Proof that Tony Stark has a heart

Directed and Produced for the PH435 project by Team Pulsars -

1) Vaishnav V Rao - 190260045
2) Manan Seth - 190260028
3) Harshda Saxena - 190260021

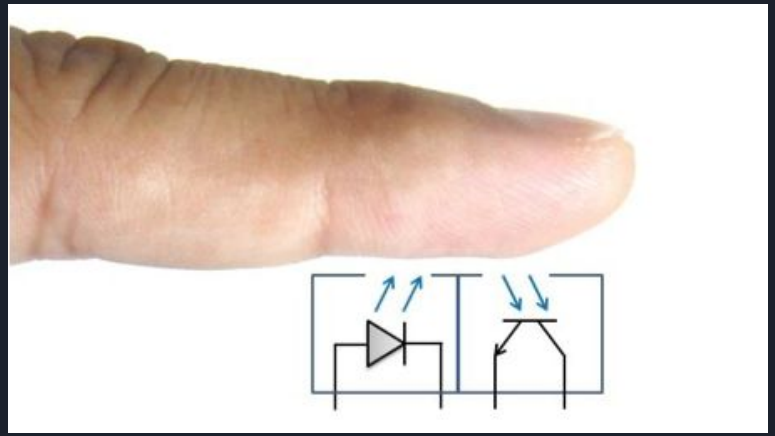
In case you fall asleep through the movie, a TLDW

Using an Arduino to read the photoplethysmography (PPG) waveform obtained through placing a finger on an infrared LED, red LED, and photodetector to measure heart rate and SpO2 (oxygen saturation). The weak IR signal will be amplified and filtered through an Op-Amp-based analog circuit. The Arduino will be used for a peak detection algorithm on this filtered signal to give the heart rate. The raw RED and IR waveforms will be used (after some Arduino signal processing) to then give the SpO2.

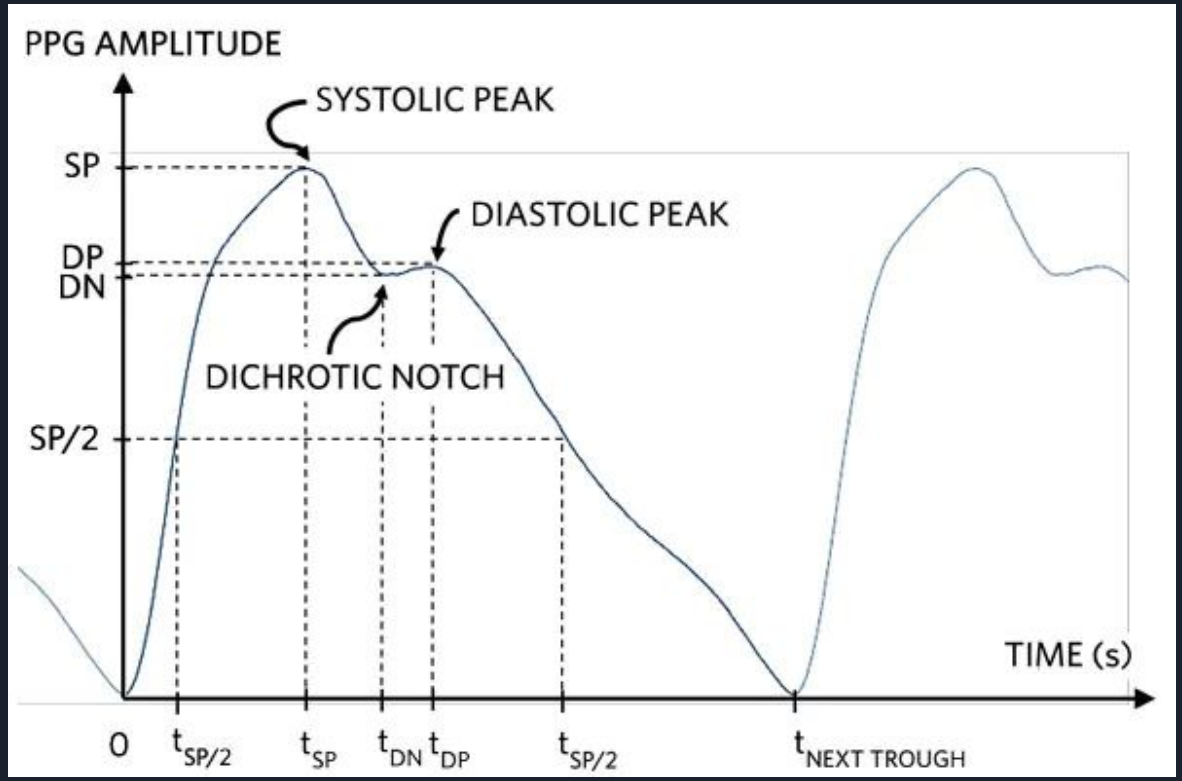
Roll Credits!
Just Kidding.

