Lab1, ECE 580

Objective
The objective of this experiment is to observe the transient response of an RC and RLC circuits with the oscilloscope, to make characteristic (amplitude vs time) measurements, and to compare the measured data with theoretical expectations.

RC Step response and timing parameters
A simple RC circuit is drawn in Figure 1.

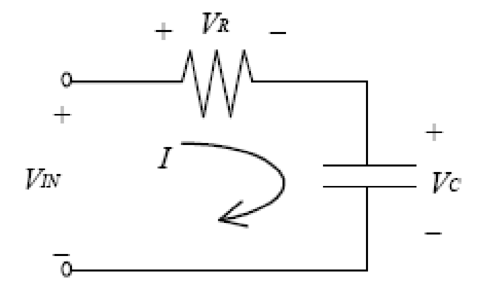
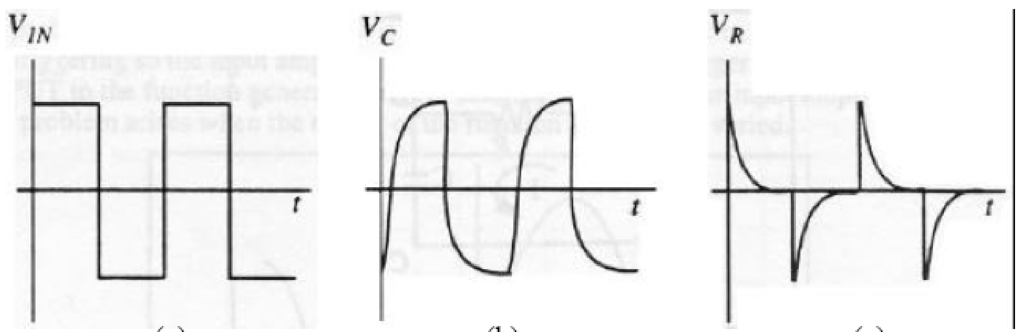


Figure 1

For the square-wave function V_{IN} as shown in Figure 2a, the responses V_C and V_R are shown in Figure 2b and Figure 2c, respectively.



(a) (b) (c)

Figure 2

The step response of a simple RC circuit, illustrated in Figure 3, is an exponential signal with time constant τ= RC. Besides this timing parameter, three other timing parameters are important in describing how fast or how slow an RC circuit responds to a step input. These timing parameters are marked in Figure 4, at three voltage levels:

a. The 10%-point is the point at which the output voltage is 10% of the maximum output voltage.
b. The 50%-point is the point at which the output voltage is 50% of the maximum output voltage.

c. The 90%-point is the point at which the output voltage is 90% of the maximum output voltage.

