INDIAN INSTITUTE OF TECHNOLOGY GANDHINAGAR

Analog Circuits (EE 321)

Project Report 2

Group No. – 1

Name	Roll Number
Saurabh Kumar	21110187
Shubham Singh	21110207
ShivKumar Parmar	20110194
Daniel Giftson	20110051

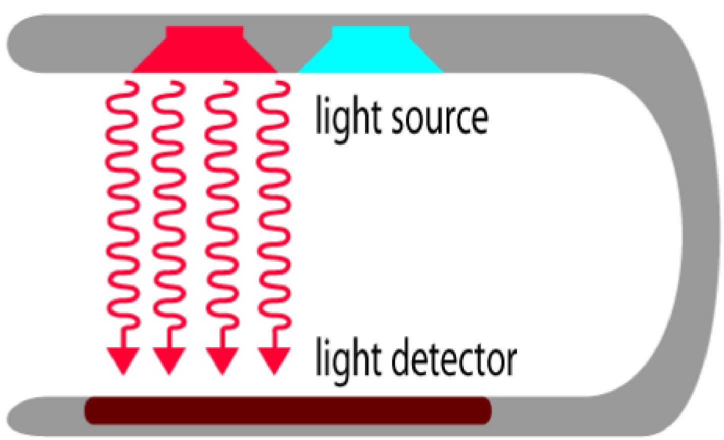
Introduction:

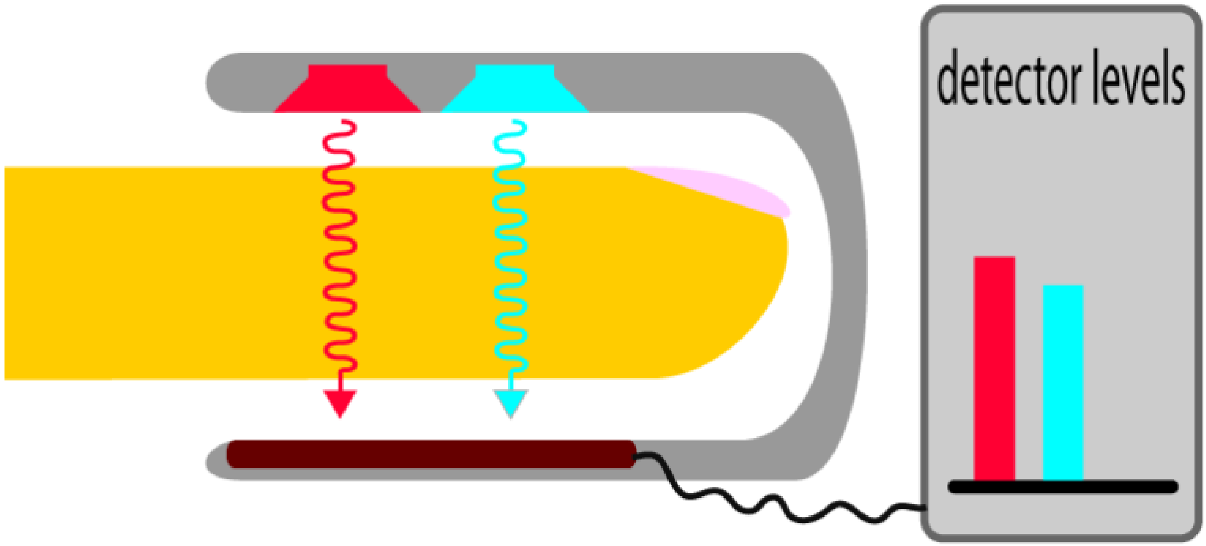
Keeping track of our health is more vital than ever in the current society. Our invention, "PulsePAL," will measure your heart rate and pulse via your finger and display it on the screen. What is the significance of this? Monitoring your heart rate and pulse allows you to gain a better understanding of your overall health. This project report looks into the development of the PulsePAL, including the technology and science that went into its development. This project also includes a preliminary sketch and components of our circuit.

