**Introduction**

**Milestone two:** *All hardware related aspects have been designed, simulated, built and tested, redesigned, rebuilt and retested to have the most accurate amplification and filtering of the input signal. More specifically this will entail the above for two active low pass filters, and a non-inverting amplifier all in a cascaded op-amp configuration. We would like our output signal from this configuration to closely model our derived transfer function.*

Written above were our goals for milestone two from our project proposal. Although we have come far in terms of designing, building and testing the hardware required to obtain a readable signal, we have not completed our biggest goal for milestone two which was to have all the hardware designed and built such that it accurately feeds the Arduino ADC with a stable signal. Although our signal is not as predictable as we want it to be due to things like ambient light and finger movement, we can clearly see a pulse which when sampled over one minute, falls nicely into the average bpm of a resting human heart. We were also able to get a faster pulse by getting our heart rate up before measuring.

Writing a custom display driver was something we did not foresee doing when writing our project proposal. Other than C’s standard library and Arduino’s I2C library, the driving of the display is being written from the ground up, although recently we shifted our focus back on hardware since we need the signal before we can display it. As of now, the driver can set the page (line) number and segment byte, in other words we can choose the row and “column” of the write pointer in memory. We can also write bytes to segments, although we have not tried implementing text/fonts, scrolling, or the ability to map a function/signal in real time.

Diagram

Description automatically generated**High Level Design**

Figure Block diagram of signal processing circuit

The top-level design for signal processing, shown in *figure 1*, consists of three main stages: Current to voltage signal conversion with a transimpedance amplifier, amplification by a non-inverting, active operational amplifier configuration followed by an active band-pass filter.

In stage one, the current induced through the photodiode is converted to a voltage signal. This stage is required for a few reasons:

First, circuit components like photodiodes have a more linear current response than its respective voltage response. In other words, the current induced by such components provides a better representation of measurement. Diodes have very non-linear voltage to current relation (refer to *figure 2*) and thus the current induced by, for example light when it hits a photodiode, will not have a voltage potential that accurately models the light being received.

A picture containing diagram

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Figure : General depiction of current to voltage characteristic of a diode. Ref: https://commons.wikimedia.org/wiki/File:Diode-IV-Curve.svg

Since we want to use the current to make our measurements, we need to convert the current signal from the diode to a voltage signal. Theoretically, we could try to design a signal processing chain around the diode current signal, although we would eventually have to convert to voltage in order to utilize essentially any ADC since they require a voltage signal to map an analog signal to digital one. Converting current to voltage as the first step in the signal chain is the only feasible way to achieve any processing since circuits like amplifiers and filters are easier to describe and model when working with voltages.

The transimpedance amplifier is essentially a standard operational amplifier with no input resistance, so its function is dependent on a feedback resistor which, in turn, provides a gain, which is depicted by the gain stage which feeds back into the TIA (see *figure 1*).

The next stage in the chain is amplification using an operational amplifier in a non-inverting configuration. Although we already have a gain in our TIA stage, it isn’t necessarily designed to serve as an amplifier although transimpedance configurations are going to have gain. Thus, we have a dedicated stage with the sole purpose of providing a gain factor which provides the largest possible signal we can produce.

**Detailed discussion of subsystems**

Transimpedance amplifierDiagram, schematic

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Figure : Transimpedance amplifier spice model

By the ideal characteristics of an op amp and the desired output we can derive the following two equations which describe the current to voltage conversion:

The voltage divider on the positive input terminal of the op amp provides a summing point, so that our signal is positive when a pulse is being measured. The following equations describe this division:

If we set then,

Since our supply voltage is 5v (v+), then V+ will be half our supply voltage or 2.5 V. Thus, our signal is shifted up by 2.5 V when a pulse is being measured.