LAB 4: Frequency and Phase Response of a Series RC Circuit.

PURPOSE

To investigate the frequency and phase response of a series RC circuit.

EQUIPMENT

(i) Oscilloscope – Tektronix 3012.
(ii) Oscillator – Wavetek 182A.
(iii) Multimeter – Wavetek DM15XL.
(iv) Prototyping board.
(v) Capacitor (C=0.047µF).
(vi) $R_1 = 200e^{\left(\frac{xxx}{300}\right)}\Omega$, where xxx is the last three digits of your student number.
(vii) $R_2 = 2R_1\Omega$

PRELAB (_/2)

1. (_/0.5) Calculate the values of R_1 and R_2.

2. (_/0.125) Explain what is meant by a *high-pass* filter. Sketch a typical shape of the magnitude Bode plot of a high-pass filter. (If Bode plots have not yet been covered in the lectures, then sketch a magnitude vs. frequency plot instead.)

3. (_/0.125) Explain what is meant by a *low-pass* filter. Sketch a typical shape of the magnitude Bode plot of a low-pass filter. (If Bode plots have not yet been covered in the lectures, then sketch a magnitude vs. frequency plot instead.)

4. (_/0.125) Calculate the "corner" frequency of the high-pass filter given in Figure 1.

5. (_/0.125) Calculate the "corner" frequency of the low-pass filter given in Figure 2.

6. (_/0.5) For the purposes of this lab, all phasor lengths will not represent the peak values but the RMS values. Impedances will then remain unchanged. Draw the phasor diagram of the circuit in Figure 1 by performing the following steps:

(a) Calculate the impedance values of the components in Figure 1 at the "corner" frequency.

(b) Use the voltage divider equation to obtain expressions for V_{OUT} and V_C. Assume V_{IN} = $5\angle 0°$ V RMS.

(c) Draw V_{OUT} and V_C as phasors, and add them graphically.

(d) Demonstrate that $V_C + V_{OUT} = V_{IN}$, where V_{IN} = $5\angle 0°$ V RMS.

7. (_/0.5) Repeat question 6 for a frequency one octave below the "corner" frequency (i.e. ½ the "corner" frequency).

NOTE: Bring a ruler and a protractor to this lab session for drawing phasor diagrams.

PROCEDURE

Part 1. High-Pass RC Coupling Circuit

1.1 (_/0.5) Connect the circuit shown in Figure 1. From the resistor drawer choose a resistor that is the closest match to your calculated value of R_1. Record this value.

1.2 Set the oscillator to give a sine wave output and adjust the voltage to give V_{IN} = 5 V RMS. Check and readjust the value of V_{IN} whenever you change the frequency.

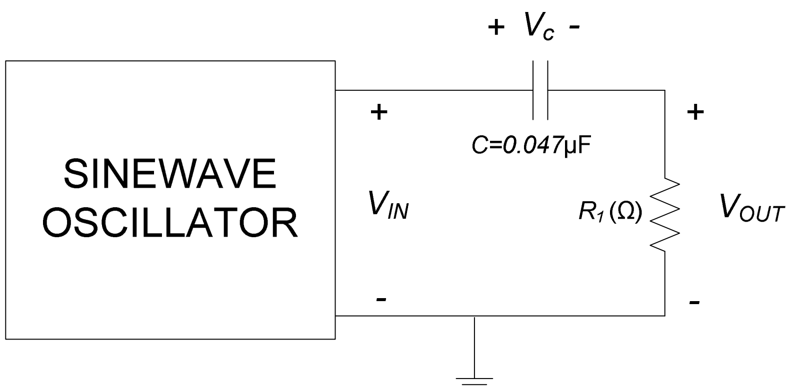

Figure 1. Circuit configuration for step 1.1.

1.3 (_/0.75) Connect channel 1 of the oscilloscope across the oscillator output, and channel 2 across the resistor. In addition, display the V_C waveform by using the 'MATH' menu as was done in step 1.3 of Lab 3.

Tabulate the values of V_{IN}, V_C, and V_{OUT} for frequencies between 100 Hz and 1 MHz. Use the frequency values given in the table at the end of Part 1.