Theory of pulse oximetry and placement of diodes and the finger:

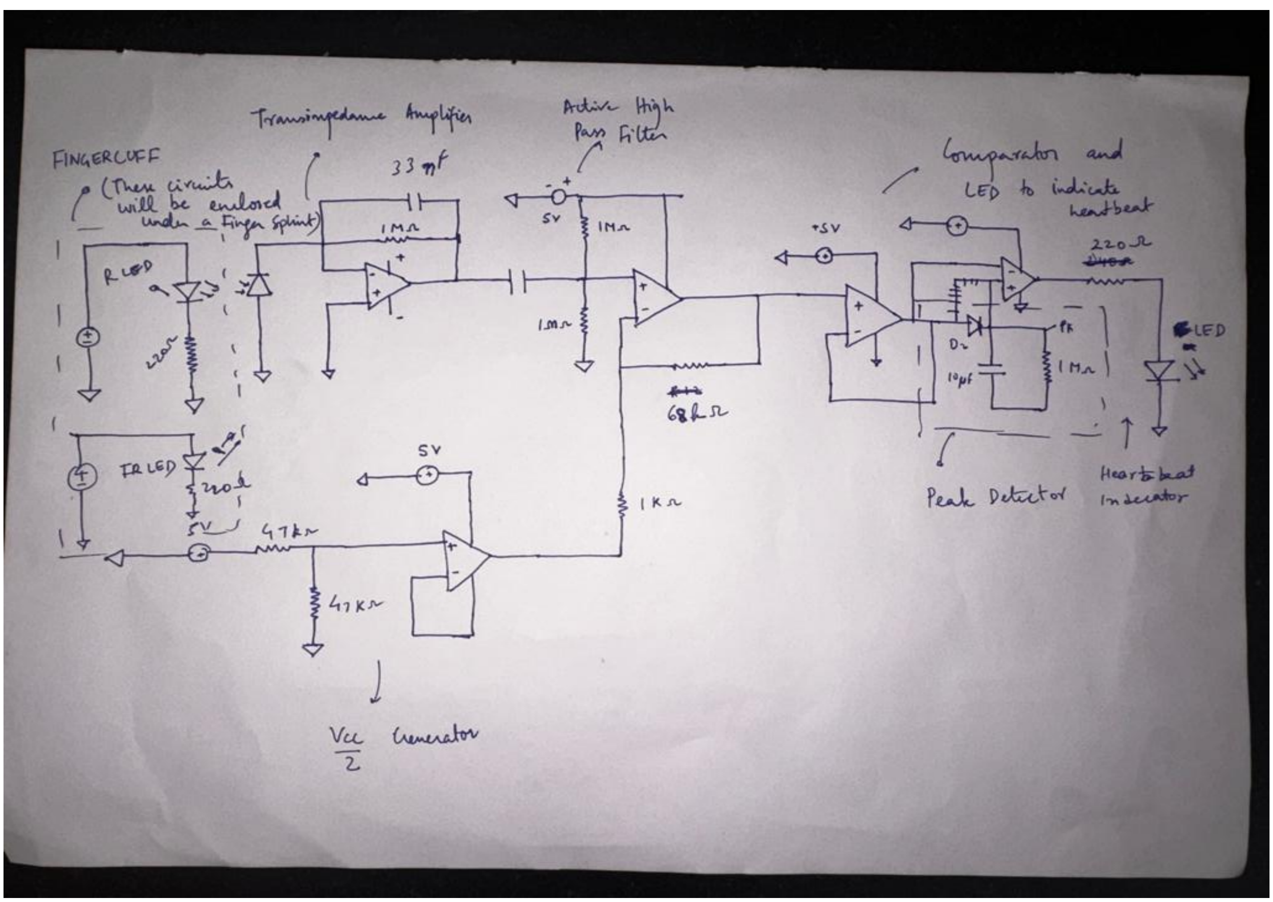
Real-life Pulse oximeters measure the heart activity as heart-rate/pulse rate and also measure how much of the hemoglobin in blood is carrying oxygen (oxygen saturation). This gadget projects a light beam through the fingertip using LEDs. The light travels through blood vessels and the skin before arriving at a photodetector on the opposite side of the oximeter. The oxygen saturation level is then determined by the photodetector by measuring the amount of light that enters the blood vessels.

Typically, red and infrared LEDs with wavelengths of around 660 nm and 940 nm, respectively, are used in pulse oximeters. The oxygenated hemoglobin in the blood absorbs red light, while the non-oxygenated hemoglobin absorbs more infrared light. The pulse oximeter measures the quantity of light absorbed by the blood to determine the heart rate and oxygen saturation level.





