Introduction:

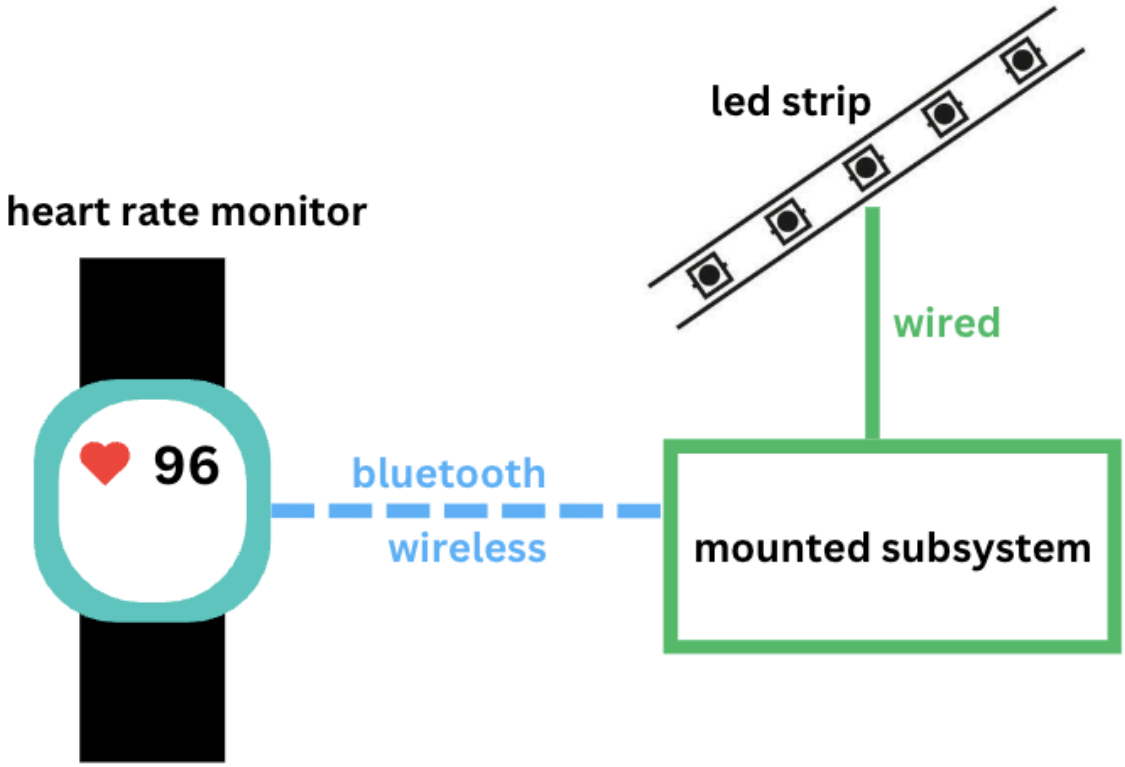
Problem: In many environments, the ambiance is heavily influenced by lighting, which often requires manual adjustment to match the mood of the space. This can be inconvenient and limits personalization. What if we had a system that could track how you are feeling and adjust the lighting system accordingly? We propose an individual lighting experience that acts as a dynamic lighting system, reacting to sound and heart rate to provide a personalized, immersive environment. This system would eliminate the need for manual intervention, offering a more cohesive ambiance that changes based on both noise and the user's emotional state.

For example, if a user is watching an action movie or playing music, the system will synchronize lighting with the intensity of the scene or sound. In addition, the system adjusts the brightness based on the user's heart rate, creating a unique experience tailored to their mood and activity.

Solution: Our project proposes the development of an intelligent lighting system that connects LED strips, which can be placed behind a TV, painting, or near a speaker. The system automatically synchronizes with the background noise of the user's activity, while also adjusting intensity based on the user's heart rate. This enhances the user experience by providing adaptive lighting that is highly personal and responsive.

