ECE 541: Electric Circuits

Laboratory Exercise #5

Scopes, Frequency, and Phase

Weeks of 11/21 (Group A) and 11/28 (Group B)

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Objective

- To observe the phase difference caused by an RC circuit with an AC voltage source.

Introduction

We want to see how the phase of the current changes, as compared to that of the applied voltage, when a sinusoidal signal is applied to a simple series RC circuit as shown in pre-lab figure 1 below. From what we have covered in class, you should expect the current to lead the voltage by some amount between 0° and 90°. The angle would be 0° if the circuit were completely resistive, and 90° if it were completely capacitive.

If the input voltage is $v_s(t) = V_m cos(\omega t)$

Then the series current through the circuit (based on sinusoidal steady state analysis) is:

$$i(t) = \frac{V_m C\omega}{\sqrt{1+(RC\omega)^2}} cos(\omega t + tan^{-1}(\frac{1}{RC\omega}))$$

The capacitor voltage can be found by taking the integral of current and dividing by C:

$$v_c(t) = \frac{V_m}{\sqrt{1+(RC\omega)^2}} cos(\omega t + tan^{-1}\left(\frac{1}{RC\omega}\right) - \frac{\pi}{2})$$

Pre-Lab Procedure

1. Consider the circuit shown below in figure 1. Note that channel A is measuring the input source and channel B is measuring the voltage across the resistor. The voltage across a resistor is always in phase with the current through that resistor so channel B shows us the phase of the series current through the circuit.

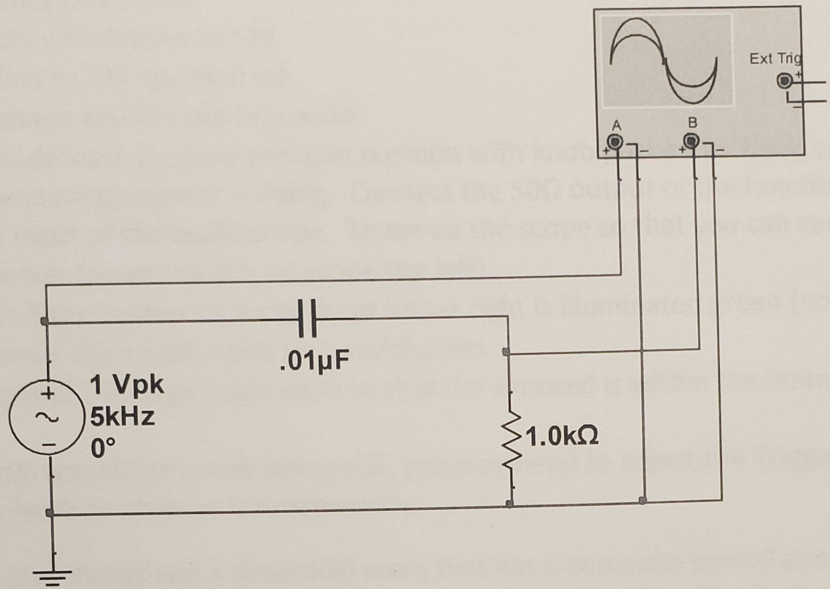

Figure 1

Calculate what the phase difference should be between the voltage applied to this circuit and the current through it.

Calculated Phase Difference = 72° = 360° * 0.00004 * 5000

Find the difference in time between the channel A wave and channel B wave (you can measure peaks or zero-crossings).

Time difference = 40 us

Repeat this procedure with a 40 kHz input frequency.

Calculated Phase Difference = 368.64 = 360 * 0.0000254 * 40000

Measured Phase Difference = 31°

In-Lab Procedure

1. For this first part, the objective is to set the function generator so that it generates a 1 kHz sine wave and verify the function generator output using the oscilloscope.

Do the following to set the function generator so that it generates the appropriate signal:

- Set the Frequency Dial to 1.0
- Set the Frequency Multiplier to X1k
- Set the DC Offset to OFF (pushed in)
- Set the Waveshape knob to the sine wave
- Set the Amplitude knob to some medium position with knob pushed in. Next, you need to look at what the function generator is doing. Connect the 50Ω output of the function generator to the Channel 1 input of the oscilloscope. To set up the scope so that you can see the wave:
- Turn on the power (power switch on scope top left)
- Make sure Run/Stop button on scope front upper right is illuminated green (not red)
- Set the Horizontal Time Scale knob to 1 ms/division
- Adjust the channel 1 Voltage Scale knob so that the sinusoid is within the boundaries of the display.
- If the sinusoidal waveform is not sitting still, you may need to adjust the Trigger Level knob. Try adjusting this knob to observe is functionality.

At this point, you should see a sinusoidal wave that has a complete period about every division on the display. To make more accurate time measurements, adjust the Horizontal Time Scale knob so that one full period takes up all or most of the display. Measure the period of the wave.

Period = 0.968us

Calculate the frequency of the wave.

Frequency = 1.033 KHz

Next, measure the amplitude of the signal. (peak to peak is fine)

Amplitude = 90.4 V

Remember that this amplitude was chosen arbitrarily. Also, note that the amplitude knob is pushed in. Next, let's see what this function generator can do. Set the Amplitude knob of the function generator to its minimum position (fully counter-clockwise). Measure the amplitude.

Minimum amplitude = -45.6 V

Then, set it to its maximum value (fully clockwise).

Maximum value = 46.4

Then, do the same with the amplitude knob pulled out.

Minimum amplitude = -5.60V

Maximum value = 5.60V

TA's Signature:

2. Construct the circuit shown in figure 1 and set the function generator to generate a 5 kHz sine wave with some arbitrary amplitude (use the scope to help set the frequency accurately).

Connect the channel 1 input of the oscilloscope to the input of the circuit and connect the channel 2 input to resistor. Be sure to have the blue channel 2 button pushed in to enable display. Channel 1 now displays the voltage applied to the input and channel 2 displays the voltage across the resistor. The voltage across a resistor is always in phase with the current through that resistor so channel 2 shows us the phase of the series current through the circuit.

Calculate what the phase difference should be between the voltage applied to this circuit and the current through it (you already did this in the prelab).

$\phi = 360° \cdot \Delta t \cdot f$

Calculated Phase Difference = $72°$

$72° = 360 \cdot 0.00004 \cdot 5000$

Measure the difference in time between the channel 1 wave and channel 2 wave (you can measure peaks or zero-crossings).

Time difference = 40 ~~[illegible]~~ us

Using this measured time difference and the known frequency, calculate the measured phase difference.

~~360 · 0.00004 · 5002~~

Measured Phase Difference = $75°$

3. Repeat this procedure with a 40 kHz input frequency.

Calculated Phase Difference (you already did this in the prelab) = $8.64°$ $= 368.64$

Measured Phase Difference = $31°$

$360° \cdot \Delta t \cdot f$

$\Delta t = 25.6$

$360 \cdot 0.0000256 \cdot 40000$

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