1.4 (_/0.5) Is $V_{IN} = V_C + V_{OUT}$ (added algebraically) true for each frequency in step 1.3? Why or why not?

1.5 (_/0.75) Plot a graph of $20 \log_{10} (V_{OUT}/V_{IN})$ against frequency on a semi-logarithmic graph paper. A sample of semi-logarithmic graph paper is included in Figure 3. Always put the log spacing on the frequency axis, and orient the graph paper such that the closer spacings are on the right. It is helpful to plot each point individually as the measurements are obtained in step 1.33, since errors can be spotted immediately by inspection.

1.6 (_/0.5) Draw a tangent to the curve where the output drops down towards lower frequencies and extrapolate it to intersect the 0 dB line. The frequency at which the intersection occurs is known as the "corner" frequency. Record this value and compare it to the value calculated in question 4 in the prelab.

1.7 (_/0.5) Measure the amplitude of V_{OUT} as well as the phase angle between V_{IN} and V_{OUT} (refer to Lab 1, Part 2) at the "corner" frequency. Remember to adjust the input signal amplitude to 5 V RMS.

1.8 (_/0.25) Show, as *phasors*:

$$V_{IN} = V_C + V_{OUT}$$

i.e. draw V_{IN} and V_{OUT} on a phasor diagram based on your measurements in step 1.7, and find V_C graphically.

1.9 (_/0.25) Compare the phasor diagram in step 1.8 to the diagram produced in question 6 in the prelab.

1.10 (_/1) Repeat steps 1.8 - 1.9 for an input signal at a frequency one octave below the “corner” frequency (i.e. ½ the “corner” frequency). Remember to adjust the input signal amplitude to 5 V RMS. Compare the results to the phasor diagram produced in question 7 in the prelab.

f	V_{IN}	V_C	V_{OUT}	$20 \log_{10} (V_{OUT}/V_{IN})$
100 Hz				
200 Hz				
400 Hz				
700 Hz				
1 kHz				
2 kHz				
4 kHz				
7 kHz				
10 kHz				
20 kHz				
40 kHz				
70 kHz				
100 kHz				
200 kHz				
400 kHz				
700 kHz				
1 MHz				

Part 2. Low-Pass RC Coupling Circuit

2.1 (_/0.5) Connect the circuit shown in Figure 2. From the resistor drawer choose a resistor that is the closest match to your calculated value of R_2. Record this value.

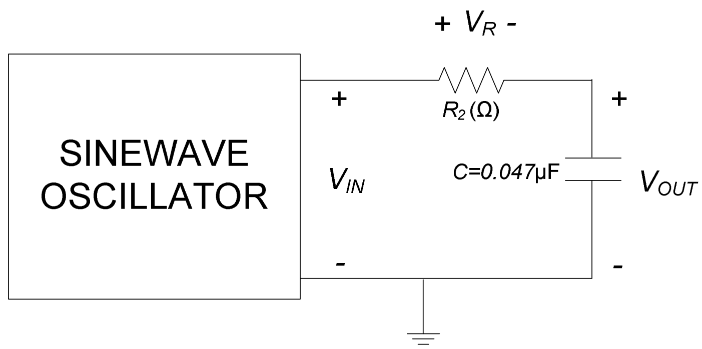

Figure 2. Circuit configuration for step 2.1.

2.2 (_/2.5) Repeat steps 1.2 - 1.6 in Part 1 drawing the tangent to the trend of the output dropping toward higher frequencies. Use the values in the following table and note that when V_{OUT} is less than 30mV the data point does not need to be plotted:

f	V_{IN}	V_R	V_{OUT}	$20 \log_{10} (V_{OUT}/V_{IN})$
100 Hz				
200 Hz				
400 Hz				
700 Hz				
1 kHz				
2 kHz				
4 kHz				
7 kHz				
10 kHz				
20 kHz				
40 kHz				
70 kHz				
100 kHz				
200 kHz				
400 kHz				
700 kHz				
1 MHz				

Compare the obtained “corner” frequency to the value calculated in question 5 in the prelab.

Four Cycle Semi-Log