AC Circuits - Oscilloscopes and Filter Circuits
Chemistry 243 - Experiment 1
Winter 2017

Pre-lab requirements and skills
1) Identification of resistors: reading resistor color code values.
2) Reading circuit diagrams; construction and use of basic circuits.

In-lab objectives
1) Learn how to build basic circuit filters and study their response to AC signals;
2) Learn to use test equipment including digital multimeters and oscilloscopes;
3) Learn to evaluate and troubleshoot basic circuits.

This lab experience is intended to familiarize you with some of the basic concepts of electronic measurement and also to introduce you to the use of some of the devices commonly encountered in any experimental laboratory. Knowledge of the basic concepts in operation amplifier circuit design and the use of these circuits will become useful as these circuits will be used in later Chemistry 243 lab experiences where you will eventually work towards building and testing a simple functioning instrument.

## Part 1: Using Oscilloscopes and Function Generators
Your first goal will be to use the test and measurement equipment in the laboratory to both generate and observe some AC signals of different shapes and frequencies. Your voltage source will be the National Instruments VirtualBench instrument, which is a computer-controlled instrument capable of generating and measuring AC and DC signals. You're going to measure these AC signals with two different oscilloscopes, one analog and one digital, to see the differences in their operation and capabilities. For each of the oscilloscopes, use a BNC cable to directly connect the FGEN output of the VirtualBench to the CH1 input of the oscilloscope. In order to see the waveform on the screen, the two main things you'll need to adjust are the TIME/DIV knob (the x-axis of the oscilloscope) and the VOLTS/DIV knob (the y-axis). You can also adjust the Trigger parameters (basically, the way the oscilloscope decides to collect a signal) on the oscilloscope (DC vs. AC coupling, the kind of signal to trigger on, etc). We are going to let you use trial and error to figure out the best way to get your signal, but you may want to read a bit about basic oscilloscope operation before you show up so you are not totally fumbling in the dark.

Once you have managed to visualize an AC sine wave and square wave on the oscilloscope, try using external triggering to actively trigger the oscilloscope. This involves connecting a BNC "t" connector to the FGEN output of the VirtualBench, and sending one end via a BNC cable into CH1 and the other via another BNC cable into the oscilloscope's external trigger connection. Do you notice any difference in the stability of the signal or any other changes? What happens now if you change from AC to DC coupling and back?

Finally, investigate the ability of the oscilloscope (if any) to perform internal signal averaging. How does the signal on the screen change when you are collecting single scans vs. averaging many scans? If there's no difference (as there may not be), what kind of signal would this averaging be helpful for?

Part 2: Frequency Dependence of High and Low Pass Filters

Construct the following circuits on the solderless breadboard. Pick one first, then do the other once you've finished all steps below (if you have time). Use the square wave output from the NI VirtualBench as the voltage source:
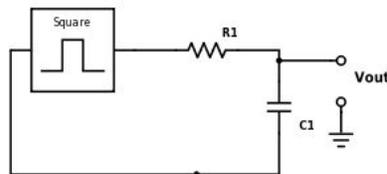
Figure 1. The low-pass filter is an RC Circuit (a resistor and capacitor in series) with a square wave input and the voltage measured across the capacitor.
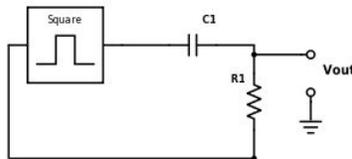
Figure 2. The high-pass filter is an RC Circuit (a resistor and capacitor in series) with a square wave input and the voltage measured across the resistor.

Choose a representative value of R (1kOhm, 10kOhm, or 100kOhm) and C (10nF, 100nF, or 1000nF), and observe V_{out} (the voltage across the capacitor) versus time for the circuit using an oscilloscope. You will need to monitor both the input (V_{source}) and output (V_{out}) signals so that you can find the correct frequency to use. Vary the frequency over several orders of magnitude and examine the frequency dependence of the output voltage. Record these values in a spreadsheet and calculate the gain (Vout/Vsource) in dB using the equation gain(dB) = 20*log(Vout/Vsource). Plot this ratio vs. the frequency on the x-axis (use a log scale for this axis). This is called a *Bode Plot*, and it tells you the frequency behavior of your RC circuit.

For each of the measurements you make, you should also measure the phase shift caused by the filtering circuit. To do this, measure the distance (in time, on the x-axis) between the peaks of the input and output signal, divide this by the frequency of the source sine wave, and multiply by 360° (one full cycle). Is there any dependence of the phase shift on the frequency of the source voltage?

Do this for the other type of filter if you have time. What changes about the Bode plot? How about the phase shift behavior?