EXPERIMENT E11: SINUSOIDAL RESPONSE OF RC AND RL CIRCUITS

Related course: KIE1005 (Circuit Analysis I)

OBJECTIVES:
To investigate the sinusoidal response of an RC and RL circuits

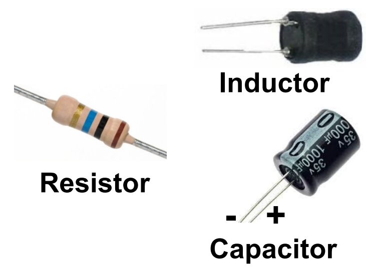
EQUIPMENT:
Function generator; oscilloscope; breadboard; wires/jumpers; resistors: 470Ω (1 unit), 1kΩ (1); capacitor 10uF (1); inductor: 1.5 mH (1)

INSTRUCTIONS:

1. Record all your results and observations in a log book or on a piece of paper
2. Follow the demonstrator's instructions throughout the experiment

REFERENCE(S):
Refer to the main references of KIE1005

TESTS:
TEST 1: Sinusoidal response of RC circuit
TEST 2: Sinusoidal response of RL circuit



INTRODUCTION:

In real life, generation, transmission and distribution of electrical power systems operate in the sinusoidal steady state, such as the electricity that is distributed to a household. Thus, it is important to know the effect of sinusoidal source on circuits and how to analyse it. The frequency of the sinusoidal source governs the sinusoidal response of the circuit.

For RC circuit, which consists of a capacitor *C* and a resistor *R* connected in series with a sinusoidal source V_{in}, the output voltage V_{out} across *R* equals to

$$V_{out} = \frac{V_{in} R}{\sqrt{R^2 + X_C{}^2}} \qquad (1)$$

where $X_C = 1/(2\pi f C)$ and *f* = frequency in Hz.

For RL circuit, which consists of an inductor *L* and a resistor *R* connected in series with a sinusoidal source V_{in}, the output voltage V_{out} across *R* equals to

$$V_{out} = \frac{V_{in} R}{\sqrt{R^2 + X_L{}^2}} \qquad (2)$$

where $X_L = 2\pi f L$ and *f* = frequency in Hz.

PROCEDURE:

TEST 1: Sinusoidal response of RC circuit

1. Find one resistor of *R* = 470 Ω and measure its resistance using a multimeter.
2. For every frequency in Table 1, calculate V_{out} using equation (1), where V_{in} = 12 Vpp, *C* = 10 uF and *R* equals to the value measured from the multimeter in step 1.
3. Connect the function generator, *R* = 470 Ω resistor and *C* = 10 uF capacitor in series on a breadboard, as shown in Figure 1.

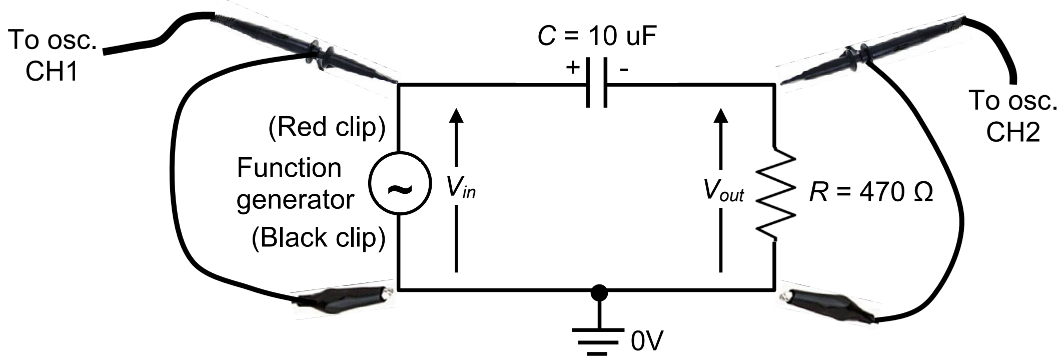


Figure 1: RC circuit

4. As shown in Figure 1, connect the oscilloscope's CH1 probe hook at point between the function generator and *C*. Connect its crocodile clip to the ground of the function generator. CH1 is now measuring the input voltage V_{in} across the function generator.
5. Connect the oscilloscope's CH2 probe hook at point between the *R* and *C*. Connect its crocodile clip to the ground of the function generator. CH2 is now measuring the output voltage V_{out} across *R*.
6. Turn ON the function generator and oscilloscope.
7. Set the function generator to sinusoidal with 12 Vpp (peak-to-peak) and frequency to 50 Hz. Press MEASURE button on the oscilloscope to view the voltage and frequency reading. Adjust the voltage and time setting of the oscilloscope or press AUTOSCALE or AUTOSET so that the positive and negative peak of the waveform can be seen clearly.
8. Record the peak-to-peak voltage of both CH1 (V_{in}) and CH2 (V_{out}) signals in Table 1. Make sure that V_{in} is 12 Vpp. Compare the measured V_{out} with calculated V_{out}. Are they almost similar?
9. By changing the frequency of the function generator, repeat steps 7 and 8 for 100 Hz, 300 Hz, 1 kHz, 3 kHz, 10 kHz, 30 kHz, 100 kHz, 300 kHz and 1 MHz. Make sure that V_{in} is always 12 Vpp. Then, calculate the voltage gain using $20\log_{10}(V_{out}/V_{in})$.
10. Repeat steps 7 to 9 but only change R = 1kΩ in Figure 1. Record the results in another table and name it as Table 2.

