EE 2245 Microelectronics Labs

Lab 2: Time-Domain Responses of 1st- and 2nd-Order Circuits (2 Weeks)

實驗室：______組別：______Names and ID Numbers: ____

Objectives：

(1) Validate conclusions regarding the behavior of capacitors in a steady-state dc network.

(2) Validate the behaviors of the 1st-order RC circuits.

(3) Design and implement a *RLC* circuit with the desired specifications.

Equipment Required :

Resistors: 1 kΩ, 5.1 kΩ, 20 kΩ

Capacitors: 1 μF, 2.2 μF, 100 μF

Instruments: Multimeter, Oscilloscope, function generator, and dc power supply.

注意：填寫實驗數據時如有『單位』請記得填入。

Procedure :

Part 1: Basic Series *R-C* Circuit

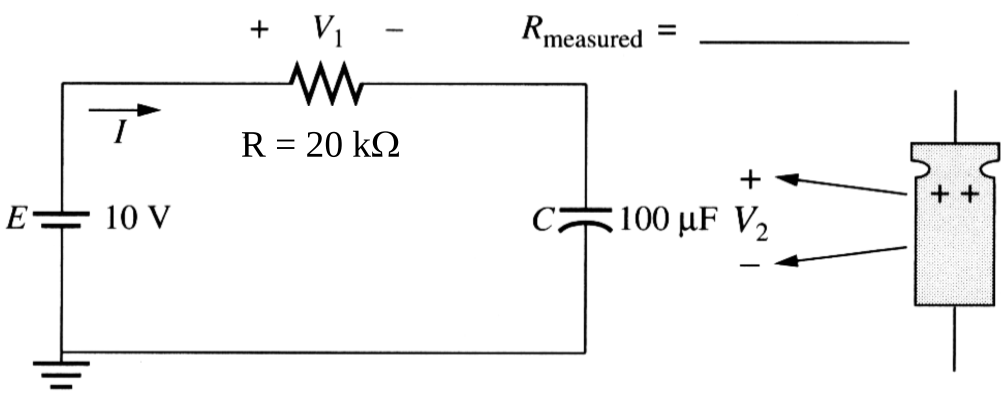


Figure 1-1

(a) Construct the network as shown in Fig. 1-1. Insert the measured resistance value. Be sure to note polarity on electrolytic capacitor as shown in the figure.

(b) Show your calculation of the steady-state value (defined by a period of time greater than five time constants) of the current *I* and the voltages V_1 and V_2.

<u>Calculation</u>:

I = ______________, V_1 =_________________, and V_2 =__________________.

(c) Measure the steady-state voltages V_1 and V_2 and calculate the current from Ohm's law. Compare with results from part 1(b).

V_1 =_________________, V_2 =__________________, and I = __________________

Comment:

(d) Calculate the energy stored in the capacitor.

Calculation:

W = __________________

(e) Carefully disconnect the supply and quickly measure the voltage across the disconnected capacitor. Please describe what you observe in the reading and explain why.

Comment:

(f) Short the capacitor by connecting a wire to both terminals and then measure V_C again. What happens after this step?

Comment:

Part 2: Time-Domain Response of the Basic *R-C* Circuit

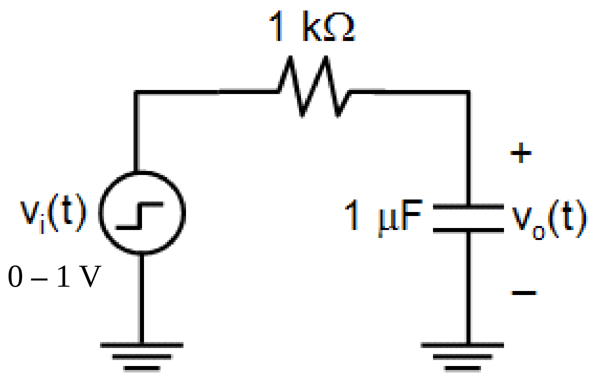


Figure 2-1

(a) Construct the *RC* circuit of Fig. 2-1. Measure the resistance and capacitance values. Use the function generator to produce the input square waveform $v_i(t)$ with <u>a minimum value at 0 V</u> and a maximum value at 1 V. Check the input waveform on a oscilloscope before you connect it to the circuit.
R = _____________, *C* = ____________