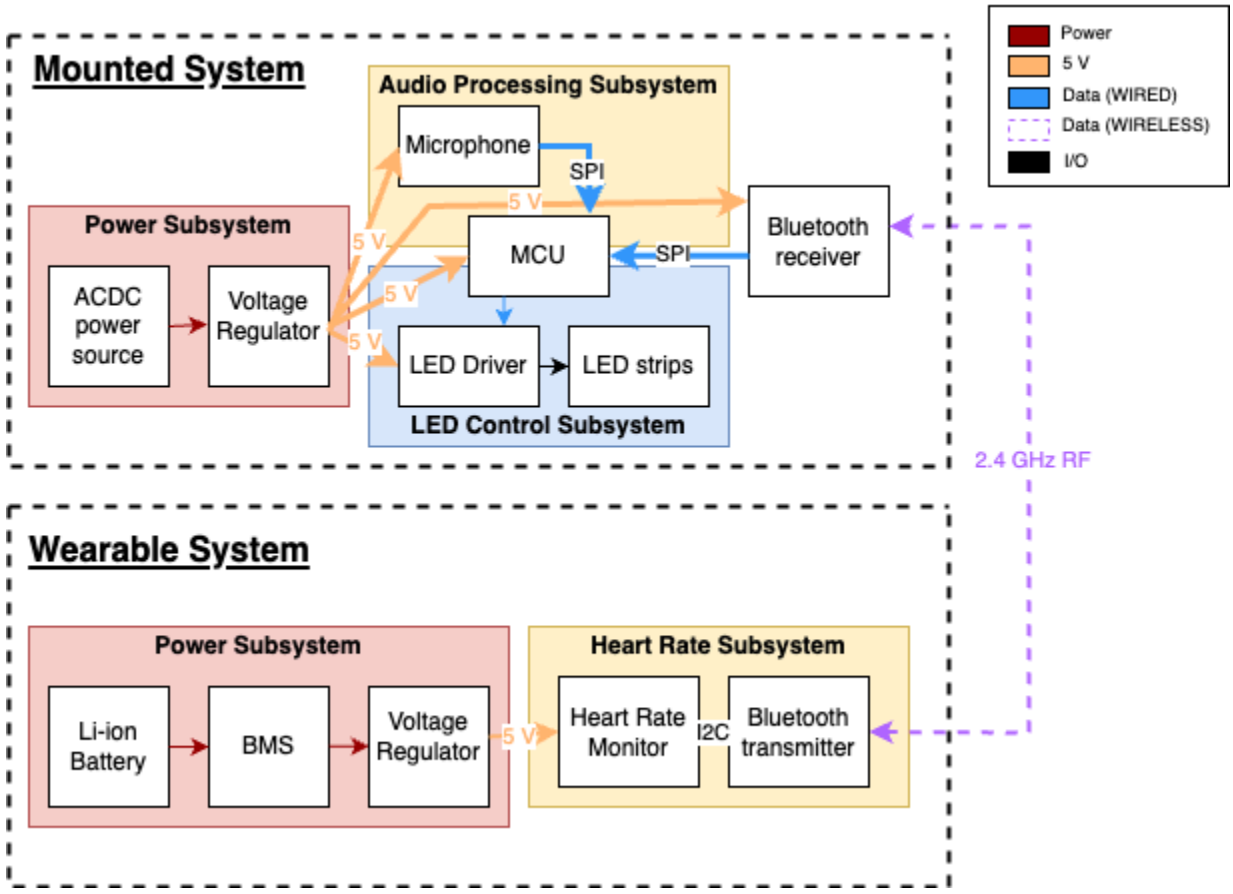
At a high level, we have an audio system that collects background audio and sends signals to change the color of the LED strip. Additionally, a heart monitor system connects to the circuit via Bluetooth and sends signals to adjust the intensity of the LED strip—brighter for higher heart rates and dimmer for lower heart rates.

Visual Aid:


led strip
heart rate monitor
wired
96
bluetooth
wireless
mounted subsystem

Design:

Block Diagram:



Subsystem Overview:

- The **Audio Processing** subsystem captures and processes audio input to detect noise levels and changes in frequency. Using a MEMS microphone, it converts sound waves into electrical signals. These signals are processed by the MCU using algorithms like Fast Fourier Transform (FFT) or amplitude-based analysis to interpret noise levels and frequency variations. This data is crucial for adjusting the LED colors, allowing the system to respond to the surrounding audio environment dynamically. This subsystem interfaces directly with the MCU, providing audio data that influences the LED Control System for color adjustments.
- The **Heart Rate Monitor** subsystem collects heart rate data using the pulse oximeter and sends it to the MCU via a Bluetooth module. The MCU then uses this information to regulate the intensity of the LED strip, adjusting brightness in real-time. The heart rate data ensures that the system can react to physiological

changes, creating an interactive lighting effect based on the user's heart rate. This subsystem transmits heart rate data to the MCU, which combines it with audio data to adjust the brightness of the LED lights.
    - The **LED Control System** manages the color and brightness of the LED strips. The LED driver receives control signals from the MCU, which processes both the audio input and heart rate data. Pulse Width Modulation (PWM) is used to control the brightness, based on heart rate, while color changes are driven by the audio analysis. This allows for fine-tuned, real-time control over the LED display, making it responsive to both environmental sounds and physiological signals. This subsystem is controlled by the MCU, which uses data from both the Audio Processing and Heart Rate Monitor subsystems to adjust the LED lights.
    - **Power Management System (Mounted)**: This system converts the incoming 120V AC power supply into a stable 5V DC output, which is used by the mounted subsystems, including the MCU, LED control system, and audio processing system. It ensures that all components receive the appropriate voltage and current to function correctly without overloading or damaging the system. This subsystem is crucial for the continuous operation of the system, as power instability would disrupt the functionality of the entire setup.
    - **Power Management System (Wearable)**: The wearable power management system powers the heart rate monitoring subsystem, ensuring that the heart rate sensor and Bluetooth transmitter have enough power to function correctly. It manages the battery to prevent it from drawing more than 500mA of current, extending battery life and enabling uninterrupted use. If the wearable power management fails, the heart rate monitor would lose power, leading to a loss of synchronization between the heart rate and the lighting system.