Circuit Diagram:



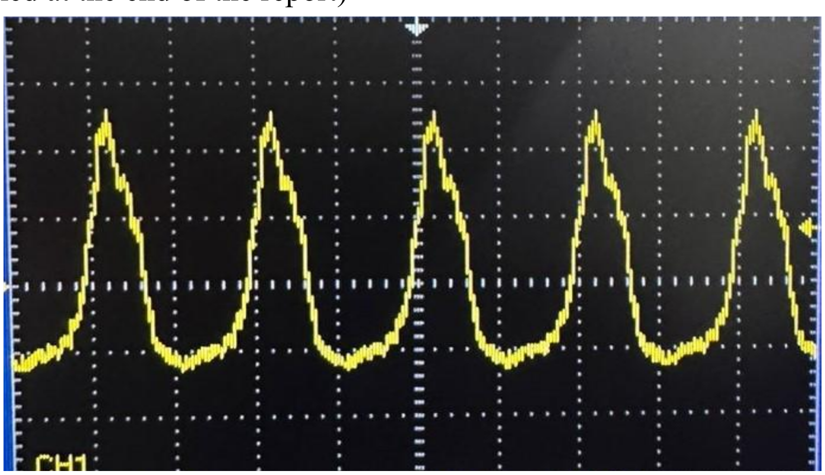
The hardware part of this pulse oximeter contains the following important parts (This will be our final circuit after continuous research)

1. Fingercuff
2. Transimpedance amplifier
3. Active High Pass Filter
4. Peak Detector and Threshold generator
5. Comparator
6. Heart beat indicator

The **fingercuff**, which is the core of this system, contains an IR LED, Red LED and a photodiode. The user will place their finger in between the LEDs and the photodiode as mentioned in the previous section. Thus, when the light from these LEDs pass through our finger, the oxygenated hemoglobin in the blood absorbs red light of 660nm, while the non-oxygenated hemoglobin absorbs infrared light of 940nm thus generating certain current by the photodiode based on the unabsorbed light passing through the finger tissues. We will be placing this system inside a **finger splint** that provides stability while measuring our pulses by ensuring that the surrounding light doesn't fall on the photodiode.

As of now, we have tested it without the finger splint but made sure that surrounding light doesn't fall on the photodiode by ensuring that the LEDs, finger, and the photodiode are closely packed thus ensuring no external light onto the surface area of the photodiode. Further to add on, we have tested only with the RED LED and not both combined due to non-working of the IR LED. But this doesn't create any issue with the type of signal that we will be operating with as part of this input signal characterization.

We observed the following signal across a 1 Mega ohm resistor connected to the cathode of the photodiode: (The live experimentation of this part is mentioned in the link of the google drive mentioned at the end of the report)



The **transimpedance amplifier** will convert the photodiode current to a voltage at the amplifier's output. We regulate the output voltage of the amplifier by adjusting the resistance value connected parallel to a capacitance value in which for this case we have taken a resistance of 1 Mega ohm. This is done to amplify weak pulse signals produced by the photodiode. The capacitance value in the feedback loop creates a low-pass filter with the 1 Mega ohm resistor. The cutoff frequency is decided upon the maximum heart-rate of observation in which in this case we have considered maximum heart-rate of observation to be around 290 beats per minute.
Thus the cutoff frequency is 4.833 Hz and thus the capacitance value obtained is around 33 nF.