(b) Calculate the *RC* time constant τ using the measured resistance.
<u>Calculation</u>:

τ = ______________

(c) Write down the output response $v_o(t)$ driven by a unit-step input $v_i(t)$ (which is replaced by a square waveform in Fig. 2-1). Calculate the output in percentage of the final value in τ, 2τ, 3τ, 4τ , and 5τ.
<u>Calculation</u>:

$v_o(\tau)$ = ______% $v_i(t)$, $v_o(2\tau)$ = ______% $v_i(t)$, $v_o(3\tau)$ = ______% $v_i(t)$, $v_o(4\tau)$ = ______% $v_i(t)$,
$v_o(5\tau)$ = ______% $v_i(t)$

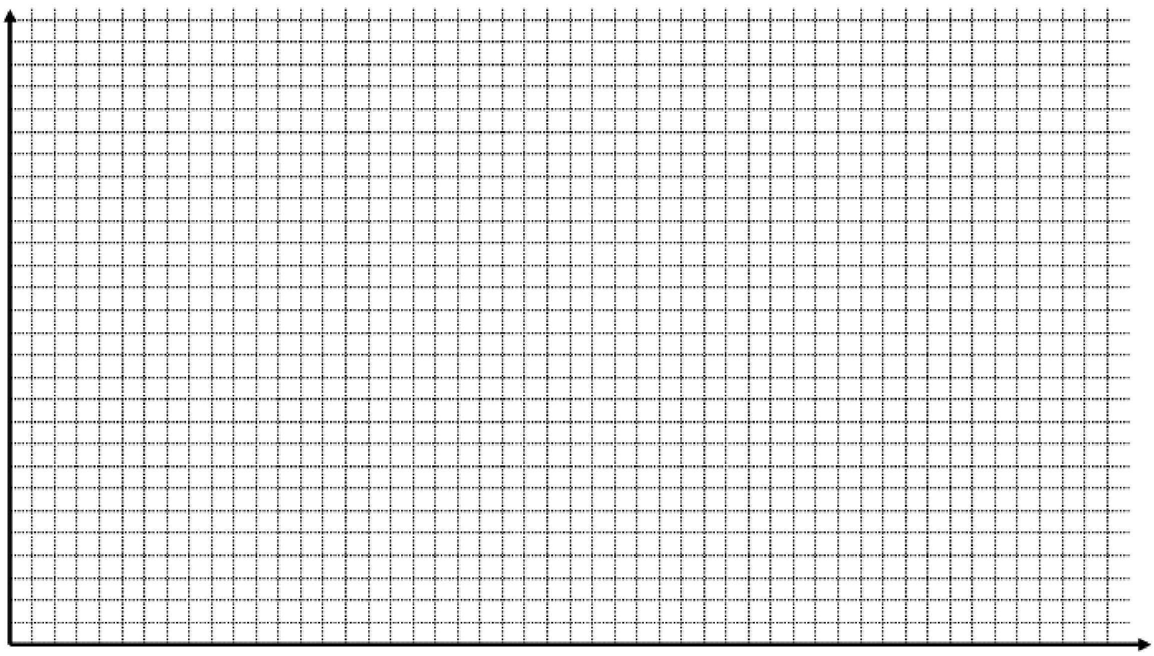
(d) Based on the time constant, determine a proper input frequency f_i that would allow you to clearly observe the transient and steady-state responses of the output waveform. Comment on how you pick the frequency.
f_i = ____________
<u>Comment</u>:

(e) Display the input and output signals on an oscilloscope. Record as many data points as possible of the output waveform in one complete charging and discharging cycle and insert them in Table 2-1.