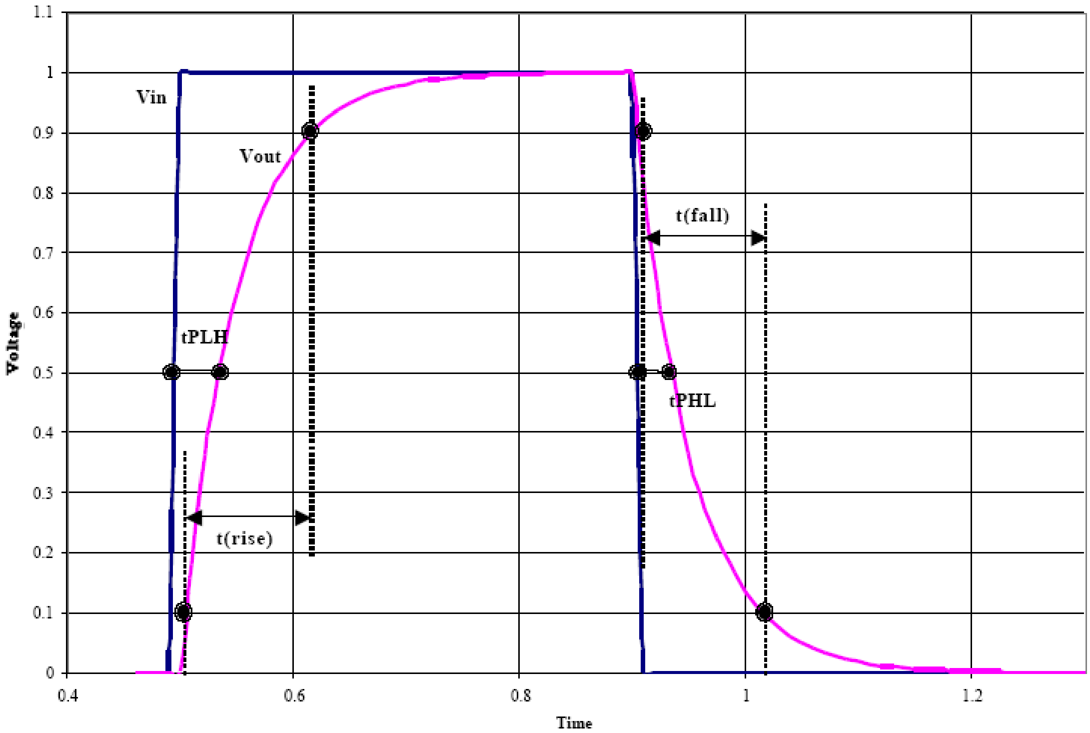


Figure 3

The three timing parameters are defined as follows:

a. Rise time: the time interval between the 10%-point and the 90%-point of the waveform when the signal makes the transition from low voltage (L) to high voltage (H). Notation: t_r.
b. Fall time: the time interval between the 90%-point and the 10%-point of the waveform when the signal makes the transition from high voltage (H) to low voltage (L). Notation: t_f.
c. Delay time (or propagation delay time): the time interval between the 50%-point of the input signal and the 50%-point of the output signal when both signals make a transition. There are two delay times depending on whether the output signal is going from L to H (delay notation t_{PLH}) or from H to L (delay notation t_{PHL}). The subscript P stands for "propagation."

Note that the rise time and the fall time are defined using a single waveform (the output waveform) while the delay time is defined between two waveforms: the input waveform and the corresponding output waveform.

LRC Circuit - Step Response

The LRC circuit shown in Figure 4 is described by a second-order differential equation. Both the frequency response and the transient response of a second-order system can be specified by the two parameters, f_n (= $W_n/2\pi$) and ξ. The resonant frequency f_n and the damping ratio ξ can be measured directly from the transient response.

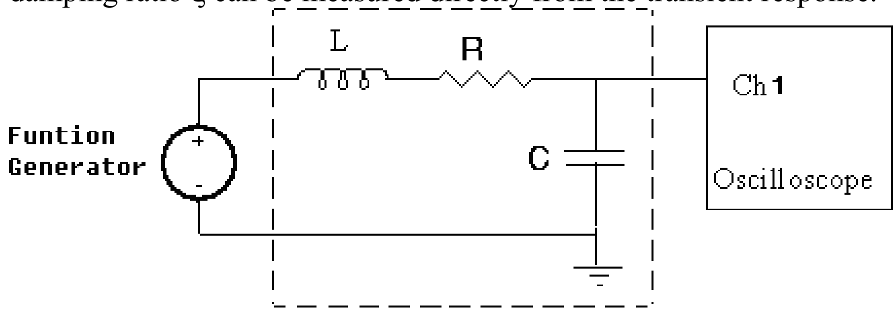


Figure 4. Second-Order Circuit

Figure 5 depicts the step response of an underdamped second-order system. The period of oscillation T_d is equal to

$$T_d = \frac{1}{f_n\sqrt{1-\zeta^2}}$$

and the product ξf_n can be determined from the damping envelope. (See Fig. 5.)