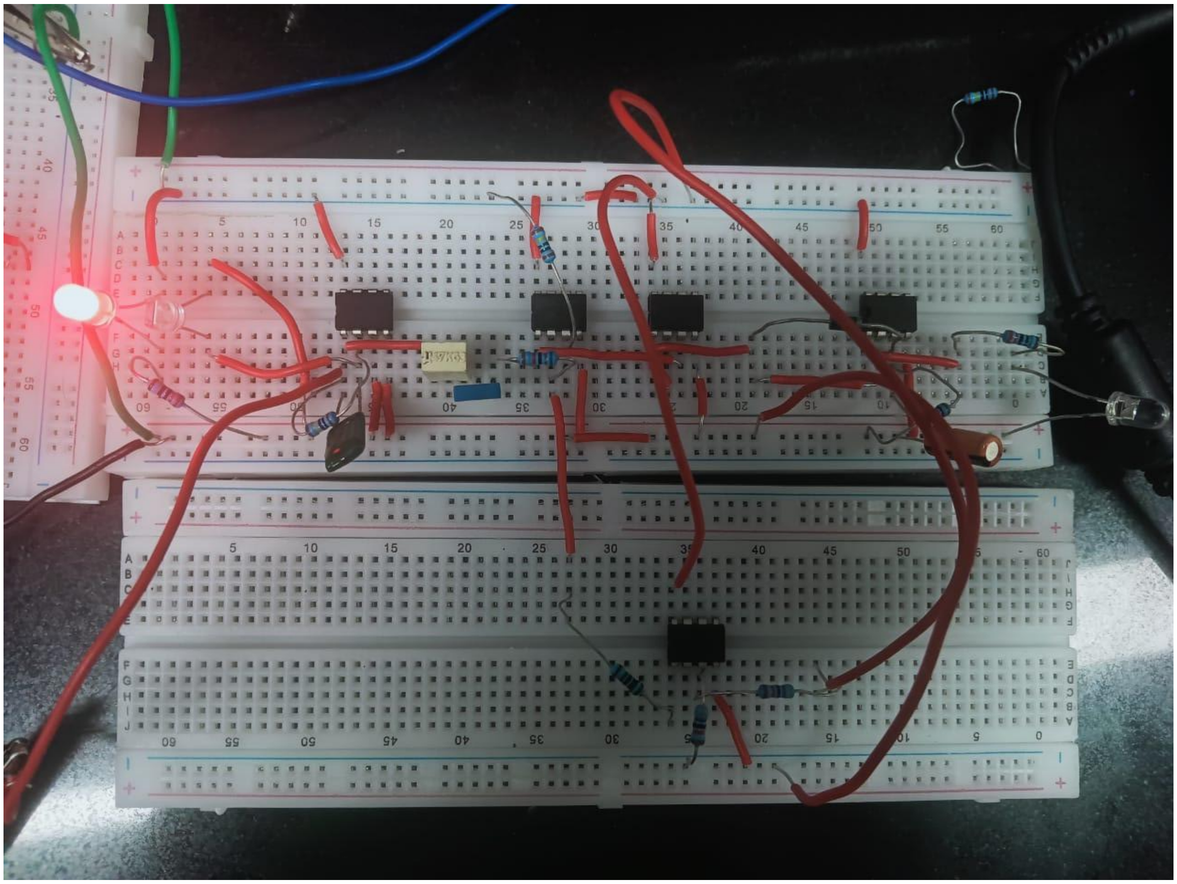
The **Active high Filter** that we have designed is of cutoff frequency of 0.56 Hz depending on the minimum heart rate of observation which in this case we have considered to be 34 beats per minute. Thus the resistance value of this active high pass filter will be around 500 kilo ohm as mentioned in the circuit diagram.

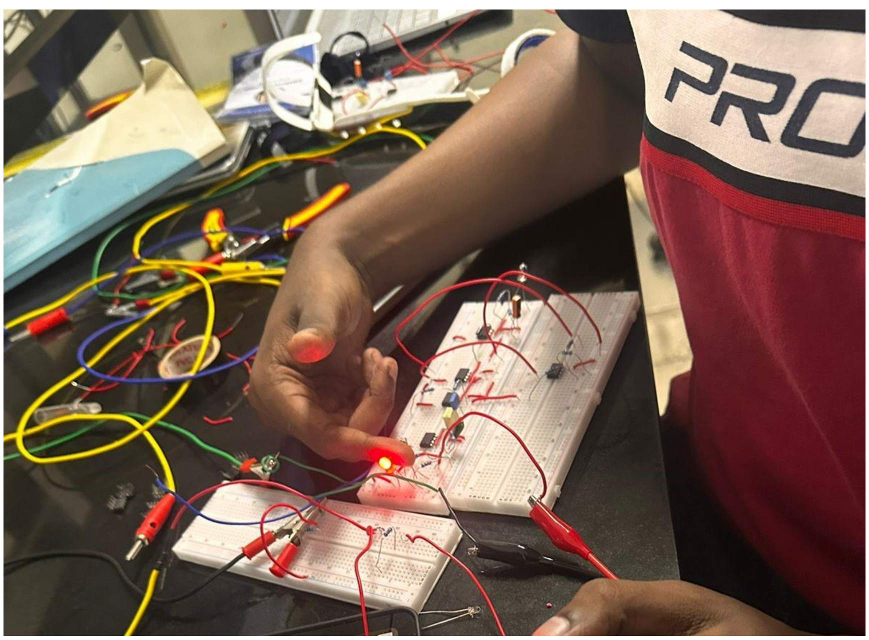
The **threshold adjuster** is pretty straightforward. The signal from bandpass filter goes through a **peak detector**. A peak detector is a circuit that holds the peak voltage of an alternating current. Finding the peak voltage allows us to set the threshold for our heart beat detector by hardware design instead of using software. Using a peak detector in the design also allows us to avoid using any sort of manual thresholding using a potentiometer or something like that. Because there is a forward voltage drop across the diode, the voltage at the output of the peak detector will be a few milliVolts lower than the actual peak voltage. This is what we want. The capacitor at the output of the diode holds the peak voltage because a capacitor stores charge. The resistor in parallel with the capacitor ensures that our capacitor will not store a single peak voltage indefinitely, but will allow the peak detected to adjust with higher or lower pulse amplitudes due to stronger or weaker pulses, respectively.