Table 2-1

Time (sec)	$v_o(t)$ (V)	Time (sec)	$v_o(t)$ (V)	Time (sec)	$v_o(t)$ (V)

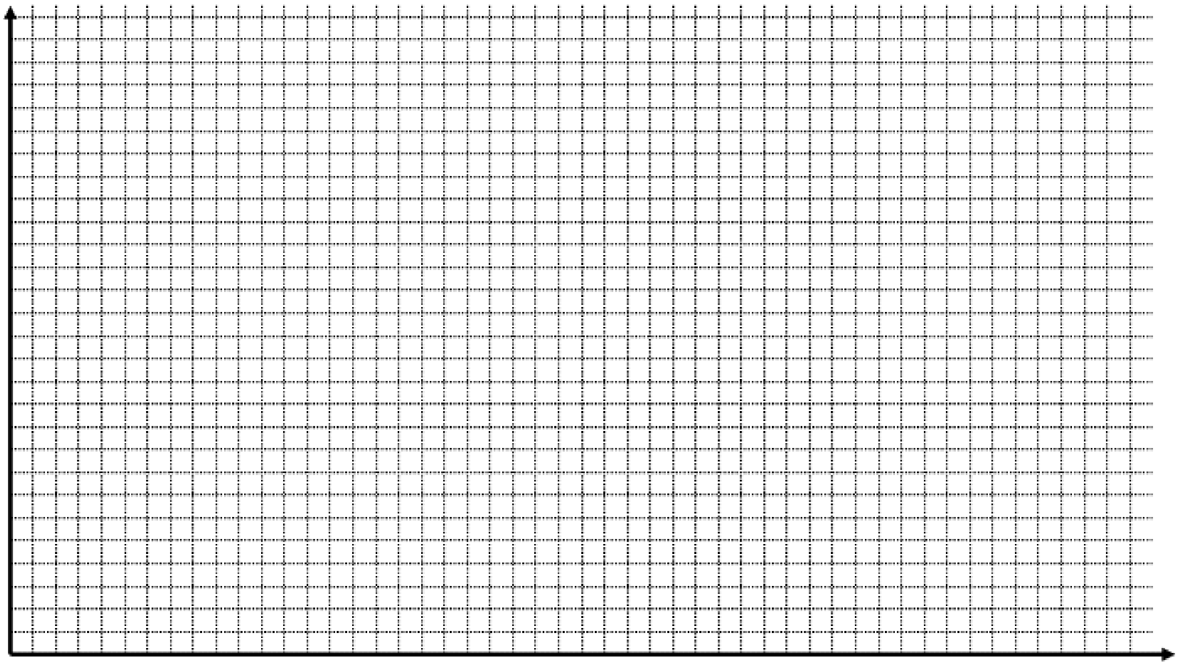
(f) Plot one period of the output response (charging and discharging) on Graph 2-1. Label the voltage and time at 63.2% of the steady-state value when charging the capacitor, and the voltage and the time at 36.8% of the steady-state value when discharging the capacitor. You must label the unit of time on the *x* axis. Calculate the capacitance value based on the measured time constant and the measured resistor value.



Graph 2-1

$C_{measured}$ = ________________

(g) Repeat part (f) by using an input square waveform with a period of only two *RC* time constants (T = 2RC). The output would look like a sawtooth waveform. Plot one period of the steady-state output waveform on Graph 2-2, and label the maximum and minimum voltage values. Comment on if the voltage levels are reasonable based on your analysis.



Graph 2-2

Analysis & Comment:

(h) Construct the *RC* circuit of Fig. 2-2. Use the function generator to produce the input square waveform $v_i(t)$ with a minimum value at 0 V and a maximum value at 1 V. Check the input waveform on an oscilloscope before you connect it to the circuit. Make sure the waveform period is proper to get a complete response.