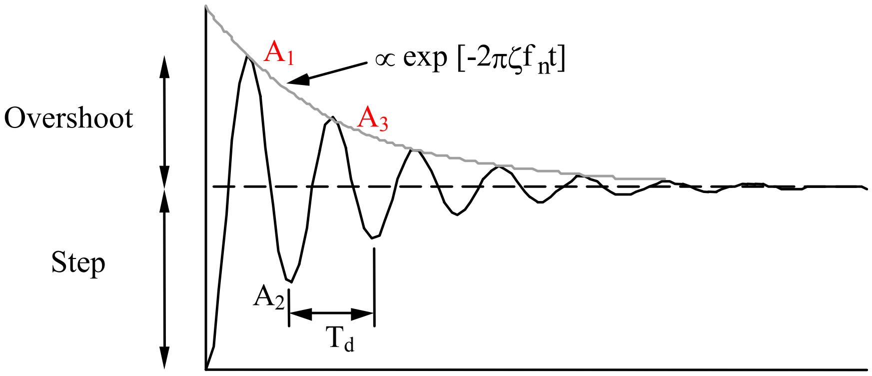


Figure 5 Step Response of an Underdamped Second-Order System

LRC Circuit – Frequency Response

The frequency response of a system is the ratio of output signal to input signal as a function of frequency. It is usually expressed in terms of an amplitude response and a phase response. For a second-order system, the amplitude response is

$$\frac{V_{out}}{V_{in}} = \frac{1}{\sqrt{[1-(f/f_n)^2]^2+[2\zeta f/f_n]^2}}$$

$$\Phi = -\tan^{-1}\left[\frac{2\zeta f/f_n}{1-(f/f_n)^2}\right]$$

Experiment #1

Assemble a circuit consisting of the series connection of a 2 kΩ resistor and a 0.1μf capacitor; connect this to the function generator with one side of the capacitor connected to ground. Use the square wave output.

Step 1: Set up the circuit shown in Figure 6. Write the equation of following circuit:

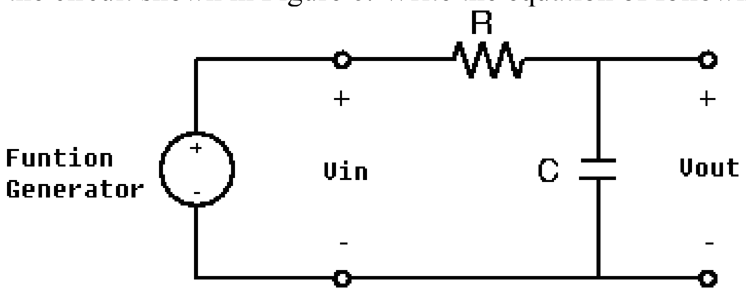


Figure 6

Calculating the equations for the following quantities:

a. The time value when the output reaches 10%, 50% and 90% of its final value
b. Rise time t_r of $V_{out}(t)$
c. Fall time t_f of $V_{out}(t)$
d. Delay time t_{PHL} and t_{PLH}

Step 2: Connect CH2 of the scope to $V_{in}(t)$, CH2 of the scope to $V_{out}(t)$

Step 3: Set the function generator to produce square wave, with 2V amplitude and 100Hz frequency.

Step 4: Use scope to measure the period T of the input signal

Step 5: Use scope to measure the time value of the 10%-point of V_{out}, the time value of the 90%-point of V_{out}, and the time value of the 50%-point of V_{out}.

Step 6: Get a hardcopy output from the scope display with both waveforms and the measured values. Turn this hardcopy in as part of your lab report.

Step 7: Use scope to measure the rise time of V_{out}, the fall time of V_{out}, and the two delay times t_{PHL} and t_{PLH} between the input and output signals.

Step 8: Get a hardcopy output from the scope display with both waveforms and the measured values. Turn this hardcopy in as part of your lab report.

