Lab 5: Pulse measurement with light

A photodiode is a device which turns photons (light) into current. The current generated by the photodiode we will use is quite small and might be on the order of 1 micro-amp for ordinary room lighting. We must turn this small current into a voltage that we can measure reliably with the analog discovery. Build the circuit shown in Figure 1 – start by leaving the 10 nF capacitor out of the circuit. The long lead of the photodiode is the positive terminal of the photodiode and should be connected to ground. If you imagine the photodiode is creating a current flow, that current cannot go into the op amps input. The current must then flow through the 1M resistor. A current flowing through the resistor means a voltage drop is generated across the resistor. It is this voltage drop across the resistor that we measure.

If you monitor the voltage out of the light detection circuit, then you should see the signal change as you cast shadows on the photodiode. Wave your hand around the photodiode and see that the signal makes sense to you. Now add the 10 nF capacitor into the circuit. You should notice a reduction in high frequency noise. The fluorescent room lights blink at a specific frequency – which many of you can hear – and you should see these fluctuations diminished a little bit by inserting the cap.

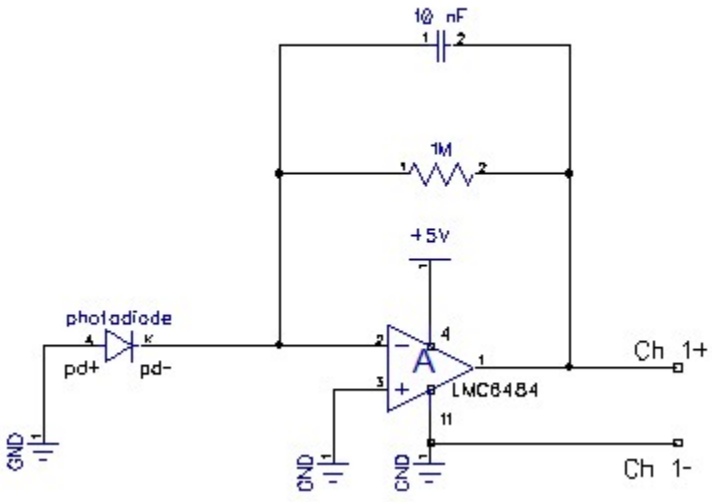

Figure 1: Light detection circuit.

Last week measured your pulse by sensing the electrical activity of your heart. This week we will repeat this measurement, but we will sense your pulse by measuring the light intensity through your finger. Your blood changes color (slightly) based on levels of oxygenation, and thus the intensity of light that passes through your finger fluctuates with your pulse. The first part of the pulse measurement circuit is shown in Figure 2.

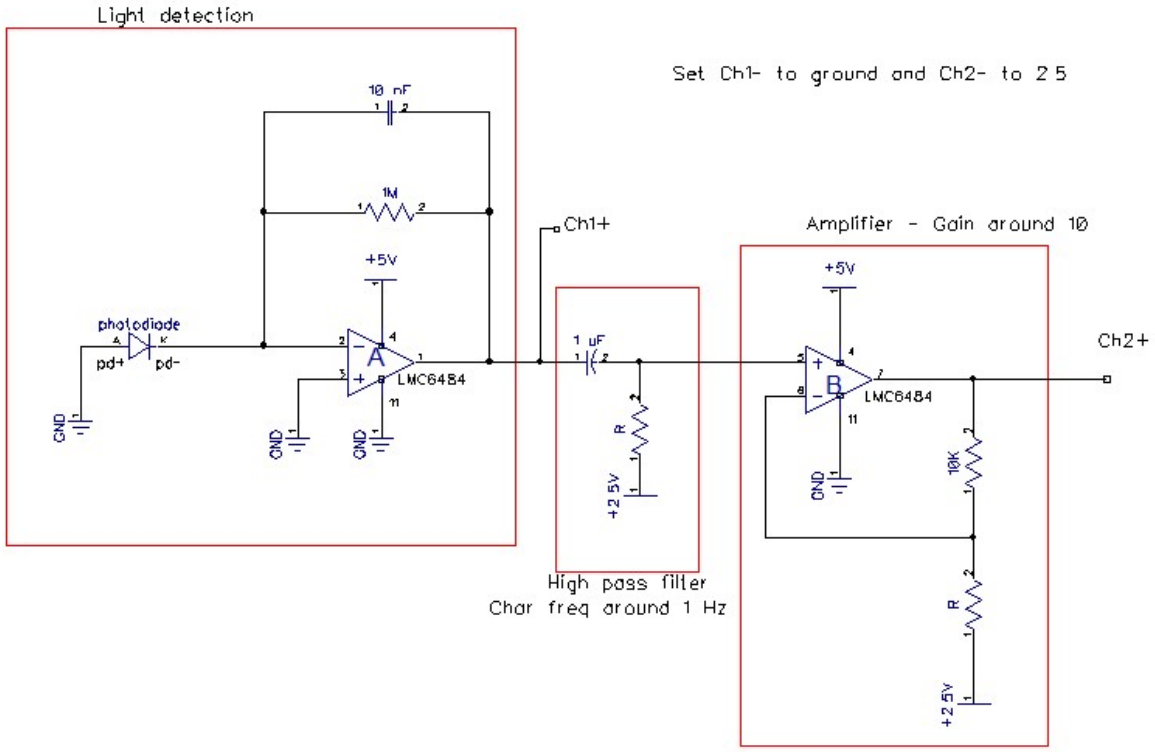

Figure 2: Pulse detection – step 1. High pass filter and amplifier.