Subsystem Requirements:

Heart Rate Monitoring Subsystem

- The heart rate sensor must provide accurate data within ±10 BPM.
    - If heart rate data was not accurate, the reaction of the lights would not be proportional to the reaction that the user is experiencing.
- Heart rate data should be transmitted to the MCU via Bluetooth within 150 ms of measurement.
    - Brightness should adjust proportionally to heart rate changes.
    - Something to note is that the MCU is also connected to the rest of the mounted system(shown in the block diagram above)
    - If the data isn't transmitted within that time frame, the reaction will be delayed and the lights will not align with the movie or the heart rate.
- Brightness should adjust proportionally to heart rate changes. For every 10 BPM change, there should be a 10% change in brightness.
    - The entire point is for there to be a reaction to the heart rate, so if there is no change, the heart rate does not contribute to the user experience.

- List of Requirements:
    - Power has to be supplied to the heart monitor or else the heart monitor would stop working
    - The bluetooth transmitter also has to work for seamless wireless data transfer to the bluetooth receiver in the mounted subsystem, or else we cannot analyze the data to provide a proper output
    - Heart rate monitor must work and not be faulty to ensure that correct data is transferred

LED Control System

- The LED control system adjusts both the color and brightness of the LED strip depending on the output from the MCU
- The components are LED drivers and the actual LED strip
- List of Requirements
    - Must be able to change the LEDS over 20 different colors
        - If the colors don't change, the LEDs don't have any effect on the user or the user's experience.
    - The LEDs must be able to pulse a maximum 120 beats per minute.
        - If the LEDs don't pulse, then the user won't be able to experience the sync of whatever they are watching to the LEDs

Audio Processing System

- This subsystem is responsible for capturing the audio input to the LED control system. The MEMS microphone converts the sound waves into electrical signals that can be analyzed. The amplitude-based analysis is used to determine the beat and noise level of the music which will be sent to the LED system and change the colors and brightness.
- This subsystem is important because always the LED to change based on surrounding sound and without it there would be no detection of sound level which leads to failure to change the color which is a high-level requirement.
- Interfaces with Other Subsystems:
    - Microphone to MCU
        - The microphone will receive the analog sound input and convert it to be sent to the MCU. The MCU must receive signals within a voltage range 0-3.3V.
    - Audio Data to LED
        - The data must be updates every 150 ms to ensure synchronization of the LED's behavior to the audio input being sent.
- List of Requirements
    - Power must be supplied to the microphone of 1.8-3.3V.
    - The microphone must be able to capture audio data within 20db of the actual sound to ensure an accurate representation of the environment or

video. Without this, the LED response will not be accurate and reflect the real audio.

Power Management System(Mounted)

- This subsystem is required to power the LED Driver, the MCU, and the Audio processing unit. It provides a steady output of 5V to power all of these subsystems to ensure proper functionality. The subsystem consists of an AC/DC converter, since this will be plugged into a wall outlet, and a voltage regulator to output the 5V.
- List of Requirements
    - Must be able to accurately convert the AC 120V input to a more usable 5V output for various other mounted subsystems.
        - If there is no power, or it is too high of a voltage, then the system won't be able to operate or the parts will burn out.

Power Management System(Wearable)

- This subsystem will power the bluetooth transmitter and the heart rate monitor. It consists of a 5V battery, a battery management system, and a voltage regulator. It will output a consistent 5V to all of the other subsystems.
- If this subsystem fails, then the bluetooth and heart rate monitor won't operate as expected.
- List of Requirements
    - Must not draw more than 500mA of current to preserve battery life.
        - If the battery dies, then the fundamental part of the entire system (heart rate monitor) doesn't contribute to the user experience.

Tolerance Analysis:

A part of the design that poses a risk to our completion is transmitting the data accurately from the heart rate monitor to the MCU in an accurate and timely manner. Say that we sample the heart rate every 100 ms, we have 50 more milliseconds for the data to be transmitted. If we have a rate of 1Mbps, we are able to transmit 0.05 Mb, which is more than enough to transmit the integer value.

Ethics and Safety:

Since we are using heart rate data and background noise, there is an issue if someone were to access that data and use it for malicious endeavors. According to ACM Code of Ethics(1.6), we have to respect their privacy and take steps to ensure that their personal data is protected such as not storing their data. As per IEEE Code of Ethics (Section 1), developers should disclose risks and obtain consent before using systems that use user data. Users should be made aware of how their data will be used and processed. It should be accessible to individuals with disabilities, as per the ACM Code of Ethics (1.4), which mandates fairness and

non-discrimination. However, we will have a warning before using this system since the lights flashing and changing intensity could hurt some people's eyes. Excessive brightness, flickering, or rapid changes in light could cause eye strain or migraines. We will ensure that the lights do not flicker too rapidly and change brightness fast enough to cause eye strain. The heart rate monitor must follow safety guidelines such as IEC 60601-1. The wearable device should not overheat for the safety of the user. Ensuring that the wearable does not overheat or malfunction is critical to user safety. Overall, we will make sure not to store and distribute the heart rate data. The system will also be easy to turn off if the lights become too much for any user.