Photoplethysmo what?

- Capillaries in our fingers rhythmically contract and expand according to our heart beat rate.
- This changes the reflectance of IR / Red light
- Photodiode detects these changes in received light reflected off of capillaries.
- Et Voila! We have gotten the PPG waveform. Now we need to remove noise and “clean” the signal

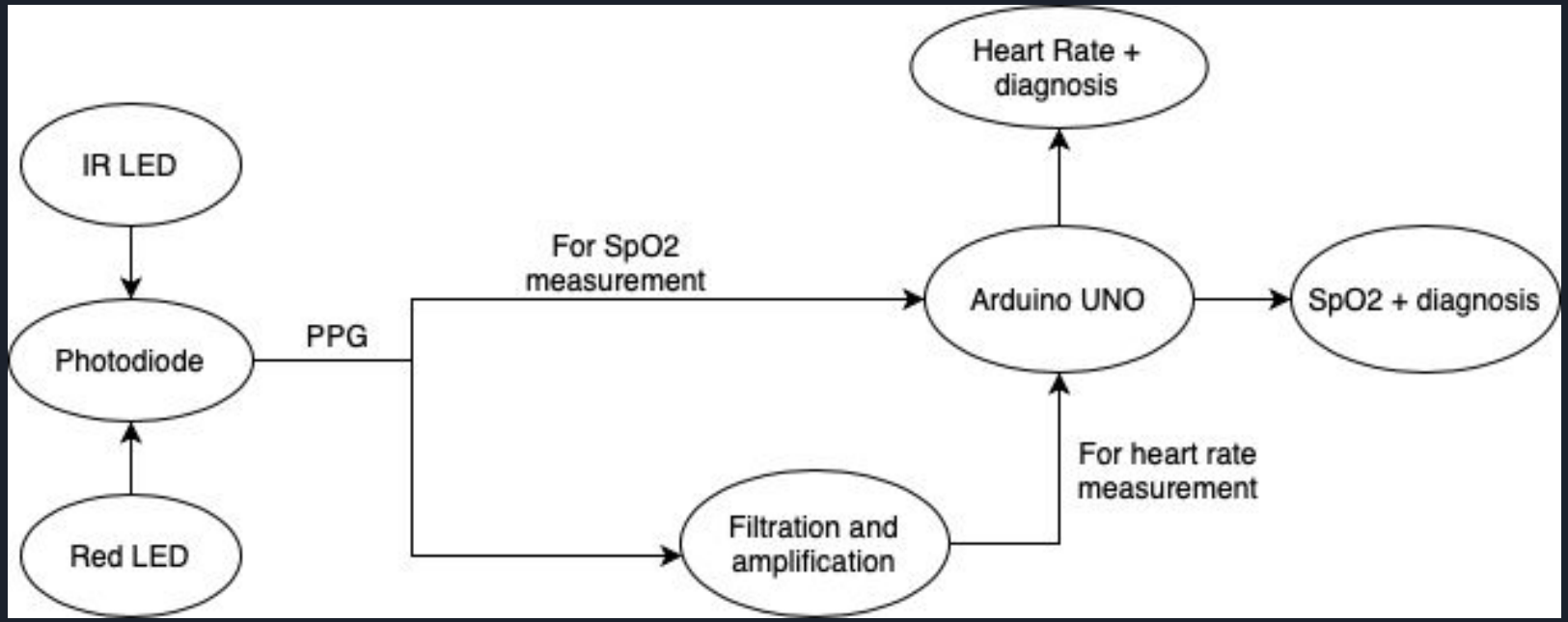


What to expect when you're expecting

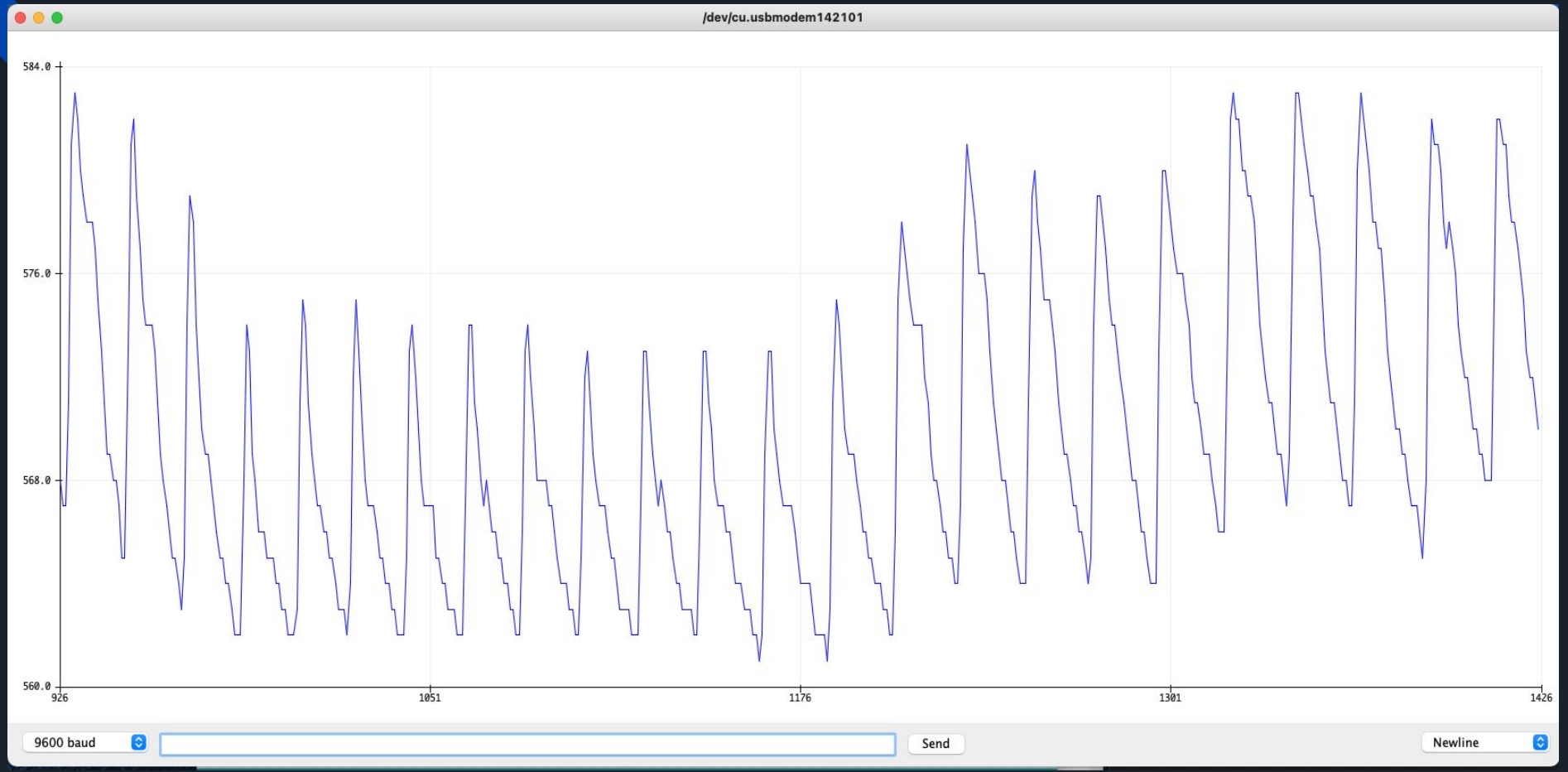


Representative characteristics of a PPG waveform

Trailer...

