EE1002 Lab 3: Study of RC and RL Circuits (Online)

I. OBJECTIVES

1. To get familiar with the online simulator.
2. To determine the reactances of a capacitor and an inductor of simple series RC and RL circuits.
3. To study the voltages and currents of the resistor, capacitor, and inductor in the series circuits at different frequencies.

II. EQUIPMENT AND MATERIALS REQUIRED

1. Computer
2. Browser
3. Online simulator Circuit-Sandbox (https://spinningnumbers.org/circuit-sandbox/index.html)

III. THEORY

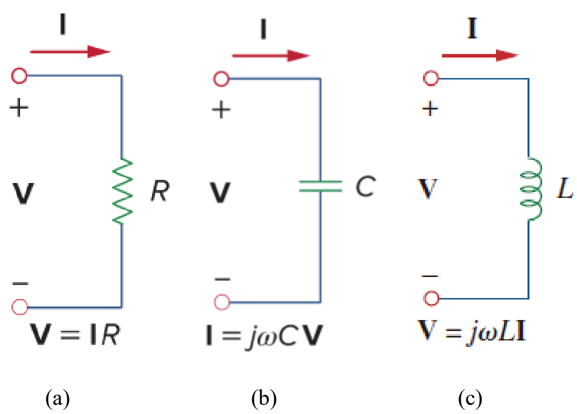

Fig.1. The voltage-current relations for a resistor and a capacitor in the frequency domain. (a) Resistor. (b) Capacitor. (c) Inductor.

The voltage-current relationships for a resistor (Fig.1(a)), a capacitor (Fig.1(b)) and an inductor (Fig.1(c)) are given by $I = V/R$, $I = j\omega CV$, and $I = V/(j\omega L)$, respectively.

III. PROCEDURE

Part A: *RC* Circuit

1. Build a circuit as shown in Fig. 2.

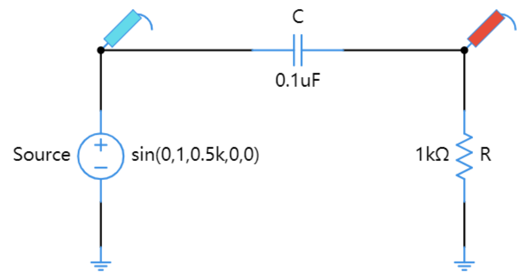

Fig.2 Circuit configuration for the measurement voltage of *R*

For "sin(0,1,0.5k,0,0)" of the source in Fig. 2, "sin" means that the input signal is sinusoidal; the first "0" means that the offset value of the signal is 0; "1" means that the amplitude of the sin signal is 1; "0.5k" means that the input signal has a frequency of 500 Hz; the second-last "0" means that the time delay of the input sin signal is 0 second; the last "0" means the phase is 0 degree.

2. Double click the voltage source and edit its properties. Choose "sin" for the type, and other properties can be set as follows:

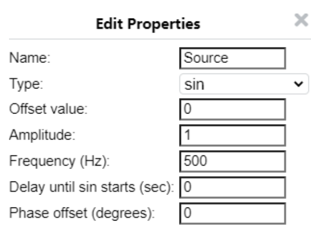

Fig.3. Settings of the voltage source

3. Insert two "Voltage probes" as shown in Fig. 2. The left and right voltage probes are for simulating the source (input) and capacitor (output) voltages, respectively. Now, you can run the simulation using the icon "TRAN" ("TRAN" stands for "Transient" but is used for all time-varying simulations. Steady-state results can be obtained if the simulation time span is sufficiently long.). You should find a suitable stop time (e.g., 0.005s) for your simulation.

4. From the simulated output voltage (ignore the first cycle of your simulated result), find the voltage V_R and current I_R (= V_R/R) of the resistor *R*. Then enter the magnitudes of V_R and I_R into Table I.

5. With reference to Fig. 4, the phase shift of the output voltage with reference to that of the input voltage can be calculated using $\phi = 360° \times t/T$. Enter the phase shits (phase angles) of V_R and I_R into Table I.

6. Swap the positions of *R* and *C* to measure the capacitor voltage, as shown in Fig.5. Run the simulation with the transient solver "TRAN". You will obtain the voltage V_C of the capacitor. Please fill in Table I with your simulated results.

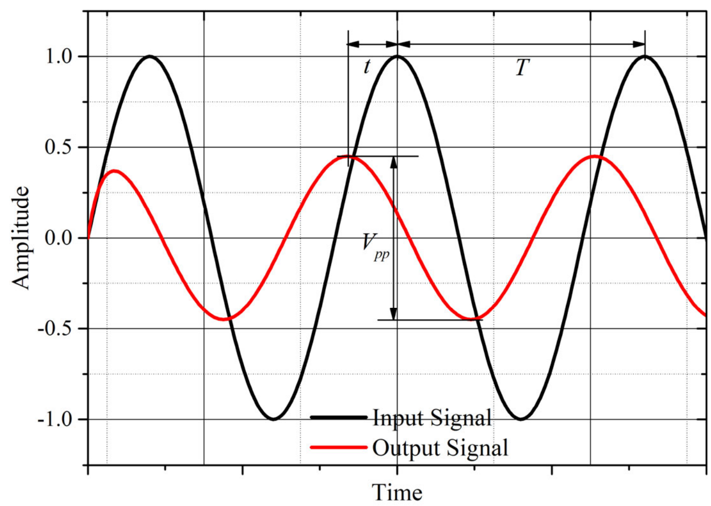

Fig.4. The input and output signals with a period of T, time shift of t and peak-to-peak voltage V_{pp}. Please do not use the first cycle of the result.