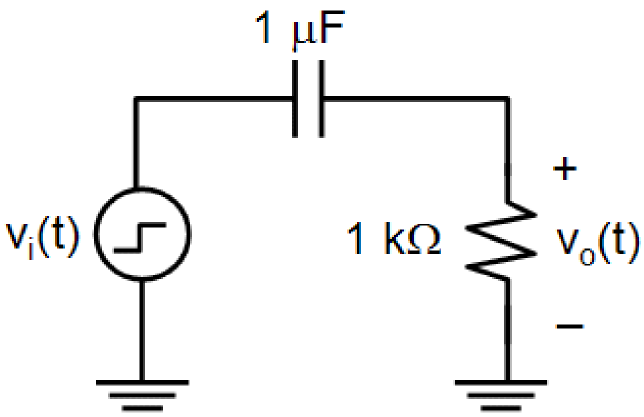


Figure 2-2

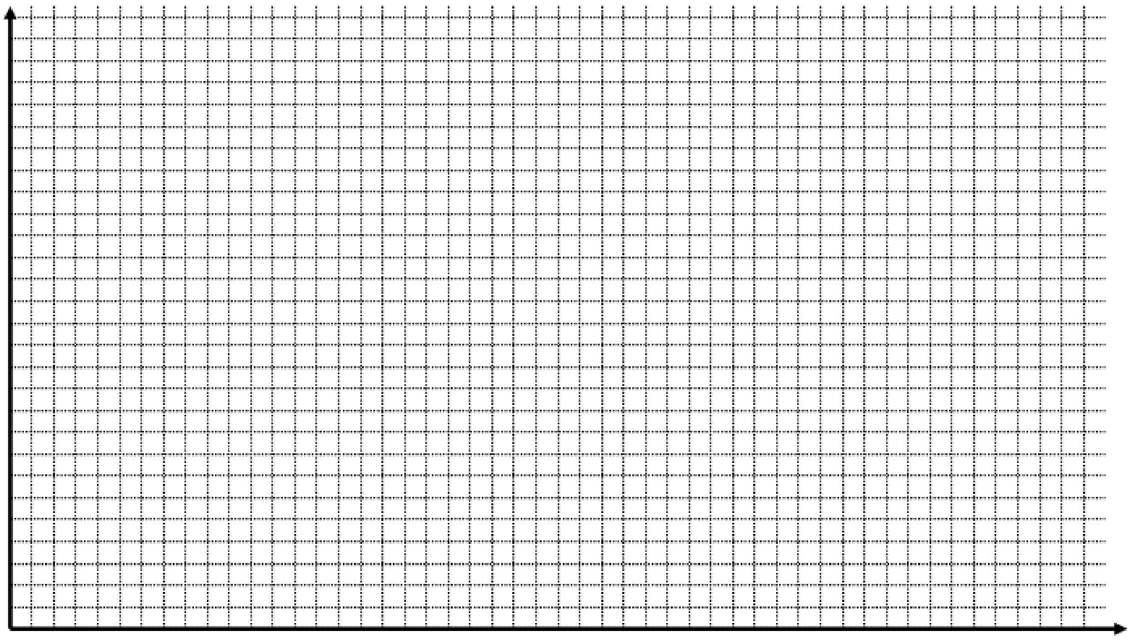
(i) Display the input and output signals on an oscilloscope. Record as many data points as possible of the output waveform in one period and insert them in Table 2-2.

Table 2-2

Time (sec)	$v_o(t)$ (V)	Time (sec)	$v_o(t)$ (V)	Time (sec)	$v_o(t)$ (V)

(j) Plot one period of the output response on Graph 2-3 and label the curve. Label the voltage and time at 36.8% of the maximum input value. You must label the unit of time on the *x* axis. Do you think the measured waveform is correct? Is it accurate based on the measured resistance and capacitance values? Comment accordingly.

Comment:



Graph 2-3

Question: Please derive the analytic expression of the step response for the RC circuit in Fig. 2-3.

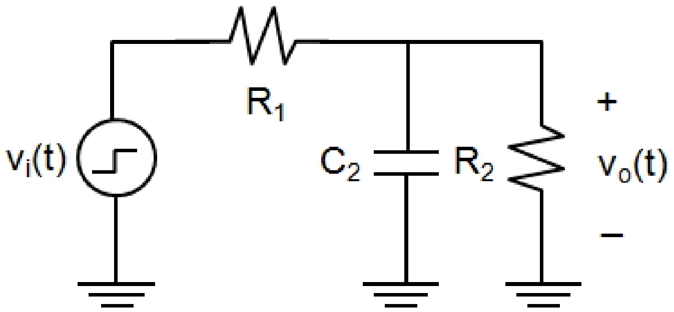


Figure 2-3

<u>Analysis</u>:

Part 3: Step Response of a RC network

(a) Construct the *RC* circuit of Fig. 3-1. Derive the output waveform $v_o(t)$ due to a unit-step input using values of R_1, C_1, R_2, and C_2 as shown.