The final component of our circuit will contain a **comparator** and **a LED** to indicate the heart-beat. A comparator compares he voltage from our pulse detector (output of the active band-pass filter) with the voltage from the peak detector using V(pulse) - V(threshold). If V(pulse) is greater than V(threshold), the comparator output is 5V, and our LEDs light up, signaling a heartbeat. If V(pulse) is less than V(threshold), the comparator output is 0V (ground).

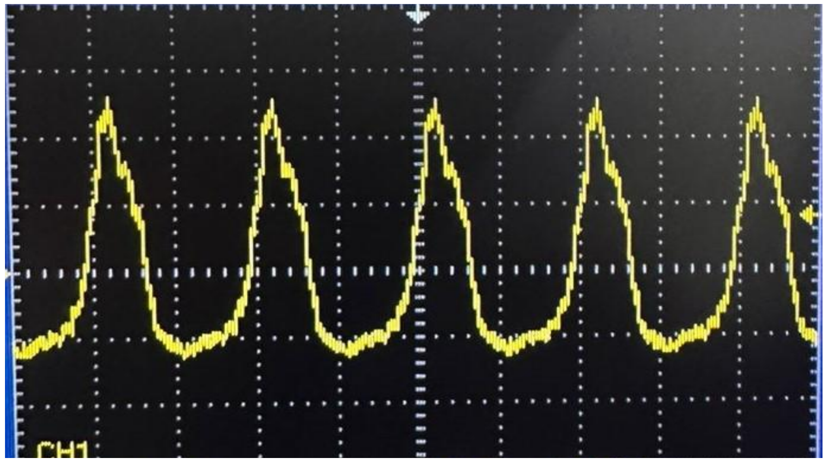
Progress:

- As of the progress, we have designed the complete circuit on the breadboard which we have provided above. (Except that you might not see the IR LED due to unfortunate malfunctioning now. But we will add IR LED to the circuit once we get a new and a proper functioning one on Monday)





- We have obtained the input signal as part of the input signal characterization which will be going through the further amplification and filtration circuits. We have obtained the following signal across a 1 Mega ohm resistor connected to the cathode of the photodiode: (The live experimentation of this part is mentioned in the link of the google drive mentioned at the end of the report)



- Due to interest of time, we haven't tested further circuits that will be connected to the photodiode even though we guarantee that once we connect the IR LED to the circuit, we can complete the observation of further checkpoints of this pulse oximetry circuit.
- We have also coded the arduino logic for calculating the heart-rate from the pulse generated (amplified and filtered final pulse) from the above pulse oximetry circuit which will be interfaced with our PC through Freeduino Mega provided to us by the lab as a replacement for Arduino Mega. We will further extend the logic to calculate the oxygen concentration and also display the output pulse signal in our PC.
- The experimentation videos and the arduino logic is provided in the G-drive link below.

Drive Link:

Drive Link for the Video.

References:

[1] *Edn.com*.Available:https://www.edn.com/simple-pulse-oximetry-for-wearable-monitor/.

[2] M. A. O., "DIY Arduino Pulse Sensor," *Instructables*, 11-Nov-2014. [Online]. Available: https://www.instructables.com/Simple-DIY-Pulse-Sensor/.