SMART HEADPHONES USED TO MEASURE PULSE TRANSIT TIME (PTT) AND PULSE WAVE VELOCITY (PWV)

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Problem Statement

The team has been tasked by the client to design and develop headphones to record a cardiac pulse signal and pair this with a smart watch to measure PTT and PWV. The design of the headphones should be small and portable with a microphone that would be attached to it. A bluetooth link to the user's watch and phone with the headphones will be required. Both the headphone and the user's watch will create a timed sensor that should thus measure the PTT and PWV of the body. This data will be recorded and shown on an app that can be accessed by the user via their phone or smart watch. The design of the headphones should be similar to that of commercial headphone models and should be compatible with mobile phone systems..

Motivation

- High blood pressure has been on the rise in the U.S. since the start of the Covid-19 pandemic [3]
- Smart watches are only 34% accurate [1]
- Blood pressure cuffs are uncomfortable and do not provide constant tracking.

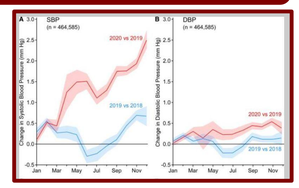

Figure 1. Blood Pressure Rates for Men and Women during Covid-19 Pandemic

Background Research

- There are no designed headphones on the market that use a microphone to measure PTT and PWV.
- $PWV = \sqrt{(A/\rho)(dP/dA)}$ where A is the cross sectional area of the blood vessel, ρ is the blood density and dP/dA is the change in pressure over the change in the cross sectional area. [4]
- ANT+ is a system in most fitness designed smart watches that could be used to transmit heart rate data from many smart watches into a program to calculate PTT and PWV. [5]

Design Specifications

- Device should be able to function for everyday use
- Material should not be invasive to the ear
- Blood pressure measurements should be comparable to those of a blood pressure cuff
- Headphones should be portable and comfortable; weight should not exceed 20% more than average headphones of 0.65 lbs

Results

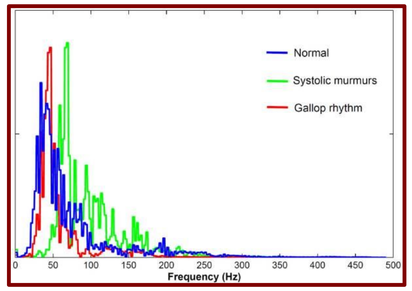

Figure 2. [2] Heartbeat Sound Frequency

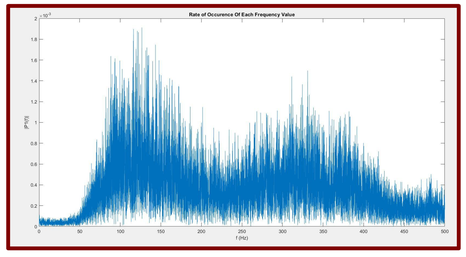

Figure 3. Commonality of Frequency Magnitudes in Analysis

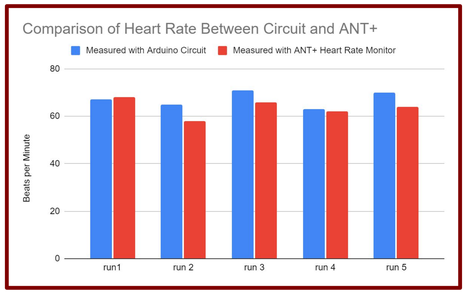

Figure 4. [2] Comparison of Heart Rate Between Circuit and ANT+

The expected sound frequency is shown in Figure 2 where the highest peaks occur between around 20 to 75 Hz. Figure 3 is the commonality of frequency magnitudes found in the analysis. These results showed the opposite of the expected values with a large spike occurring after 75Hz. Future work would prioritize a lower frequency microphone in order to avoid these higher sound frequencies from being recorded.

The results from figure 4 show that using the arduino board circuit shown in figure 6 can provide comparable results to an on the market product. These results could be more accurate with a product that can apply a more constant pressure at the wrist.

Material Costs

The primary Materials necessary for this project included the following:

~ Microphones
~ ABS filament
~ Speaker cushions
~ LED heart rate sensors
~ Stethoscope
~ANT+ receiver
~ ANT+ compatible heart rate arm monitor
~ Wireless blood pressure cuff

The final cost for the project was $344

Testing

- Microphone Testing:
  - Ability of the microphone to pick up heartbeat sound in the chest area and around the ear.
  - Create visual graph of the heartbeat through matLab.
  - Ability to differentiate the background noises from the heartbeat.
- LED Heart Rate Sensor Testing:
  - Comparing data of the sensor with an electronic handcuffs
  - Creating graph of the sensor reading to study the results

Final Design

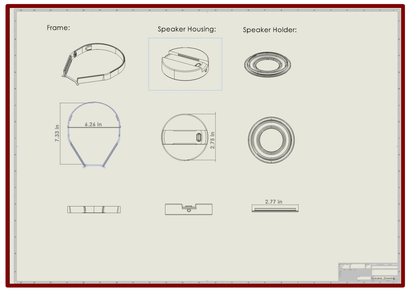

Figure 5. 3d Printed Headphones dimensions

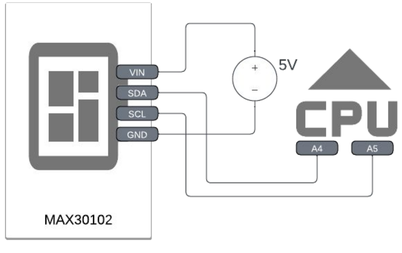

Figure 6. Heart Rate Monitor Circuit Diagram

References

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