Note that the first section enclosed in the red box is the same as shown in Figure 1. Note that you have built the other pieces of the circuit in this lab and previously in the course. The functions of the other sections of the circuit are shown in red boxes. At this stage we will add a high pass filter and amplifier. Note that we have specified approximate values for the characteristic cutoff frequency of your filter and your amplifier gain. We have left one of the resistors in each function unspecified. You will need to select appropriate resistors. Please note that there is no single "right" answer. A range of values will work fine. Too big or too small would be bad, but anything close to the specified functional range should work just fine. You could try a few values for each unknown resistor and see how the circuit behaves and what you like best. **NOTE:** The LMC6484 op amp is a quad package – meaning there are 4 op amps in a single 14 pin package. Which op amp you use for which part of the circuit does not matter. We assumed a certain order for op amps A and B. You may find it more convenient to use a different order based on your breadboard layout.

Once the circuit is built, lightly place your finger over the photodiode. You should not press down hard as this will reduce the circulation to your finger. Just touch lightly. Hold still for a few seconds (resting your hand on the table works well) and your pulse should barely appear but you may need to zoom in to a 10-50 mV/div scale on the scope. This circuit is sensitive to the absolute intensity of light and thus you need to hold still for a moment to let the high pass filter do its work.

Once you are convinced that the first few functions are working, complete the circuit as shown in Figure 3. The complete circuit will add a low pass filter and an additional amplifier. Note that we are again specifying function and keeping some resistor values unknown. As before, a range of resistor values that get near the targeted cutoff and gain should work pretty well. Experiment a little and see what works best for you. Again, to test the circuit put your finger lightly on the photodiode and at the final output you should more clearly be able to see your pulse.

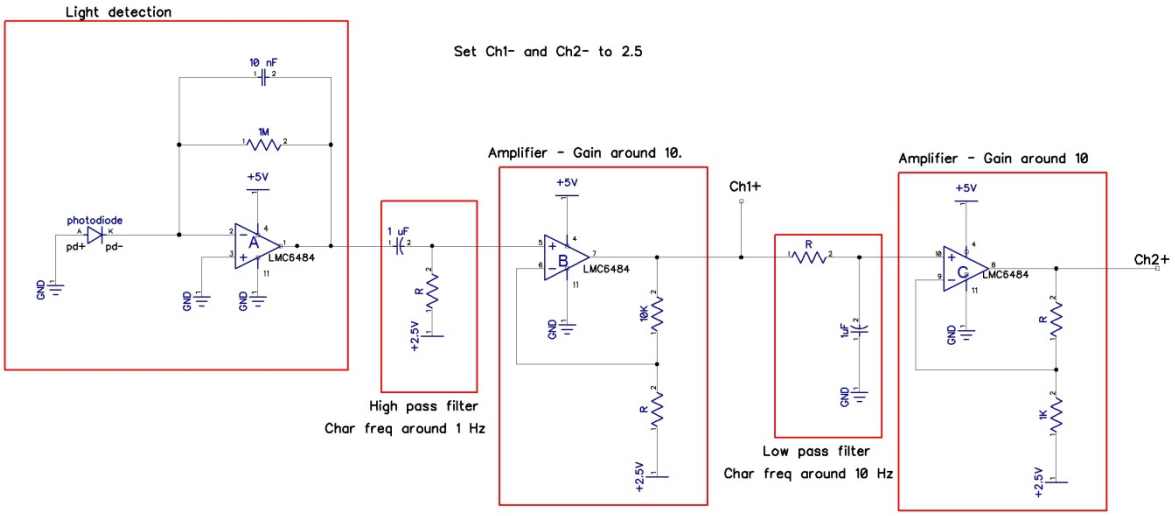

Figure 3: Circuit to measure light intensity through your finger.

Deliverables:

The deliverables for this part of the lab should include.

1) Your final circuit schematic, i.e. a copy of figure 3 but with your final values selected. You can hand sketch it. Include the resistor values on the schematic. Include the actual cutoff frequencies and amplifier gains as part of the block diagram (as in Figure 3). You can sketch the circuit, but it should be neat enough that someone else in the class could build the circuit off your drawing.
2) Provide a short explanation/calculation that shows how you selected resistor values.
3) A picture of your final circuit. It should be neat with clipped straight wires, low profile resistors, clean lines, and no loopy stuff.
4) At least two plots of your circuit working at different points in the development- i.e. after the system in Figure 2 and Figure 3 are complete. Provide some short interpretation as to why the signal looks different at different points in the circuit.