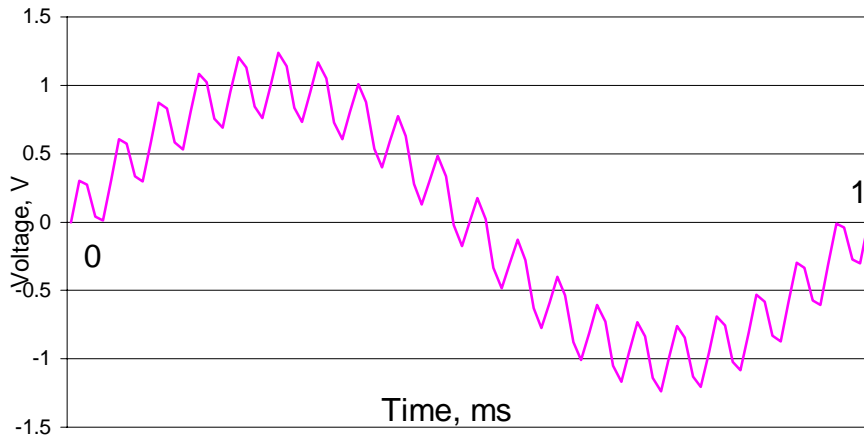# RC Filter

Pre-lab Questions

1. What are some typical uses of RC filter circuits?

2. Given a low-pass filter with a 2 KΩ resistor and a 0.2 µF capacitor, find the corner frequency.

3. Design an RC filter that removes the high frequency noise from the signal seen below.

Purpose

- To introduce resistors and capacitors

- To introduce the concept, construction, and utility of low-pass and high-pass RC filters

Components

| Qty.	Item
1	motor/tachometer unit
1 ea.	1 kΩ and 10 kΩ resistors
6	capacitors, 1 of each given value - (0.047µF, 0.1µF, 0.47µF, 0.68µF, 10µF, 1000µF)

Introduction

Resistor-Capacitor Filter Circuit:

The impedance of a capacitor is $1/(j\omega C)$ where j is the complex variable, ω is frequency in rad/sec (2π rad/sec = 1Hz), and C is capacitance in Farads. The following equation relating input voltage, Vi and output voltage, Vo for the circuit shown in Figure 1 is obtained by using the voltage division formula:

$$Vo = \frac{1/(jwC)}{R + 1/(jwC)} Vi \qquad \text{or} \qquad \frac{Vo}{Vi} = \frac{1}{1 + jwCR}$$

The frequency dependent term $1/(1+j\omega CR)$ is called the Transfer Function of the circuit. For a given sinusoidal input voltage, Vi, the magnitude of the output voltage, Vo, is given by

the product of Vi and the magnitude of the Transfer Function (evaluated at the frequency of Vi). We will verify this relation by the following experiment.
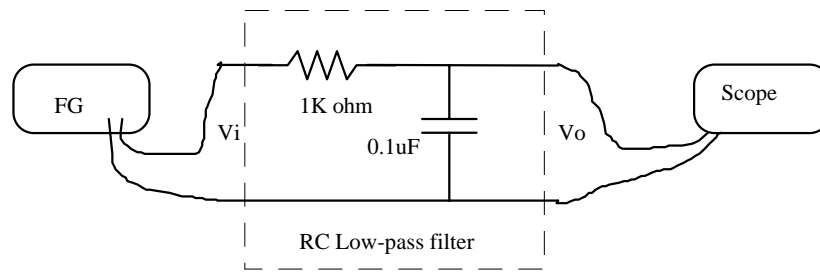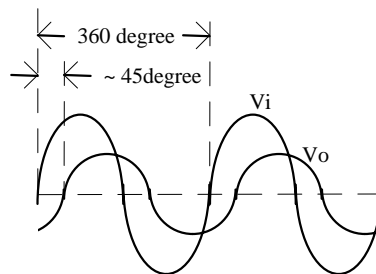

Figure 1 RC low-pass filter

Procedure

1. Construct the <u>single-stage RC Low-pass filter circuit</u> shown in Figure 1.

2. Set Vi to 5 volts p-p at 500Hz and record the amplitude of Vo. Repeat this measurement with the frequency of Vi set to 1.6 kHz and 10 kHz. Compare the ratio of the input voltage and the output voltage (i.e., Vo/Vi) with the magnitude of the Transfer Function evaluated at the corresponding frequency. **What can you conclude from this comparison about the relationship between the magnitude of the transfer function and the ratio of the input and output voltages? Explain. Why is this circuit called a "low-pass filter"?**

The phase lag of a circuit can be thought of as the amount of delay in the signal as it goes through the circuit. Phase lag is measured in degrees as shown in Figure 2. The phase lag of the circuit shown in Figure 2 is the angle of the transfer function, $1/(1+j\omega CR)$, evaluated at the frequency of the signal. We will verify this relation by the following experiment.

3. Set the scope to dual-trace mode. Display both Vi and Vo on the scope at the same time. (Ask the TA for help if needed). Measure the phase lag of this circuit as shown in Figure 2 at Vi=1.6 kHz. **Does the theoretical value match the observed value?** Capture the waveforms using BenchLink Scope for your report.

Figure 2 Phase lag of Vo.

4. Set the function generator to output a 1 kHz square wave at 5 V p-p magnitude. Add a DC offset, so the waveform runs 0 to 5 V. Build a low pass filter having a corner frequency of 100 Hz. (Record the values of R and C that you use). Apply the square wave to your filter. What does the resulting waveform at the output of the filter look like? What is its "DC" value? What is the "ripple" on top of the "DC" level? Capture these waveforms for your

report using BenchLink. Comment on how you might be able to use this in your project to detect where the IR beacon is?

5. Form a high-pass filter from what you just built. What does the resulting waveform at the output of the high-pass filter look like? Capture these waveforms for your report using BenchLink. What is its "DC" value and ripple? Why is the DC value so different than with the low pass filter?

Questions

Questions are in bold letters in Procedures.