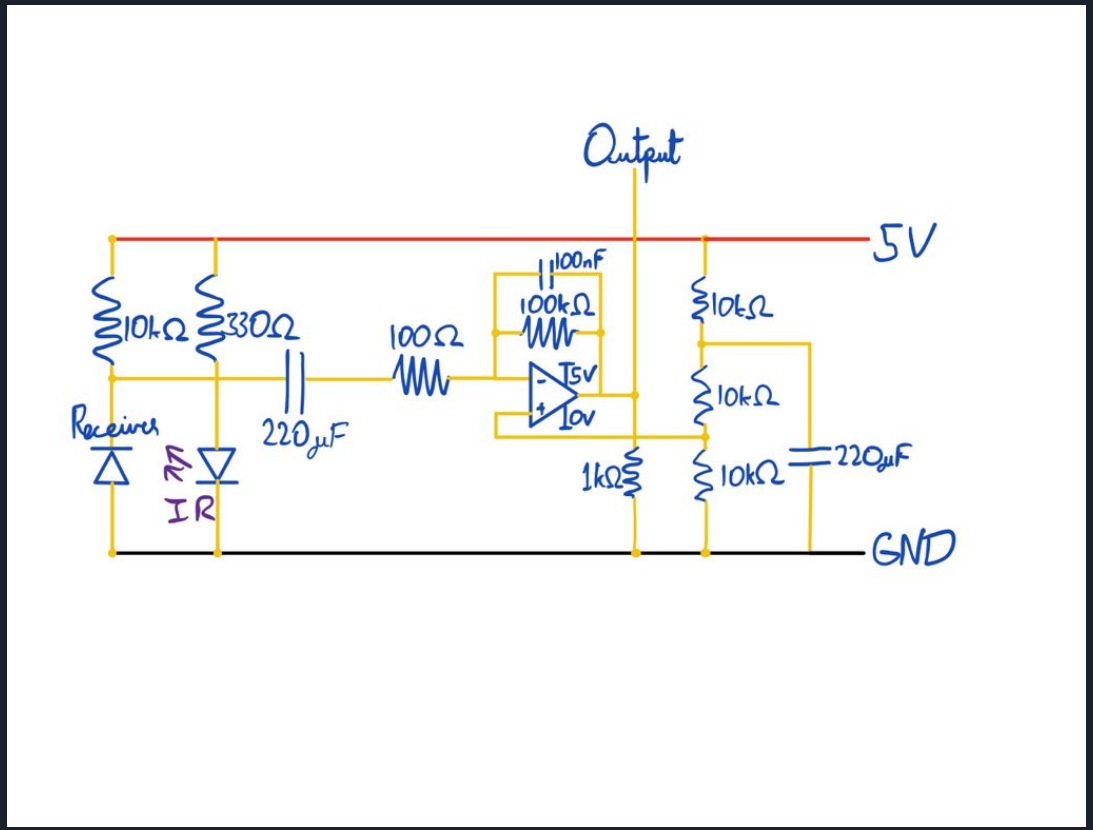

Heart Rate + diagnosis
IR LED
For SpO2 measurement
Arduino UNO
SpO2 + diagnosis
Photodiode
PPG
For heart rate measurement
Red LED
Filtration and amplification

What happens when we take analog reading from the photodiode directly?