Table 1

Frequency *f* (Hz)	Measured V_{out} (Vpp)	Measured V_{in} (Vpp)	Measured voltage gain = $20\log_{10}(V_{out}/V_{in})$ dB	Calculated V_{out} (Vpp) using equation (1)
50				
100				
300				
1k				
3k				
10k				
30k				
100k				
300k				
1M				

TEST 2: Sinusoidal response of RL circuit

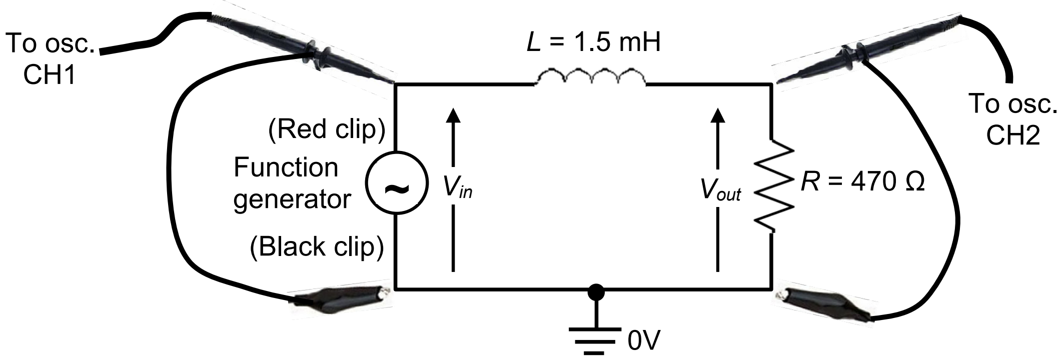


Figure 2: Circuit for RL circuit experiment

1. Connect the function generator, R = 470 Ω resistor and L = 1.5 mH inductor in series on a breadboard, as shown in Figure 2.
2. As shown in Figure 2, connect the oscilloscope's CH1 probe hook at point between the function generator and L. Connect its crocodile clip to the ground of the function generator. CH1 is now measuring the input voltage V_{in} across the function generator.
3. Connect the oscilloscope's CH2 probe hook at point between the L and R. Connect its crocodile clip to the ground of the function generator. CH2 is now measuring the output voltage V_{out} across R.
4. Turn ON the function generator and oscilloscope.
5. Set the function generator to sinusoidal with 12 Vpp and frequency to 50 Hz. Press MEASURE button on the oscilloscope to view the voltage and frequency. Adjust the voltage and time setting of the oscilloscope or press AUTOSCALE or AUTOSET so that the positive and negative peak of the waveform can be seen clearly.
6. Record the peak-to-peak voltage of both CH1 (V_{in}) and CH2 (V_{out}) signals in a table similar to Table 1. Name it as Table 3.
7. Repeat steps 5 and 6 for 100 Hz, 300 Hz, 1 kHz, 3 kHz, 10 kHz, 30 kHz, 100 kHz, 300 kHz and 1 MHz. Make sure that V_{in} is always 12 Vpp.
8. Repeat steps 5 to 7 but only change R = 1kΩ in Figure 2. Record the results in another table and name it as Table 4.
9. For every frequency in Table 3 and 4, calculate V_{out} using equation (2). Compare your measured V_{out} with the calculated V_{out}. Are they almost similar?

DISCUSSION (include them in your lab report):

1. Derive equations (1) and (2) by referring to Figure 1 and Figure 2.
2. Plot the measured voltage gain (in dB) vs. frequency (in Hz) from your Table 1 and 2 in one graph (x-axis is in base-10 logarithm). What is the effect on the voltage gain when the resistor value R in RC circuit is larger?
3. Plot the measured voltage gain vs. frequency from your Table 3 and 4 in one graph. What is the difference of the sinusoidal response between RC and RL circuits?
4. From your Table 1, 2, 3 and 4, compare your measured V_{out} with calculated V_{out}. Do they agree with each other? Identify the source of the difference if any.

END OF EXPERIMENT