Experiment #2

Step 1: Set up the circuit shown in Figure 7.(L=0.8H, R=2 kΩ, C=0.1µf)

Step 2: Connect CH1 of the scope to $V_{in}(t)$, CH2 of the scope to $V_{out}(t)$

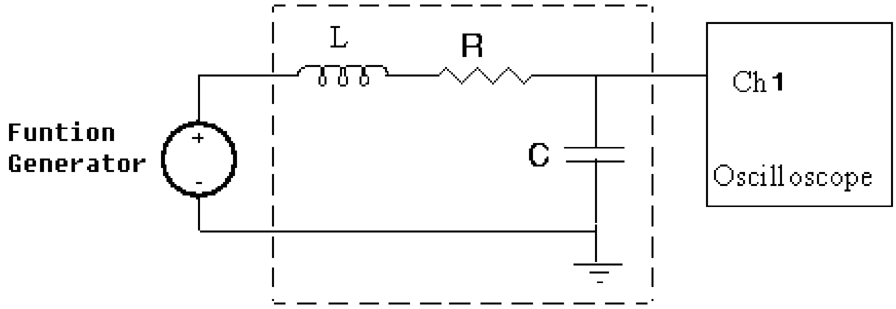


Figure 7

Step 3: Set the function generator to produce square wave, with 2V amplitude and 100Hz frequency.

Step 4: Determine the resonant frequency f_n and the damping ratio

Step 5: Change the resistance and observe the effect on the resonant frequency and on the damping. Change the capacitance and observe the effects. Describe your observations. How do the changes affect the overshoot and frequency? Turn this hardcopy in as part of your lab report.

Step 6: Use scope to measure the rise time and overshoot of $V_{out}(t)$

Step 7: Get a hardcopy output from the scope display with both waveforms and the measured values. Turn this hardcopy in as part of your lab report.

Step 8: Change the function generator output from a square wave to a sine wave. Vary the frequency of the sine wave from 100 Hz to 2 kHz. For each frequency measure the amplitude ratio of the output-to-input signal. For each frequency, determine the phase angle by measuring the time delay between the input and output signals.

Step 9: For each frequency, determine the phase angle by measuring the time delay between the input and output signals. Plot phase against frequency on semi-log paper.

Lab1 report , ECE 580

(RC & LRC Transient Response)

Your Name:________________________________

Partners: ________________________________

Date: ________________________________

1. **RC Step response and timing parameters**

Value of the circuit:

R:	
C:	
Amplitude of $V_{in:}$	
Frequency of $V_{in:}$	

1) Equation of the RC Circuit ($V_{out}(t)$)

2) Waveform of the RC step response

3) Value of time parameters:

Value of parameters(s)	Value calculated	Value measured
t (10% V_{out})		
t (50% V_{out})		
t (90% V_{out})		
t_r (rise time)		
t_f (fall time)		
t_{PHL} (delay time, H to L)		
T_{PLH} (delay time, L to H)		

4) Explain the differences between time value calculated and time value measured

2. LRC Step Response

Value of the circuit:

R:	
C:	
L:	
Amplitude of $V_{in:}$	
Frequency of $V_{in:}$	

1) Write the equation of RLC circuit ($V_{out}(t)$)

2) Waveform of the LRC step response

3) Period Determination

Td1		
Td2		
Td3		
…		
Td (average)		Error: ±

Td calculated: ________________

Compare the differences:

4) Analyze the LRC circuit to demonstrate that:

$$f_n = \frac{1}{2p\sqrt{LC}} \quad \text{and} \quad \xi = \frac{1}{2} R\sqrt{C/L}$$

5) Calculation of f_n and ξ

6) Estimates of f_n and ξ(overshoot method)

7) What effect did changing the resistance has on the step response?

8) What effect did changing the capacitance has on the step response?

3. LRC Frequency Response (10 point)

Frequency, f	V_{in}	V_{out}	$M = V_{out}/V_{in}$	ϕ