Marvellous Conditioning Unit (MCU)

- Basically an inverting amplifier with gain = $-R_f / R_{in} = -1000$
- Capacitor in the feedback loop- integrator/ low pass filter (cutoff= 16Hz). Serves to block 50Hz noise
- Capacitor in the inverting input- differentiator/ high pass filter (cutoff=7Hz). Serves to remove the DC offset
- 1.66V at non inverting input sets the reference about which the AC part of amplified waveform oscillates



Extending the MCU

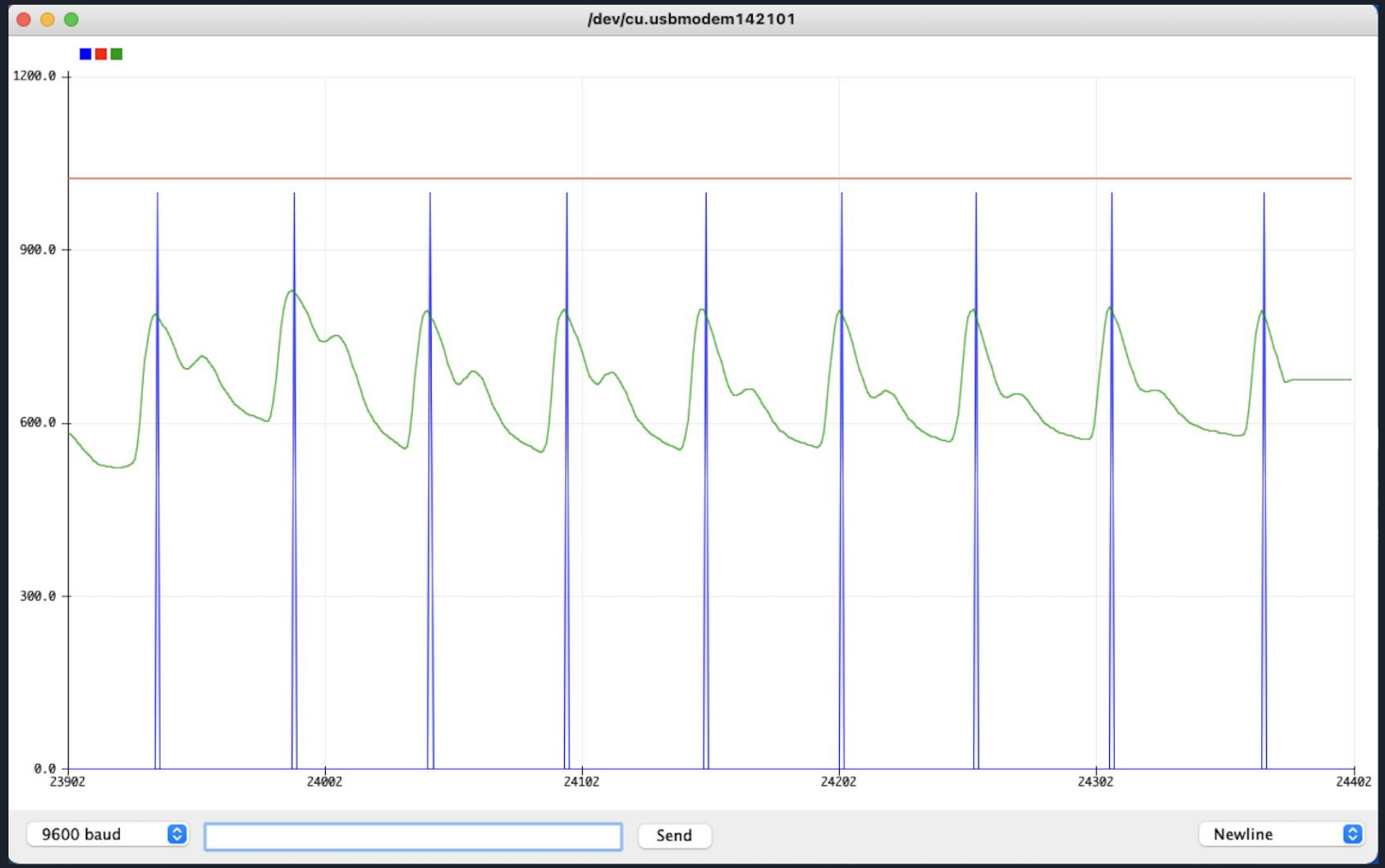
- Use the nice Serial Plotter feature on arduino (Recall output was inverted)!
- Employ peak detection algorithm to find the maximas in the code
- That should give the maximas, and the time periods can be used to give BPM!

