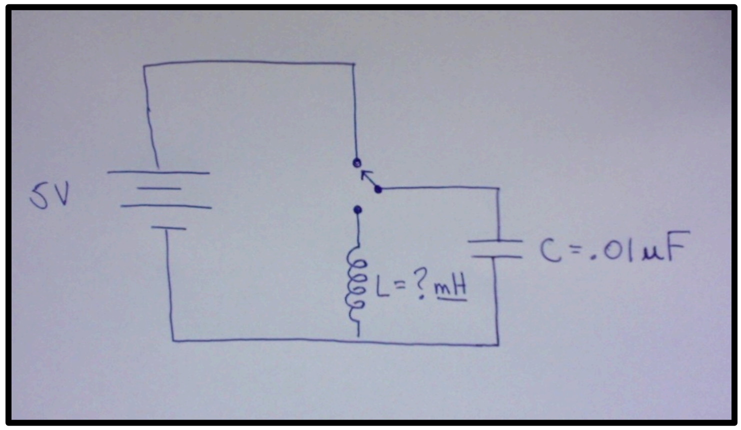
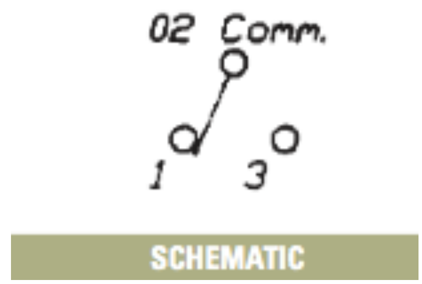
Lab 8: Basic Filters: Low-Pass and High Pass

Names: 1.) ____________________ **2.)** ____________________ **3.)** ____________________

Beginning Challenge: Build the following circuit. Charge the capacitor by itself, and then discharge it through the inductor. Measure the frequency of the resulting signal and calculate the value of the inductor.



Hints: The small black switch provided is a spdt (single pull-double throw. The center pin is always connected).



Measure the voltage across the capacitor on channel one. Set the scope to 2v/division, and 400 us/division. Run a single sequence with the trigger level at about 2 volts. Use the measure feature on the scope to find the frequency.

Draw a rough sketch of the signal and explain what is happening.

Calculate the inductor value. Show your work here.

Objectives:

1. Show students how circuits can have frequency-dependent resistance, and that many everyday signals are made up of many frequencies. We will explore how to filter these signals with resistors and capacitors.
2. To analyze the effect of frequency to the output voltage specifically to low-pass and high-pass filters.
3. To plot the output voltage-frequency response of RC low and high pass filters

Introduction:

In electronic circuits systems it is often helpful to separate a specific range of frequencies from the total spectrum. A filter is a type of circuit that passes a specific range of frequencies while rejecting other frequencies. A passive filter consists of passive circuit elements, such as capacitors, inductors and resistors.

Four basic types of filters:

1. Low-pass filter: designed to pass all frequencies below the cut-off frequency and reject all other frequencies above the cutoff
2. High-pass filter: designed to pass all frequencies above the cut-off frequency and reject all other frequencies below the cutoff
3. Band-pass filter: passes all frequencies within a band of frequencies and rejects all other frequencies outside the band.
4. Band-stop filter: rejects all frequencies within a band of frequencies and passes all frequencies outside the band.

In this lab we will explore the low and high-pass filters.

Cutoff frequency:

In physics and electrical engineering, a cutoff frequency, corner frequency, or break frequency is a boundary in a system's frequency response at which energy flowing through the system begins to be reduced (attenuated or reflected) rather than passing through.

Typically in electronic systems such as filters and communication channels, cutoff frequency applies to an edge in a lowpass, highpass, bandpass, or band-stop characteristic – a frequency characterizing a boundary between a passband and a stopband. From a graph we can find the cutoff frequency by finding the frequency where the magnitude of the output voltage is 70.7% off from the maximum value. In another way, the frequency when the signal magnitude is Vpp/sqrt(2). It can also be calculated from the R and C values as

$$f_{cutoff} = \frac{1}{2\pi RC}$$

<u>**Warm Up:**</u> Open up the AC+DC Circuit Construction Kit from PHET:

http://phet.colorado.edu/en/simulation/circuit-construction-kit-ac

We used a similar applet in the beginning of the semester, but this one now has AC voltage sources! This will let us explore the effect of frequency on resistors and capacitors.