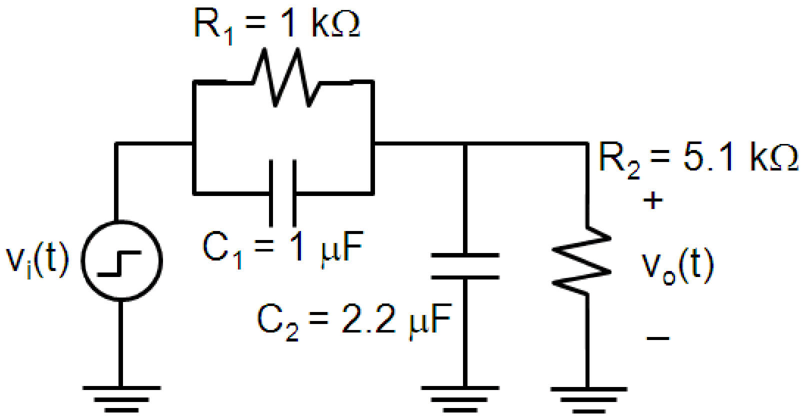


Figure 3-1

<u>Analysis</u>:

(b) Measure the resistance and capacitance values. Use the function generator to produce the input square waveform $v_i(t)$ with <u>a minimum value at 0 V</u> and a maximum value at 1 V. Check the input waveform on a oscilloscope before you connect it to the circuit. What the input frequency f_i of $v_i(t)$ that you pick? Why?

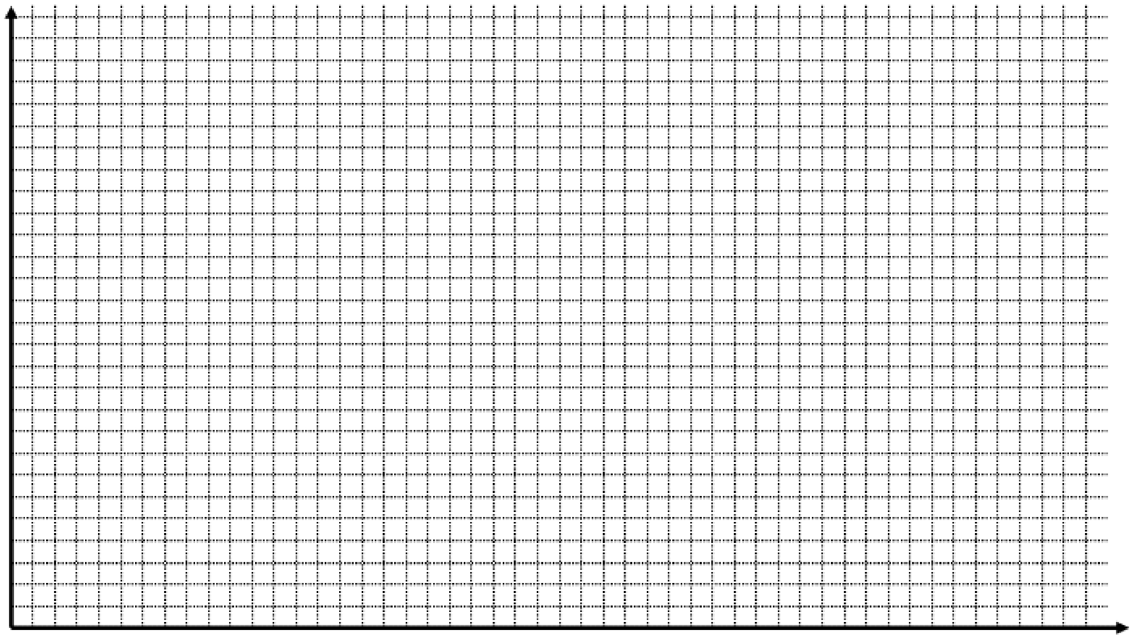
R_1 = ______________, C_1 = _____________, R_2 = ______________, C_2= _____________
f_i = _____________Hz
<u>Comment on the choice of f_i:</u>

(c) Display the input and output signals on an oscilloscope. Record as many data points as possible of the output waveform in one period and insert them in Table 3-1.