If only Life was that easy!

- Problem 1 : Random peaks will be detected -
- Solution 1 : Count how long waveform has been rising for, detect peak if more than some threshold

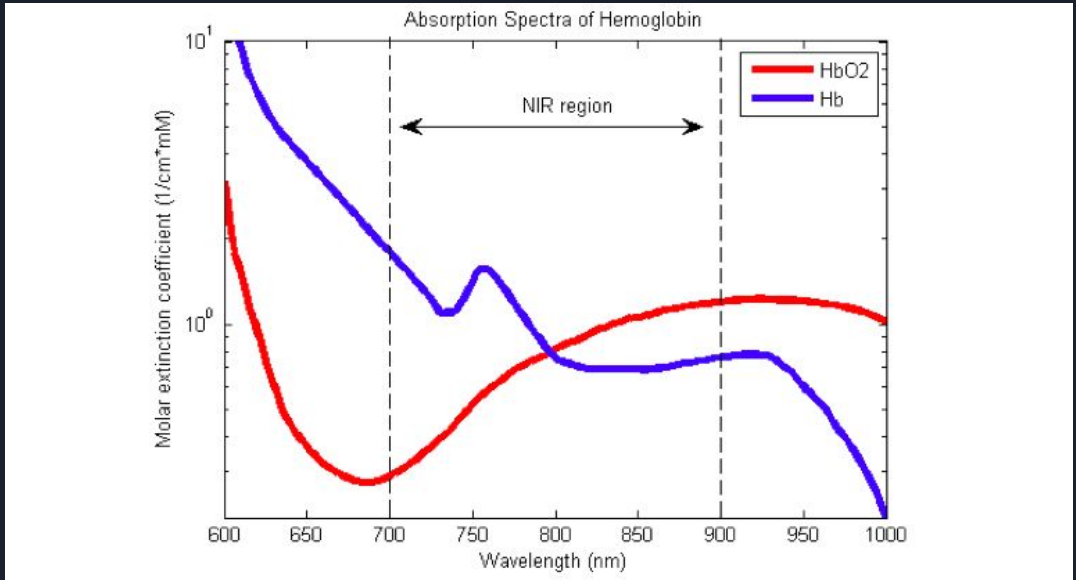
- Suggestion 2 : We know from previous labs averaging gives cute values for frequency
- Solution 2: Count only those time periods which are within 10% of each other

Results of our labour (blue spikes indicate peaks detected)



The physics of saturation (oxygen, not intellectual capacity)

- Spo2 literally measures the saturation of oxygen in the blood, by measuring the haemoglobin saturation
- Oxygenated blood is red, a connection with how well it absorbs certain wavelengths?



AC/DC

- We calculate

$$R = \frac{(Red_{max} - Red_{min})/Red_{min}}{(IR_{max} - IR_{min})/IR_{min}}$$

- The difference corrects for the effect of the tissue pulsations, and the ratio measures fraction of oxygenated to deoxygenated

- Calibrate using multiple points and store bought oximeters for a linear relation - SpO2 = m*R + b