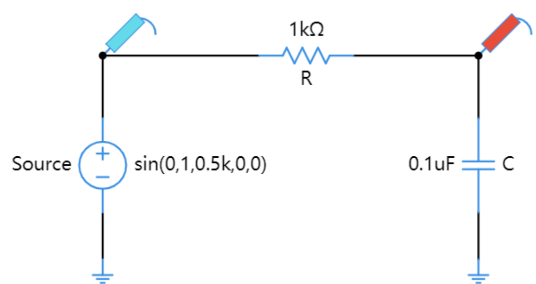

Fig.5. Circuit configuration for simulating V_C of the capacitor.

7. Repeat Steps 1 to 6 for the frequencies given in Table I.

Table I. Simulated/calculated values of the *RC* circuit given in Figs. 2 and 5.

Freq. (kHz)	V_R (pp)*		$I_R = I_C$ (pp)*		V_C (pp)*		*Calculation*		*Theory*
	Mag (V)	Angle (°)	Mag (mA)	Angle (°)	Mag (V)	Angle (°)	R (Ω)	jX_c (Ω) $= V_C/I_R$	jX_c (Ω) $=1/(j\omega C)$
0.5									
1									
2									
4									
8									

* The subscript "pp" in V_R (pp), I_R (pp), and V_C (pp) means the peak-to-peak value.

Part B: *RL* Circuit

Change the capacitor in Part A with an 0.1H inductor, as shown in Figs. 6 and 7. Repeat Steps 1 to 7 in Part A and fill in Table II with your simulated results.

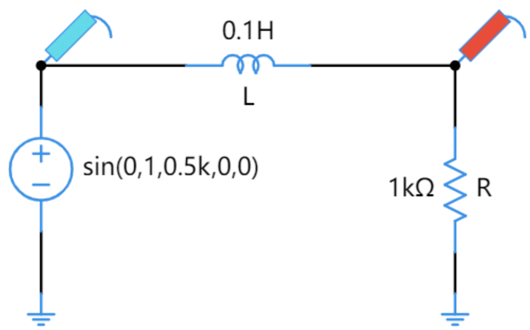

Fig.6 Circuit configuration for the measurement voltage of *R*.

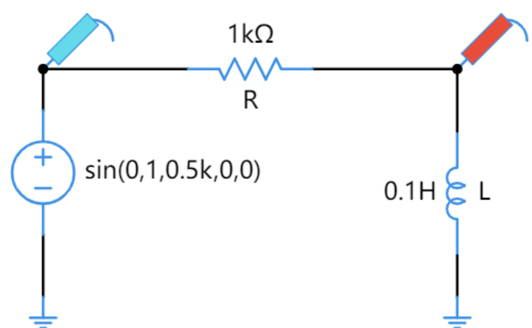

Fig.7 Circuit configuration for the measurement voltage of *L*.

Table II. Simulated/calculated values of the *RL* circuit given in Figs. 6 and 7.

Freq. (kHz)	V_R (pp) *		$I_R = I_L$ (pp)*		V_L (pp) *		*Calculation*		*Theoretical*
	Mag (V)	Angle (°)	Mag (mA)	Angle (°)	Mag (V)	Angle (°)	R (Ω)	jX_L (Ω) $= V_L/I_R$	jX_L (Ω) $= j\omega L$
0.5									
1									
2									
4									
8									

* The subscript "pp" in V_R (pp), I_R (pp), and V_C (pp) means the peak-to-peak value.

V. DISCUSSION

1. Calculate X_C [$= 1/(j\omega C)$] from 1 kHz to 20 kHz with a step of 2 kHz. Plot the curve of X_C with the calculated data as a function of frequency. Also show in the same graph your simulated data obtained in Table I. Explain the discrepancy between the simulated and calculated results.

2. For the circuit in Fig. 2, plot the phase difference between the calculated voltage and current of the resistor R (voltage phase – current phase) as a function of frequency. Also include in the same figure the simulated result obtained from Table I. Repeat this step for the capacitor. Are your results expected? Explain briefly.

3. Calculate X_L ($= j\omega L$) from 1 kHz to 20 kHz with a step of 2 kHz. Plot the curve of X_L with the calculated data as a function of frequency. Also show in the same graph your simulated data obtained in Table II. Explain the discrepancy between the simulated and calculated results.

4. For the circuit in Fig. 6, plot the phase difference between the voltage and current of the resistor R (voltage phase – current phase) as a function of frequency. Also include in the same figure the simulated result obtained from Table II. Repeat this step for the inductor. Are your results expected? Explain briefly.

REFERENCES

1. M. O. Sadiku, S. M. Musa and C. K. Alexander, Applied Circuit Analysis, McGraw Hill, 2012.
2. C. K. Alexander and M.O. Sadiku, Fundamentals of Electric Circuits, 5th Edition, McGraw Hill, 2012.