Table 3-1

Time (sec)	$v_o(t)$ (V)	Time (sec)	$v_o(t)$ (V)	Time (sec)	$v_o(t)$ (V)

(d) Plot one period of the output response on Graph 3-1. Do you think the measured waveform is accurate based on the measured resistance and capacitance values? Comment accordingly.
<u>Comment:</u>



Graph 3-1

Part 4: Design Problem: Under-Damped Response of the 2nd-Order Series *RLC* Circuit

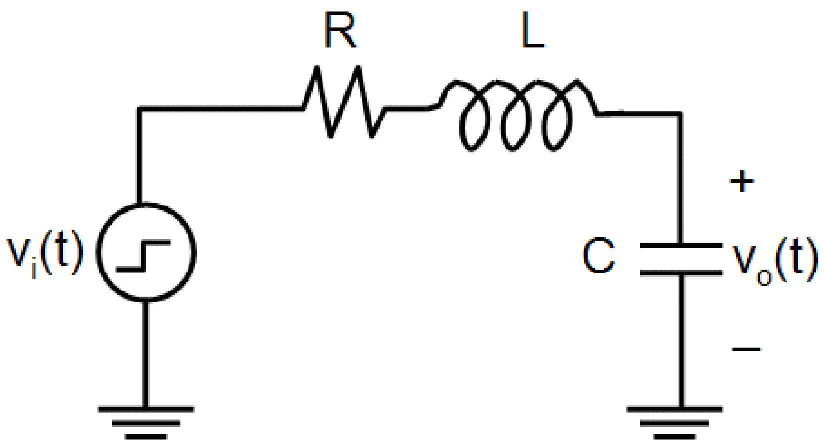


Figure 4-1

(a) A 2nd-order series *RLC* circuit is shown in Fig. 4-1. You are required to select the proper *R*, *L*, and *C* in the circuit to achieve the following design specifications for the output response under a step input (use square waveform with the minimum and maximum values of 0 V and 1 V, respectively).

(1) Rise time = 70 to 80 μs;
(2) Overshoot = 25 to 35%

Show your calculation for the design, and report values of the passive elements. Report the passive elements that you actually use in experiment.

R_{cal} = ________________, L_{cal} = ________________, and C_{cal} = ________________
R_{exp} = _____________, L_{exp} = _______________, and C_{exp} = _______________
Calculation:

(b) Display the input and output signals on an oscilloscope. **Be aware, the function generator has a source impedance of 50 Ω which will affect the total resistance.** Record the data points of the output waveform when the capacitor is charged in Table 4-1. **You must show TA your waveform with the correct rise time and overshoot.**

Table 4-1

Time (sec)	$v_o(t)$ (V)	Time (sec)	$v_o(t)$ (V)	Time (sec)	$v_o(t)$ (V)

Measured rise time = _____________, measured overshoot = ___________%

(c) Change the resistor in the circuit with another value, and record the values of rise time and overshoot. You must make sure the output is underdamped.
R_{exp} = _________, rise time = _____________, overshoot = ___________%
Please analyze whether the values of rise time and overshoot are reasonable based on R_{exp}.

Analysis:

(d) Change the resistor in the circuit until you get a critically damped response (overshoot = 0). Record the resistor value and analyze whether resistor value is reasonable.

R_{exp} = ________

Analysis:

Question: Please derive the step response of the RLC circuit in Fig. 4-2.

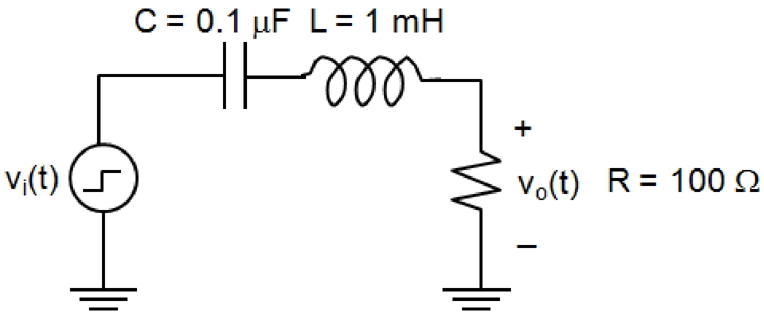


Figure 4-2

Analysis: