Pulse Measurement with Light

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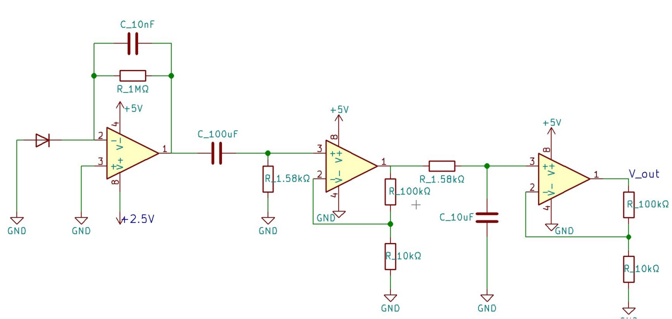
Abstract

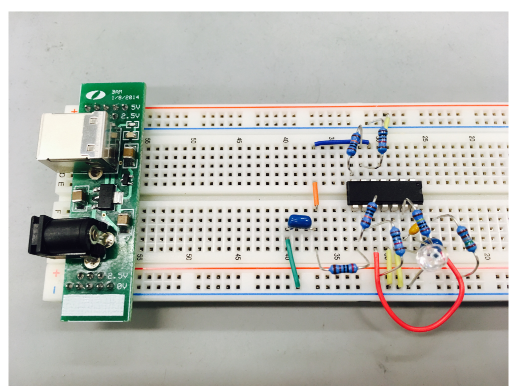
The purpose of this lab is to make use of the properties of an op-amp to take measurement of pulse again but with the help of a photo diode instead of electrodes.

1 Description

In this lab, a pulse measuring circuit was constructed with a photo diode and three op-amps in addition to a low pass and high pass filter. The photo diode is capable of turning photons into current. Making use of the op-amp property that its input takes nearly zero current and by bridging the negative input and the output of the op-amp with a large resistor, a voltage difference was created across the resistor as current starts to flow, and as much current needed as the rest of the circuit needs to perform its function is supplied by the op-amp. After the signal passes through the high pass filter, the circuit was isolated and amplified with a no-inverting amplifier. Once the signal passes through the low pass filter, it is amplified again. The output can be measured with reference to +2.5V. Eventually, by placing a finger on the photo diode, the amount of light passing through the finger varies as the oxygen level in the blood changes according to the pulse, and the different current generated at photo diode can be recorded as voltage in the end.



(a) The circuit schematics.



(b) The breadboard layout of the circuit.

Figure 1: The photo diode circuit used in this lab

For the second part of the lab, students are asked to change the circuit in their own ways. Shown in Figure 2 was the circuit I created to measure my pulse.

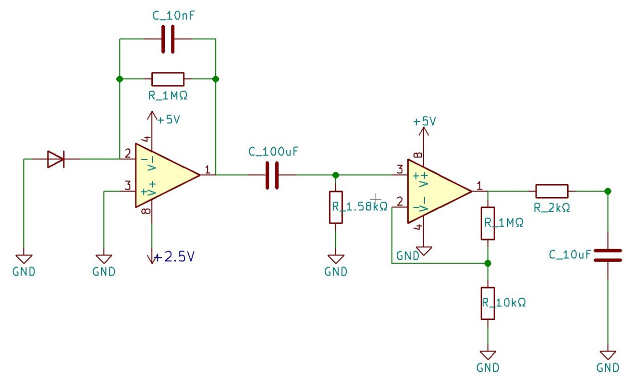


Figure 2: My own altered circuit.

2 Evidence

In Figure 3, the pulse measurement taken with the circuit provided in the lab is shown.

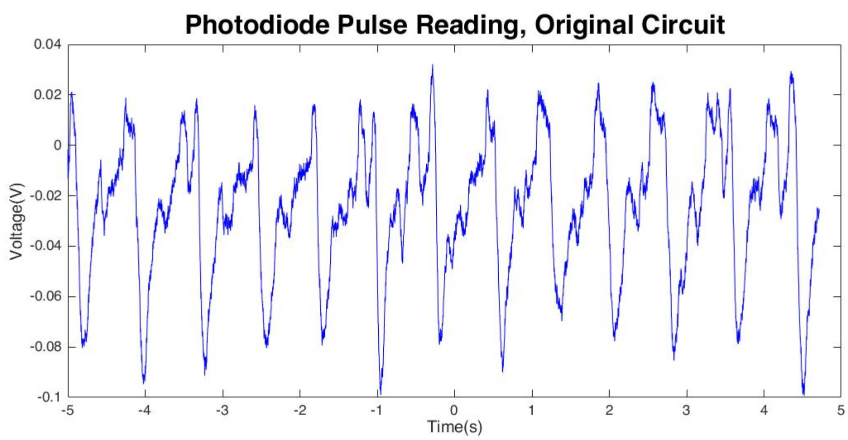


Figure 3: Pulse measurement with the circuit provided in the lab description.

