ESP32 Huzzah Pulse Oximeter

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1 Background and Project Overview

First discovered in China in 2019, COVID-19 entered mainstream media in the U.S. after the CDC announced its outbreak overseas to the nation. The virus quickly spread across the United States, hospitalizing and killing hundreds of thousands over the course of 3 years. The illness primarily affected the respiratory system, and its infectious nature meant that both hospitals and healthcare workers struggled to keep up with the sudden influx of new patients each day.

Though the speed of COVID-19's spread has lessened, our healthcare system still faces a number of issues. For one, a report by the Washington Post (N=1,327) notes that 55% of health care workers feel burned out. A combination of long shifts, constant pressure, and a lack of support and appreciation all likely contribute to this burn out, which can and will push nurses to quit. Overall, the U.S. Bureau of Labor Statistics reports a typical average of 193,100 openings for nurses each year due to "the need to replace workers who transfer to different occupations or exit the labor force." As the pandemic continues to rage on, that number will likely only continue to rise as more and more nurses look to quit their profession for one reason or another. Supporting our nurses and making their jobs easier is one of the best ways to help alleviate this issue, which is what we hope to achieve.

At times, hospitals can be very busy and short-staffed, which can make it difficult to give attention to the patients that need it the most. Our project looks to solve this issue by helping healthcare workers improve their response times and prioritization of patients through timely notifications on their mobile devices. By combining pulse oximetry, a non-invasive test used to measure BPM and blood oxygen saturation, and internet functionality, we hope to notify healthcare workers of sudden drops in oxygen saturation levels or BPM.

2 Calculations

Pulse oximetry is centered around three facts: first, that oxygenated hemoglobin absorbs more infrared light than deoxygenated hemoglobin; second, that deoxygenated hemoglobin absorbs more red light than oxygenated hemoglobin; and third, that the volume of blood remains relatively constant while the amount of oxygenated and deoxygenated hemoglobin varies during a normal cardiac cycle. These three facts serve as the basis for our project's design and all the calculations we make. (Note that red light has a wavelength of about 620 - 750 nanometers and near infrared light starts at about 800 nanometers.)

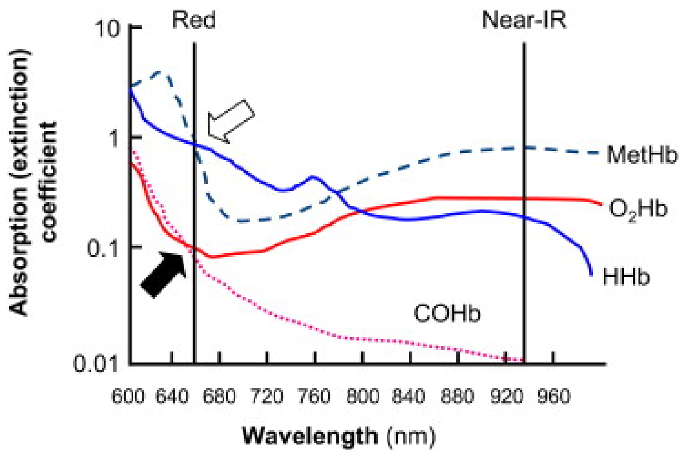

Figure 1: Absorption Coefficient of Oxygenated and Deoxygenated Hemoglobin (Red and Blue Lines)

To calculate BPM, we simply measure when the amount of infrared light absorbed by a subject's finger increases. The amount of oxygenated hemoglobin present in your blood stream increases whenever your heart pumps to deliver oxygen to your cells, which increases the amount of infrared light that is absorbed by your blood. By measuring this, we can determine the amount of time between "peaks" of infrared light absorption and in turn, determine what one's heartrate is.

To calculate oxygen saturation (O2 Percentage), we must first calculate a ratio, R, which is determined by measuring the amount of red light vs. infrared light that is absorbed by your blood. The next step is to then associate this ratio with its corresponding blood oxygen level. This correspondence must be established as R values can vary from oximeter to oximeter due to a variety of factors such as the strength of the LEDs being used or the sensitivity of the photodiodes. In our project's case, we found this correspondence by using an oximeter from a smart watch.

The value R in our oximeter is calculated as:

$$R = \frac{V_{RedMax} - V_{RedMin}}{V_{RedMin}} \frac{V_{IRMin}}{V_{IRMax} - V_{IRMin}}$$

3 Oximeter Design

A pulse oximeter, in theory, is a relatively simple piece of machinery. It consists of three main parts: a red LED, an infrared LED, and a photodiode.

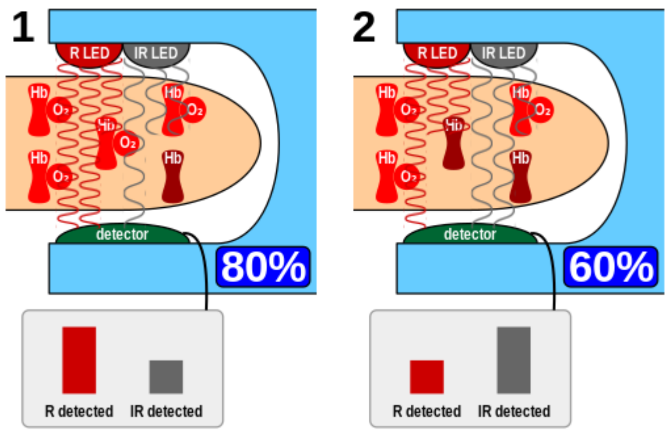

Figure 2: Depiction of an Oximeter

Our oximeter follows a similar design with some minor adjustments. For one, our design makes use of two red LEDs as one LED is not strong enough. Our design also makes use of two photodiodes: one for detecting IR light, and the other for detecting red light. Our design also connects to an OLED display which shows your BPM and oxygen saturation levels in real time. Through MQTT, our oximeter also sends blood oxygen levels and BPM to a feed and will automatically send a notification via email to your phone if blood oxygen levels ever drop below 91%. Note that the pins selected are not arbitrary and do matter for the functionality of the oximeter. Pin 36 is used for the IR photodiode and pin 39 is used for the red photodiode.

