4.2 Design Exploration

4.2.1 Design Decisions

Some key design choices for our current prototype are listed below.

ESP32 Pico

This is a microcontroller with integrated 2.4 GHz Wi-Fi and Bluetooth capabilities. It is being used for the user wearable subsystem. It will serve as the central control for our project, collecting and processing data from our selected sensors. The decision on this specific microcontroller was based on its Bluetooth capabilities. This wireless communication is vital for our project to function as proposed because there needs to be a method of dialogue between microcontrollers to exchange the information that the user is in distress and thus needs comfort from their canine. Without this wireless capability, the canine microcontroller would need to be connected through wire to the user wearable. This creates inconvenience and becomes an obstruction to lifestyle.

ESP32 WROVER

Similarly, this microcontroller is equipped with the same Wi-Fi and Bluetooth capabilities. The reason for this decision was that it was readily available and was compatible with the ESP32 Pico. This is being used to process the distress signal from the Pico to control a haptic motor for the canine.

DC ERM Motor Vibration

This is the vibration device that will signal to the canine that their owner is in distress. Many different design options came up for this decision. Between DC and AC power, as well as the mechanical design choices. This is a human and discrete method of signaling to the canine that their owner needs comfort.

MAX86150 - Integrated Photoplethysmogram and Electrocardiogram

This is dual-integrated with a PPG and EKG sensor. The PPG measures blood pressure, and EKG measures heart rate. Choosing this sensor will ensure we are receiving the necessary physiological data to detect PTSD symptoms.

4.2.2 Ideation

For at least one design decision, describe how you ideated or identified potential options (e.g., lotus blossom technique). Describe at least five options that you considered.

One of the design decisions that we had to make was what kind of motor we would use to create the vibration inside of a dog vest. We had a choice between working with AC or DC motors as well as working with types of motors, including eccentric rotating mass (ERM) vibration motors, Linear resonant actuators (LRAs) or Solenoid actuators.

ERM vibration motors work by rotating an off-center mass attached to the motor shaft. When the motor spins it causes the whole device to vibrate.

LRA vibration motors work by using a magnetic mass and a voice cell. The AC signal drives the coil, and the mass oscillates back and forth, creating vibration. These devices are energy efficient.

Solenoid actuators work by using electromagnetic forces to create linear motion, which causes vibrations in the device.

4.2.3 Decision-Making and Trade-Off

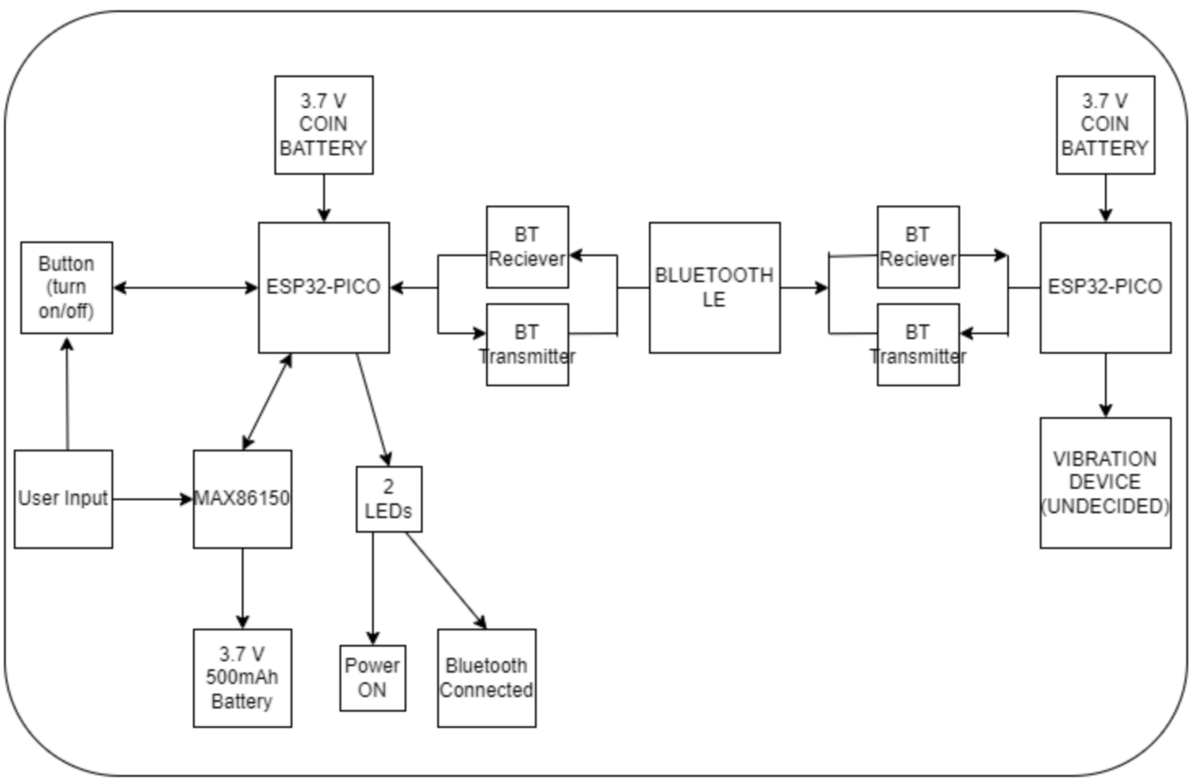
We chose to use a DC motor because we have a power source that is DC power. We chose to use an ERM motor as opposed to an LRA or solenoid actuator because of its discrete size and low decibel output. We needed to make sure that the vibration device operated in a humane manner when attached to the dog vest. The ERM motor was the best choice for this because its DB output was about 50 DB.