The pulse recorded with the circuit I set up was provided in Figure 4.

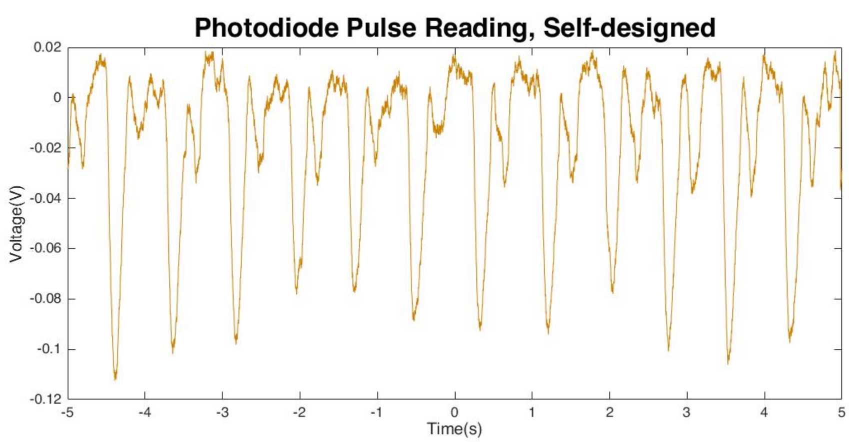


Figure 4: Pulse measurement with the circuit I altered.

The pulse recorded in the EKG lab is provided below for comparison.

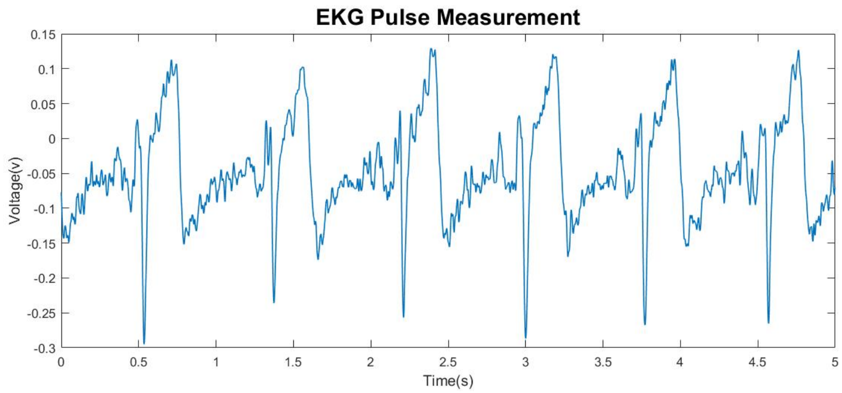


Figure 5: Pulse measurement in the EKG lab.

3 Interpretation

Even though the general circuit structure was provided in the lab description, the specific choice of resistors and capacitors were left to us to decide. Both non-inverting op-amps were specified to have a gain of around 10. To achieve that, I pick 100 k and 10 $kOhm$ resistors. The calculation for the resulting gain is shown below.

$$\frac{V_{out}}{V_{in}} = \frac{R_1 + R_2}{R_2} = \frac{100k + 10k}{10k} = 11 \tag{1}$$

As suggested by the lab description, the high pass filter should have a cut-off frequency of around 1Hz, so I chose 100 uF and 1.58 k. The cut-off frequency is calculated as follows.

$$f_c = \frac{1}{2\pi RC} = \frac{1}{2\pi \times 100uF \times 1.58k} = 1.007Hz \tag{2}$$

The low pass filter is supposed to filter out anything above roughly 10Hz, and my choice was a 10 uF capacitor and a 1.58k k.

$$f_c = \frac{1}{2\pi RC} = \frac{1}{2\pi \times 10uF \times 1.58k} = 10.073Hz \tag{3}$$

The voltage output of the circuit came out pretty close to the measurement taken across the two wrists in the EKG lab.

For my own circuit, I decided to make the overall circuit with fewer circuit and apply more aggressive high frequency filtering. The two non-inverting amplifier would ideally amplify the voltage by 100 times or 121 times in how I picked my resistor values. As a result, I shrank my circuit from two non-inverting op-amp to one non-inverting op-amp by changing the value of R1 from 100 k to 1 M.

$$\frac{V_{out}}{V_{in}} = \frac{R_1 + R_2}{R_2} = \frac{10k + 1M}{10k} = 101 \tag{4}$$

The more aggressive low pass filter is used to cut off high frequency noises.

$$f_c = \frac{1}{2\pi RC} = \frac{1}{2\pi \times 10uF \times 2k} = 7.958Hz \tag{5}$$

The resulting pulse recording has drops that are more dramatic than the recording taken with the suggested circuit, but a repeating pattern that has pretty much the same frequency as previous recording can be observed. As a result, we may call the change a success.