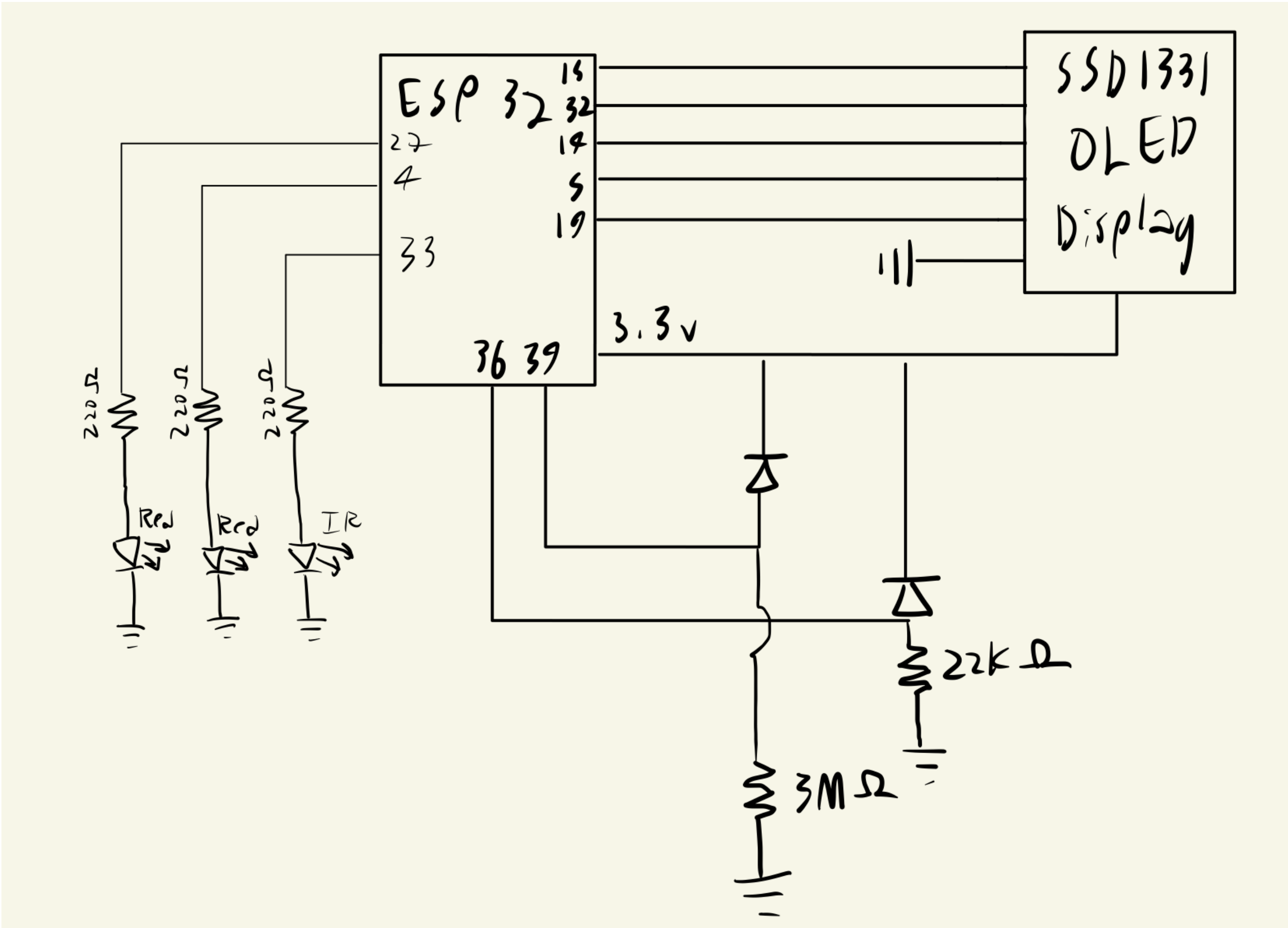

Figure 3: Diagram of the Circuit Used for Our Oximeter

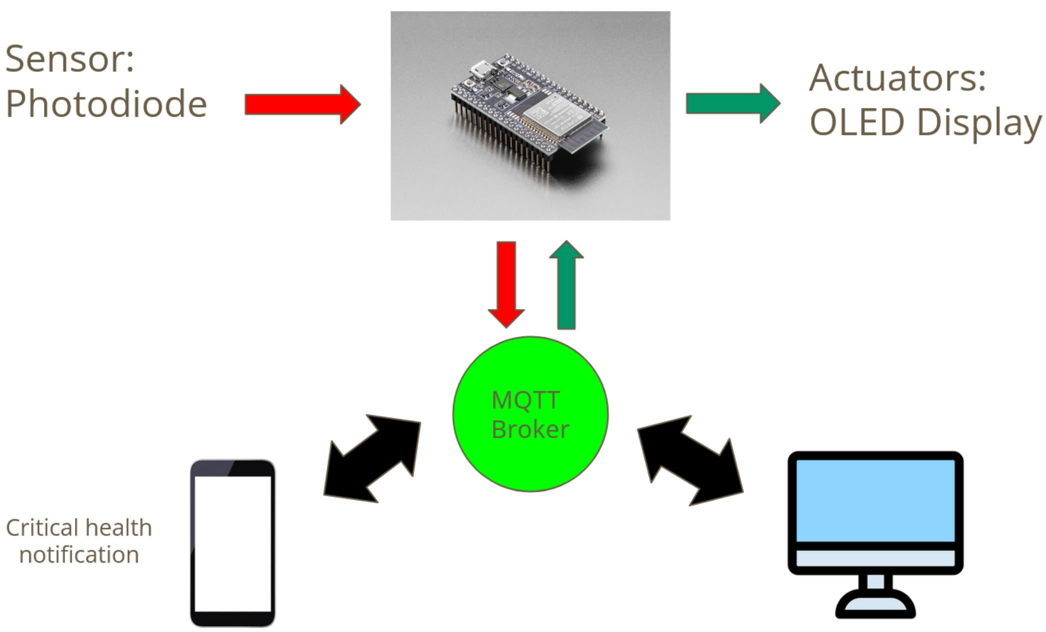

Figure 4: Diagram Depicting How Information Is Measured, Displayed, and Sent

4 Video of Our Oximeter

A video of our project in action can be found at this link: https://youtu.be/kpwHtJF1q5M

5 Conclusion

Our current oximeter design is fully functional and can display a fairly accurate BPM. The blood oxygen percentage however, tends to be much more variable. It also tends to take a long time before enough "good" measurements are taken to display BPM and oxygen saturation. These issues are likely due to several factors such as interference from external light sources, inaccurate calibration of the R value, the LED not being bright enough for the photodiode to pick it up, and cables slipping/parts shifting between uses of our oximeter. The photodiodes on our oximeter may also be applied poorly to the finger of our users, which may cause light to reach the detector while not passing through blood.

These issues however, are solvable with a few design adjustments. For one, we could use brighter LEDs to ensure the photodiode is able to pick up the incoming red light. We could also redesign the housing to prevent external light from interfering with our measurements. Redesigning the housing could also solve the issue of cables slipping and parts (i.e. the photodiodes and LEDs) moving in between uses, which would help address inconsistencies between measurements. Better housing would also solve the issue of light bypassing the finger entirely

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