Lab 8: Pulse measurement with light

A pulse oximeter is common piece of hospital equipment that is used to measure a patients pulse and the oxygen content of their blood. The device works non-invasively by shining and detecting light through the finger. We will build the first part of this device, the pulse detector.

**Part 1.**

A photodiode is a device which turns photons (light) into current. The current generated by the photodiode we will use is quite small and is 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. 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 a **10 nF capacitor in parallel with the 1 M resistor** to 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 capacitor.

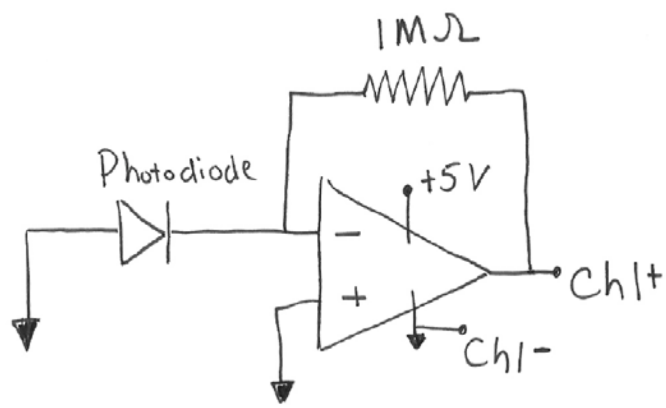


**Figure 1: Light detection circuit.**

Previously, you 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. A simple pulse measurement circuit is shown in Figure 2.

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 the component values unspecified. You will need to select appropriate components. 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.

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 appear but you may need to zoom in the 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.

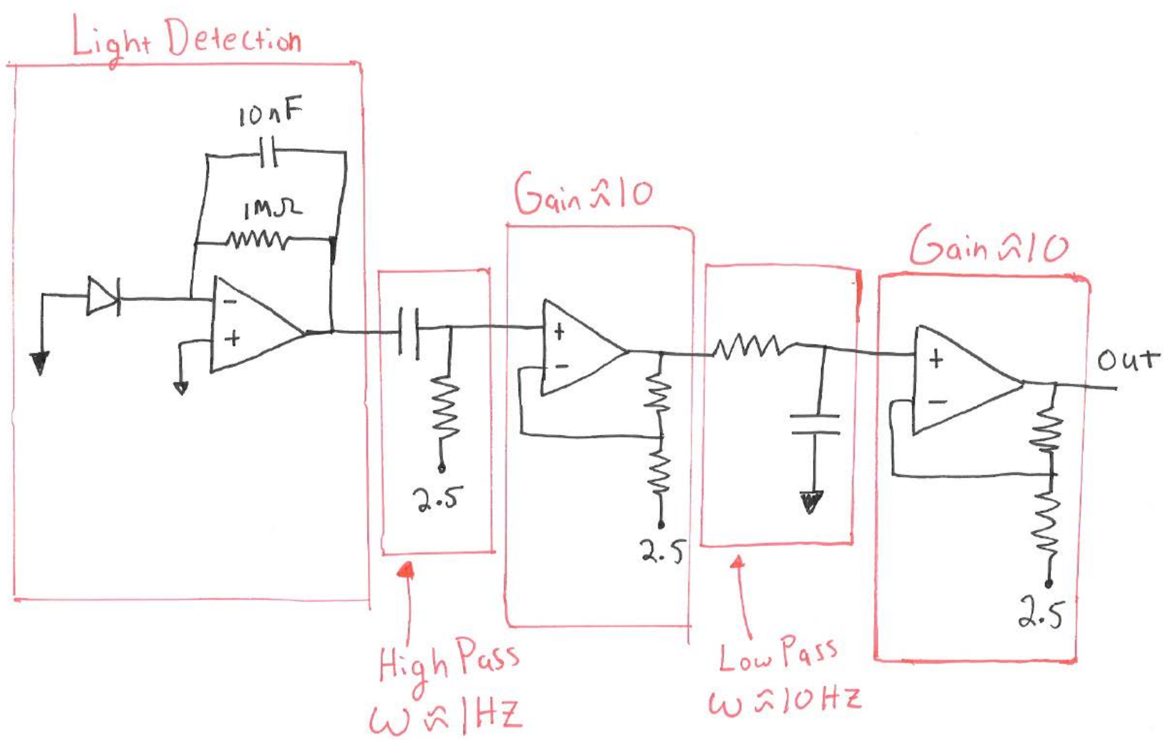


**Figure 2: Circuit to measure the variation in light intensity through your finger.**

The deliverables for this part of the lab should include.

1) Your final circuit schematic, i.e. a copy of figure 2 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) One nice clean scope trace of your pulse.

**Part 2.**

Choose one of the following options:

1) If you are a little behind in the course, stop working on this light pulse lab once you have Part I working, use the remaining time to catch up or just complete the write-up for this week. DO NOT LEAVE LAB BEFORE 3:10. Stay and work on whatever you need to catch up.
2) If you are not behind, taking Figure 2 as the starting point, try to design a more effective pulse detector using the same basic circuit but with perhaps a little more aggressive filtering, amplification or achieve the same function with fewer components. Compare your results to ours. Include your circuit design with some rationale in your lab report.