4.3 Proposed Design

4.3.1 Overview

Our design begins with a device worn on the wrist of the veteran, which is capable of detecting PTSD episodes. When the device detects the episodes, it signals a device worn by a service dog to alert the dog of the episode. The wrist-worn device consists of a battery, a microcontroller, and a PPG sensor. The microcontroller is an ESP32 which can take and process data from the PPG sensor. The PPG sensor is a photoplethysmogram which is able to read data from the veteran and send this data to the ESP32, which processes the data in order to determine heart rate and PTSD episodes. The ESP32 microcontroller also has built in bluetooth capability in order to send signals to the dog-worn device. The dog-worn device consists of another ESP32, a haptic motor, and another battery.

4.3.2 Detailed Design and Visual(s)



The wrist-worn ESP32 connects to the onboard MAX86150 PPG sensor through standard I2C. The microcontroller latches raw IR data data from the PPG according to the ESP32 MCLK output. The raw data is passed through the MSPTD beat detection algorithm to extract useful heart rate data. The heart rate data goes through additional analysis to determine if a signal needs to be transmitted to the dog. This device can be powered on and off by the user to avoid false positives in PTSD detection. The wearable is powered by a 3.7V 500mAh rechargeable battery. Using Bluetooth Low Energy, the ESP32 on the wearable device communicates with the ESP32 in the unit that sits within the dog vest. This unit is powered by the same kind of 3.7V battery. When the ESP32 receives the correct signal from the ESP32 on the wearable, the device in the dog vest vibrates to give the dog the signal that is needed for the dog to go to its owner.

4.3.3 Functionality

Describe how your design is intended to operate in its user and/or real-world context. What would a user do? How would the device/system/etc. respond? This description can be supplemented by a visual, such as a timeline, storyboard, or sketch.

Our design is meant to be as simplistic as possible to remove any point of failure with our product. We implemented a pancake vibration device that will trigger the dog's response to the PTSD attack. We also implemented a blood pressure sensor in the PPG sensor. This sensor will provide the microcontroller with accurate data so that an algorithm can detect the presence of a PTSD attack. The user will have a button to turn off the device so they can do activities that may cause a false presence of PTSD. An example of this is physical activity as simple as going for a run and exercising. The user will also get to interact with LEDs on the device that detail battery power, on or off, and Bluetooth connection. These choices are meant to make interaction with our device simple and easy. The design for the dog satisfies all requirements for a discrete device that triggers a react out of the dog. We chose a small pancake vibration device to be as quiet as the device can be triggering that response from the dog.

4.3.4 Areas of Concern and Development

Our design satisfies VetDog's requirements and meets user needs by detecting biometrics and communicating with a vibration device. This is the basic functionality and core of the design, which should satisfy requirements. We have also done a good job at building a system that is cheaper for the user than similar wearable devices, which was a base need of our user. Apart from this core, we have not reached the point in development for a few user needs and requirements such as wearability and practicality.

Our primary concerns are making sure that the design is wearable and conducive to a normal lifestyle. Although we have a good technological base for our design, the end goal is to have a device that allows veterans to live their lives as normally as possible, and the size of our device does not allow for that at the moment. Along with size, it is simply not a wearable device at the moment.

Despite not meeting these requirements at the moment, we have clear plans for meeting them in the future. Once we have proven the core functionality of our technology, our efforts will be pointed towards scaling down the size design as much as possible. This will allow us to have freedom in the design of the actual wearable, as we see bulkiness as a limiting factor when it comes to comfortability and practicality, which are paramount in an everyday device like this. We will also have to shift our focus from technical design to user empathy as we find a balance between functionality and user comfort.

4.4 Technology Considerations

For our project, we are utilizing microcontrollers. These are advantageous because they can be used to read raw data and create algorithms to process them. However, with our design solution, we need to create a device that is wearable and due to the microcontroller bulkiness, this makes this goal challenging. As a solution, we hope to contact BAE Systems to create a PCB design using the ESP32 CPU to make a smaller version of our current microcontroller and create a wearable solution.For the vibration device, we chose a DC ERM haptic motor. This is a non-invasive and discrete solution, however, there are some concerns with power consumption. Another design option was the linear resonant actuator, as this is the most power-efficient, however, it creates a higher dBA output which is concerning dealing with an animal with sensitive hearing.

MAX86150 this is our photoplethysmogram and electro-cardiogram sensors. There are some concerns in regard to the accuracy of the PPG sensor. This is because current market solutions have yet to be perfected in creating a wrist-wearable device that accurately reads blood pressure. Nonetheless, this is the best current solution we can offer the project given the market solutions.

4.5 Design Analysis

So far, we have spent our time developing functionality of individual components and modules within our design. We have configured bluetooth to send signals from the human-worn microcontroller, as well as gotten the microcontroller to interface with the mounted PPG sensor. We have also gotten the evaluation kit for the PPG to output data to a laptop, and gotten it to accurately detect heart rate from this data. We have not gotten the proposed design from 4.3 to work yet as we have not yet put all the modules together. Based on this, our plans for future design and implementation involve putting all modules together, and working out any bugs that come up. Looking farther in the future, we will need to scale down our design considerably in order for it to fit on the veterans wrist. An additional design consideration would be adding accelerometer functionality in order to differentiate a PTSD attack from exercise when the device is actually worn by a veteran.