Part 1: RC Filters

The EKG can be quite sensitive to noise. The quality of the result without any filtering can depend quite sensitively on the electrical environment you are conducting your experiment in. The most prominent source of noise for us is 60 Hz from the AC power. While you may be able to see your heart rate without any filtering, cleaning up the signal will show the features that are important to a doctor who would read your test results. In the first part of this lab you will explore some filters in isolation then we will apply similar filters to the EKG circuit. Note that these filters have the same behavior as those you will use later, but have different component values.
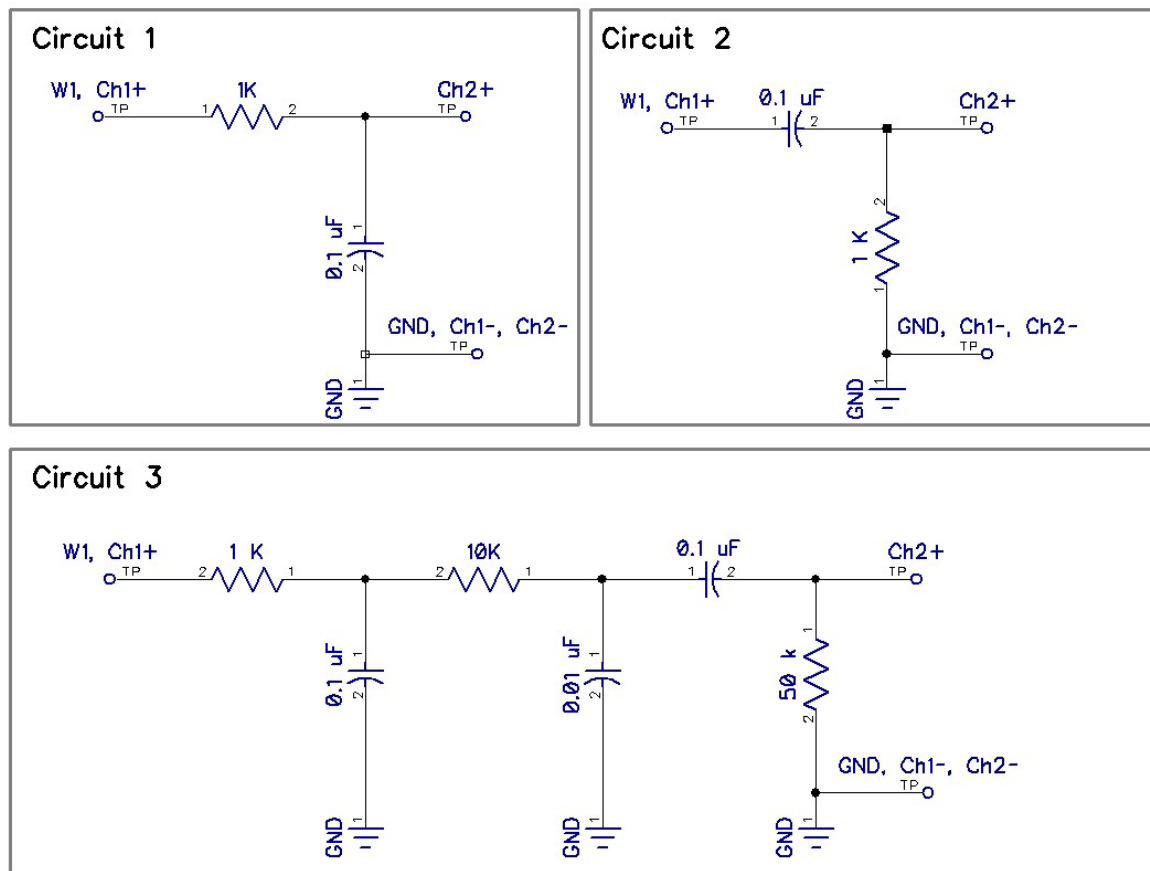

Figure 1: Three different RC filters.

You will create three circuits, a high-pass filter, a low-pass filter, and a set of three connected filters. These three circuits are shown in Figure 1. Construct and test the behavior of each circuit, independently, in turn. Connect the W1 (waveform output 1, solid yellow wire) from the Analog Discovery to the input of the filter. Use the Scope's channel 1 to measure the input to the circuit, and use the channel 2 to measure the output. Turn on the waveform generator in software as in last week's lab. In the arbitrary waveform generator, make the output signal a **sine wave**, with an offset of 0 volts and amplitude of 1 volt. Open the scope and turn on the two measurement channels so you can see both the filter's input and output signals. Adjust the time scale, voltage scale, and trigger so you can easily observe the output signal relative to the input. Adjust the frequency

of the waveform to be lower, higher, and around the characteristic frequency of the filter given by the RC time (don't forget to convert rad/s to Hz). Observe how the filter behaves qualitatively at both low and high frequencies. Watch the amplitude of the output as well as the phase between input and output. You should recall from lecture how these circuits behave. Make sure you seem to get the result you expect.

Once you have some intuitive feel for how the filter is operating qualitatively, go to the main screen for the Analog Discovery. Click on "Welcome" tab select "network". The network analyzer will automatically create a Bode plot for you. Adjust the frequency range, 10 Hz to 100 kKHz is a good place to start, though you may want to adjust this range. Click "single" to conduct a single frequency sweep. Save the Bode plot data through the export feature for each circuit.

You should have three experimental bode plots from the three circuits in Figure 1. The data from the experimental Bode plots should be compared (i.e. overlayed on the same plot in MATLAB) to the predicted behavior which we derived in lecture (see notes on the course website and the YouTube lectures). For the circuit with three filters, you can assume that the three filters which make this circuit are independent and that the resulting response is just the simple combination. The reality is that there is some coupling, but this was made weak by making the resistors larger as we proceed down the chain. Provide some interpretation of your Bode plot. Denote the characteristic cutoff frequencies for your filters on your plots. Be careful with units of Hz and rad/s.   Also be careful that the Waveforms software outputs the Bode plot data in units of dB.

At this point in the course, the derivation of the predicted behavior likely seems a little mysterious to you. That is OK, we will go over this concept many times throughout the year and this is our first exposure. Note that there should be near perfect agreement between the experiment and theory.

CLEAR THESE COMPONENTS FROM YOUR BREADBOARD BEFORE PROCEEDING.