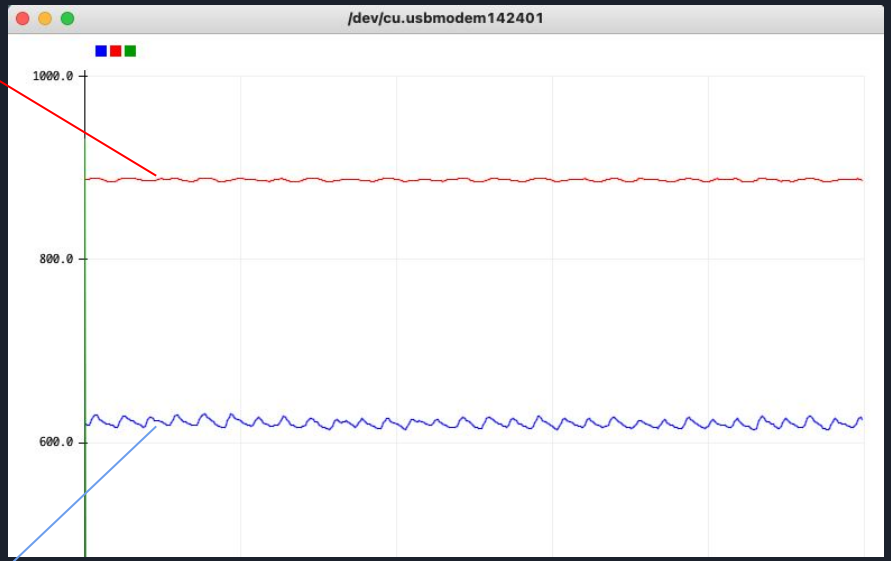
- Problem : Requires both DC and AC components!

All the analog hardwork gone for a toss!

Blinking? Beats me...

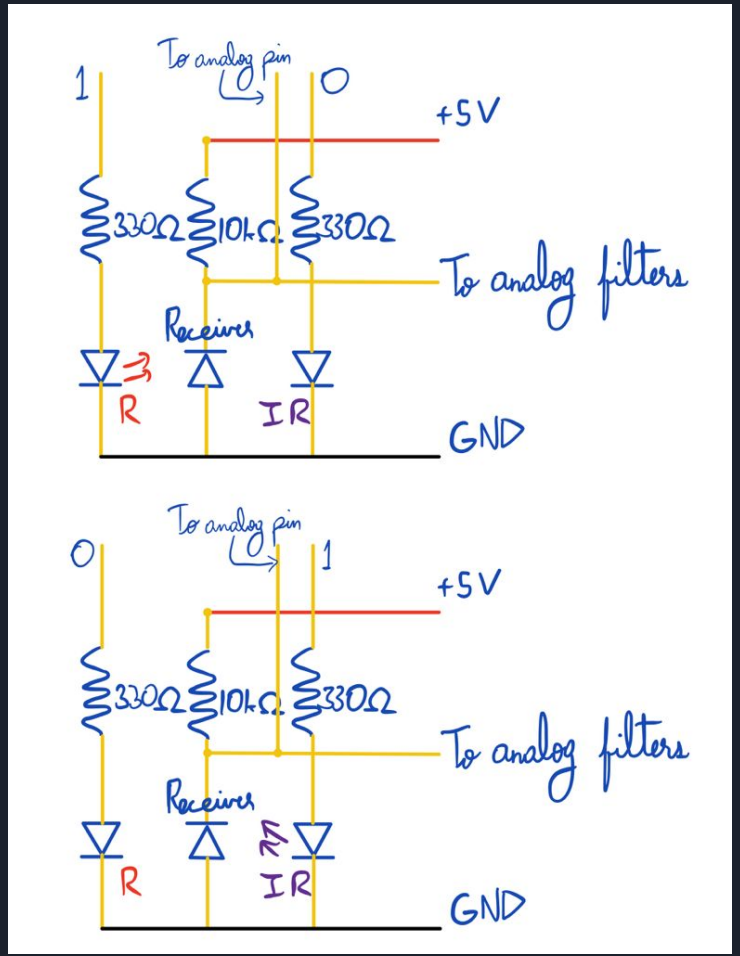
- Switches at a much larger frequency than heart beat (time of the order of 10s of milliseconds). Hence virtually simultaneous readings of Red and IR