Follow along as we look into how frequency affects resistors and capacitors.

A) Create a circuit using an AC Voltage source, a resistor, and a Voltage Chart from the Tools category. Use the chart to measure the voltage across the resistor. What kind of waveform does the AC Voltage source produce?

B) The AC Voltage source's frequency can be changed from 0 to 2 Hz by right-clicking on it and selecting "Change Frequency." Sketch your voltage vs. time plots for 0.2 Hz and 2 Hz below. How does changing the frequency affect the resistor's behavior?

0.2 Hz

2.0 Hz

C) Now add a capacitor in *series* with the resistor. Also add a new voltage chart and measure the voltage across the capacitor as well. Sketch the voltage vs. time plot for your resistor and capacitor. Hint: pause the simulation.

Resistor

Capacitor

D) Change the resistor to have a resistance of 4 Ohms, and set the frequency to 0.1 Hz. How does the size of the voltage drop across the resistor and capacitor compare? Write a relationship between the resistor, capacitor, and AC Voltage source's voltages. Hint: Kirchoff's Voltage Rule.

E) Now change the frequency to 2.0 Hz. How do the voltage drops across the resistor and capacitor compare now?

<u>Lab Equipment:</u>

Oscilloscope (no AC coupling: i.e. blocks low frequencies)
Function Generator
Circuit Breadboard
10 kΩ resistor
0.01 μF capacitor

<u>Procedure:</u>

Low-pass Filter

1. Set up the circuit in figure 1. Channel 1 is observing the incoming signal and channel 2 is looking at the out coming signal. Make sure you use the same ground point in your circuit for both channels.

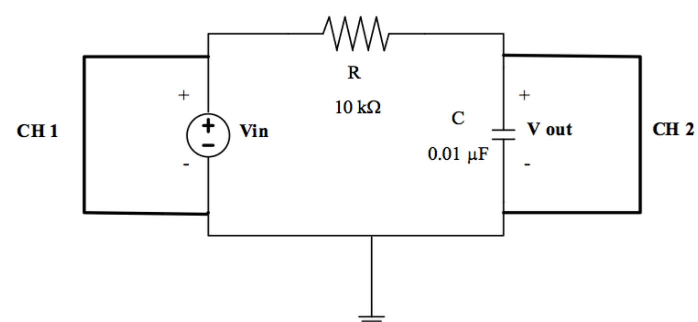


Figure 1

2. Set the Vin to 3.5 volts peak to

peak (3.5 Vpp) at 500 Hz.

3. Use the measurement tools on the scope to measure the amplitude and frequency of the incoming signal and outgoing signal.
4. Record the data for 10 points from 500 Hz to 10,000 Hz
5. Graph the results of Vout vs. frequency
6. Use the graph to find the cutoff frequency.
7. Calculate the cutoff frequency and compare

High Pass Filter

1. Build the circuit in figure 2
2. Repeat the above procedure for the high pass filter and find its cutoff from the graph and calculation

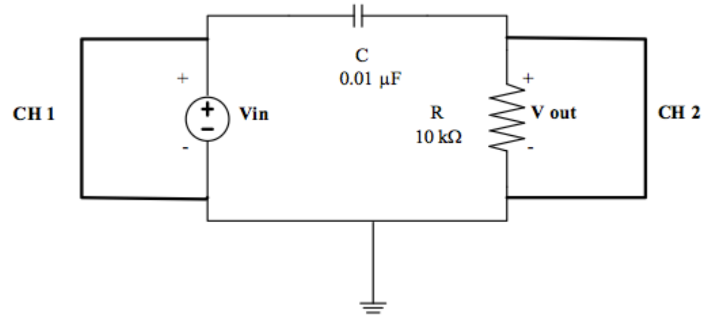


Figure 2

Discussion:

1. What would happen to the value of fc if the value of the capacitor C for the low-pass and high-pass filters is increased?

2. What would happen to the value of fc if the input voltage is increased?

3. What would happen if you replaced the capacitors in the above circuits with inductors?

Challenge:

1. Build a band pass filter
2. Build a speaker crossover (High frequencies go to speaker 1 and low frequencies go to speaker 2)