ENGN/PHYS 207—Fall 2020
Assignment #5
Op-amps: The Rail Splitter and Active Band Pass Filter

Circuits You'll Build

Note: both of these will become core pieces of your PPG circuit for the final project. Layout the components tightly and carefully, economizing on space!

1. Rail-splitter which outputs a stable $V_{DD}/2 = 3.3/2$ V = 1.65 V reference voltage.
2. Active band-pass filter with bias. This is *The Works*: it filters; it amplifies; it centers the output around the mid-way reference point! It mops, dusts, does the laundry and dishes too!

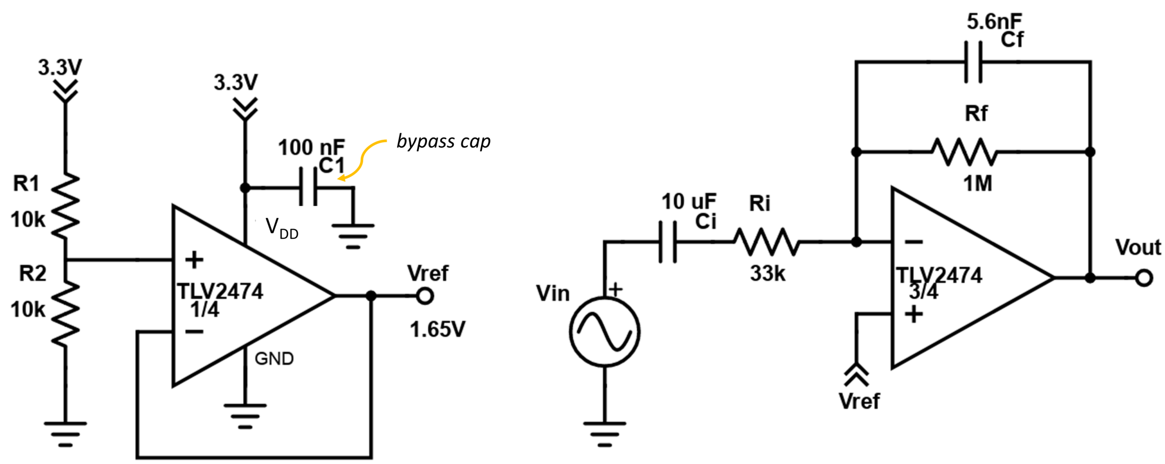

Figure 1: Op-amp based circuits intended for the PPG system. Left: Rail splitter. Right: active BPF. Note the output of the rail splitter serves as the reference voltage connected to non-inverting input of the active BPF. The fractional numbers such as "1/4" indicate which amp number to use out of how many total (read: "amp 1 out of 4").

Lab Skills You'll Learn

1. Wiring basic op-amp configurations (inverting amp, buffer)
2. Implementing active filters

1 Rail Splitter

The purpose of the rail splitter is to provide a stable reference voltage. The buffer op-amp insures that the reference voltage remains at $V_{DD}/2 = 1.65$ V in this case, regardless of what is connected downstream.

1. Wire the ***rail-splitter*** with op-amp ***buffer*** in Figure 1, left. Note the bypass capacitor connected to the power rail. This serves to hold the op-amp power supply voltage firmly at $V_{DD} = 1.65$V in the face of a dynamic power demands. If the power source voltage begins to sag, the capacitor—which has already been charged—says "Don't worry friend! I got you! Have some extra charge I've stored to hold tight at 3.3V!" Don't you just love it when op-amps offer an internal monologue?

2. Confirm there is a 1.65V at the input and output voltage with no load connected to the buffer's output

3. Confirm the output voltage V_{ref} remains at 1.65 V regardless of what is plugged into downstream. You can do this by connect, say, 3 different resistors at the output of the buffer, measuring the voltage present across each. Choose, sensible resistor values in the kΩ range.

2 Active BPF

The purpose of this circuit is to both ***filter and amplify*** a signal! As a bonus, it centers the output around the mid-way point so that we can properly amplify positive and negative going wiggles in the input signal.

1. Build the circuit in Figure 1, right. Note that it is suggested you use the 3rd out of 4 op-amps inside the TLV2474 quad amplifier. This is indicated by the 3/4 label.

2. Confirm the circuit works as promised. Namely that is amplifies, filters, and set the baseline output of 1.65V when the input signal is grounded ($v_{in}(t) = 0$).

   (a) First, ground the input. What is the DC level of the output? Is it 1.65 V? Hopefully, yes! If not, something is amiss. When you are done with this step, disconnect the input from ground, because...

   (b) Next, we'll input sine waves from the picoscope to see the amplifying and filtering nature. BEFORE connecting the AWG to your circuit, set the amplitude to be 50 mV and set the frequency to 2 Hz. Then connect the AWG of the picoscope to the input V_{in} of the active BPF. View the input and output signal simultaneously on channels A and B, respectively. Carefully note the peak-peak amplitude of the input and output. Ditto for the phase shift.

   (c) Let's purposely put the amplifier into saturation. Increase the amplitude of the AWG sine wave to 100 mV, then the 200 mV. What do you see in each case? Do NOT increase the amplitude any further!

   (d) Now its time to sweep out the frequency response of the circuit. Similar to what you did in Lab 3, to sweep out enough data to determine the ***decibel gain*** $G(f)$ dB and ***phase*** $\phi(f)$ vs. $\log_{10} f$. Plot your results for the magnitude response as you go. Do the cutoff frequencies occur where you expect? Is the gain in the pass band what you expect?

(e) Lastly, let's see the effect of the active BPF. Assume the input signal to the active BPF is given by a superposition of cosines plus a dc offset as follows:

$$v_{in}(t) = 1650 \text{ mV} + \sum_n a_n \cos(2\pi f_n t + \phi_n)$$

where $a = [100, 20, 10, 10]$ (units of mV); $f = [0.05, 1, 2, 120]$ (units of Hz); $\phi = [0, 0, \pi/2, 0]$ (units of rad). Plot the input and output signals (Matlab strongly recommended!) over the time interval $0 \leq t \leq 10$.

3 What to turn in

1. Frequency response experimental data overlaid on theory curves for the active BPF. You should show two plots here (just as you did in lab 3!)—one for the decibel gain and one of for the phase shift.
2. Maximum of 1 paragraph text analyzing the performance of the system relative to the expected behavior. Do the cutoffs occur where you expected? Was the gain in the pass band what you expected? Is the baseline offset appropriately set? Essentially compare and contrast what you drew up on paper vs. what the real-life system. Are there regions of excellent agreement? Poor agreement? (If so, briefly explain).
3. Result for active BPF, section 2, part 2e. Include a caption that in 3 sentences or less highlights the action of the filter—compare and contrast the input vs. output.
4. Show any relevant theory and/or calculations in an Appendix.