PPG from Red LED

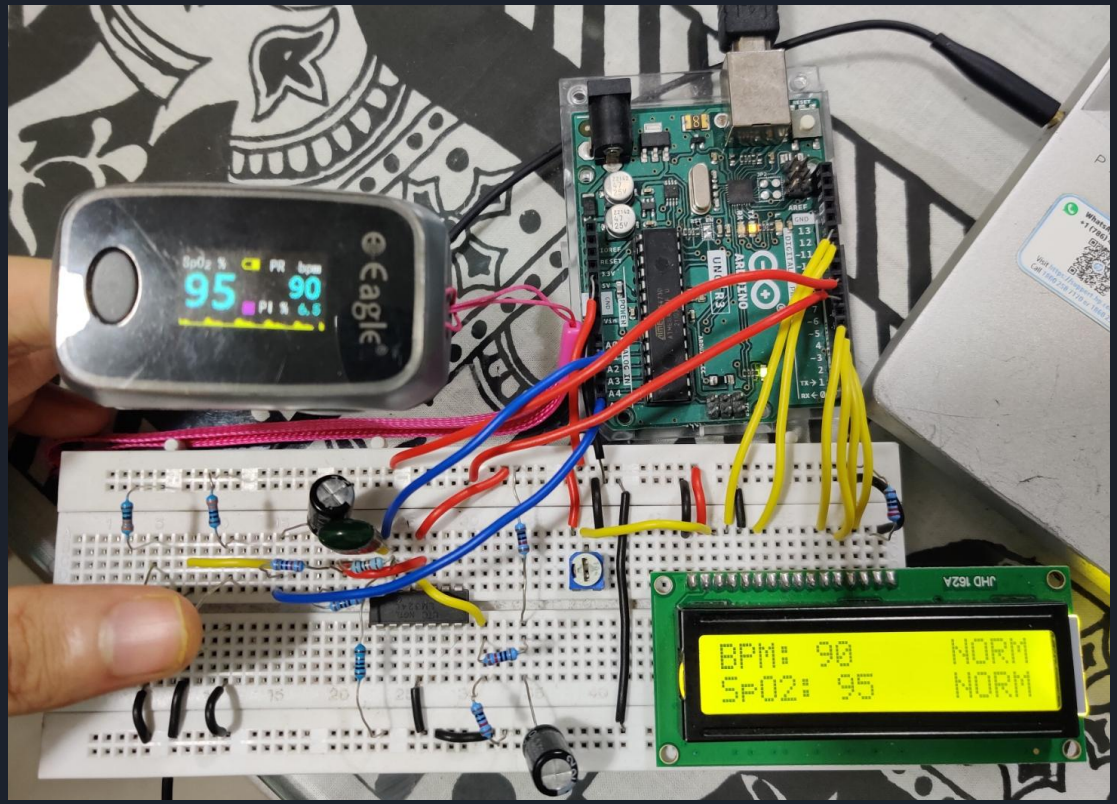


PPG from IR LED

- Average over 20ms to eliminate 50Hz noise
- Perform a “moving average” over 4 of these averaged values to get a cleaner signal



The final cut



Demo Link:
https://drive.google.com/file/d/18IRyRh_dR_GLdbjtlxFVJ9v7nEaHoQui/view?usp=sharing

Possible Sequels

Respiration Rate:

- Small envelope variations which can be seen in the PPG
- A method for finding this is called VFCDM (Variable Frequency Complex Demodulation) which uses EMD Empirical Mode Decomposition) to find the IMF (Intrinsic Mode Functions) (yes, a lot of words)
- The signal was already pretty sensitive, very complicated procedure to find RR

Cardiac Output :

- Amount of blood in volume pumped by the heart in a minute
- Current method of determining this is invasive
- Maybe possible via placing these sensors apart?

Post Credits

Thank you!

Special thanks to our TA, Nitin Pawar sir for providing clarity on multiple topics, and Prof. Bhalerao for this wonderful opportunity