissajous Figure: Apply 2 V pp sine wave (with 0 offset) of frequency *f* = ***500 Hz***, ***5 kHz***, and ***25 kHz***. In each case, observe both V_i and V_o with respect to time, and measure the amplitude ratio and the phase angle. Now, observe and plot the Lissajous figure, and calculate the amplitude ratio and the phase angle from the Lissajous Figure, and match these with your prior observations.

C. Bode Plot: Using starting frequency of 100 Hz, stopping frequency of 200 kHz and a 2 V pp sine wave, obtain the Bode magnitude and phase plots. Find out the 3dB cut-off frequency from the plot. Plot both the Bode magnitude and phase plots. Measure the phase at frequency *f* = ***500 Hz***, ***5 kHz***, and ***25 kHz***, from the Bode phase plot and match these with your prior observations.

Experiment 3: RL Integrator or Low Pass Filter of Figure E3 (*4 + 3 + 3 = 10 marks*)

A. Pulse Response: For a 2 V pp square wave input with zero offset (–1 V to +1 V), obtain the time response of this circuit for frequency *f* = ***10 kHz***, ***50 kHz***, and ***200 kHz.***

1. For each frequency, observe and sketch V_i and V_0 with respect to time.
2. Mention the frequency at which the circuit is performing the integration operation and explain the reason. For that frequency, measure V_o and verify the integration. Show your calculation and result.
3. For *f = 50 kHz*, choose any two convenient points on either the rising or falling parts of V_0 and measure the corresponding voltages and time intervals. From the readings, obtain the time constant τ of the circuit.
4. Choose *f = 50 kHz*, and observe both V_i and V_o. Now, apply an offset voltage to the input and observe how the output V_o is changing. Note down your observation and explain.

B. Lissajous Figure: Apply 2 V pp sine wave (with 0 offset) of frequency *f* = ***10 kHz***, ***50 kHz***, and ***200 kHz***. In each case, observe both V_i and V_o with respect to time, and measure the amplitude ratio and the phase angle. Now, observe and plot the Lissajous figure, and calculate the amplitude ratio and the phase angle from the Lissajous Figure, and match these with your prior observations.

C. Bode Plot: Using starting frequency of 1 kHz, stopping frequency of 500 kHz and a 2 V pp sine wave, obtain the Bode magnitude and phase plots. Find out the 3dB cut-off frequency from the plot. Plot both the Bode magnitude and phase plots. Measure the phase at frequency *f* = ***10 kHz***, ***50 kHz***, and ***200 kHz***, from the Bode phase plot and match these with your prior observations.

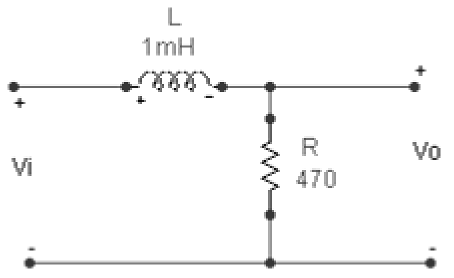


Fig. E3

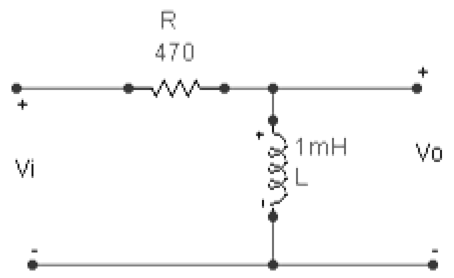


Fig. E4

Experiment 4: RL Differentiator or High Pass Filter of Figure E4 (*4 + 3 + 3 = 10 marks*)

A. Pulse Response: For a 2 V pp square wave input with zero offset (–1 V to +1 V), obtain the time response of this circuit for frequency *f* = ***10 kHz***, ***50 kHz***, and ***200 kHz***.

1. For each frequency, observe and sketch V_i and V_0 with respect to time.
2. Mention the frequency at which the circuit is performing the differentiation operation and explain the reason. For that frequency, measure V_o and verify the differentiation. Show your calculation and result.
3. Choose *f* = *50 kHz*, and observe both V_i and V_o. Now, apply an offset voltage to the input and observe how the output V_o is changing. Note down your observation and explain.
4. Increase the input signal frequency beyond 200 kHz and note down the minimum frequency at which the linear tilt seen in the V_0 waveform is negligible. Explain the reason.

B. Lissajous Figure: Apply 2 V pp sine wave (with 0 offset) of frequency *f* = ***10 kHz***, ***50 kHz***, and ***200 kHz***. In each case, observe both V_i and V_o with respect to time, and measure the amplitude ratio and the phase angle. Now, observe and plot the Lissajous figure, and calculate the amplitude ratio and the phase angle from the Lissajous Figure, and match these with your prior observations.

C. Bode Plot: Using starting frequency of 1 kHz, stopping frequency of 500 kHz and a 2 V pp sine wave, obtain the Bode magnitude and phase plots. Find out the 3dB cut-off frequency from the plot. Plot both the Bode magnitude and phase plots. Measure the phase at frequency *f* = ***10 kHz***, ***50 kHz***, and ***200 kHz***, from the Bode phase plot and match these with your prior observations.