Music Discovery Band

ECE 445 Design Document

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1 Introduction

1.1 Objective

Many people do not know how to go about discovering new music because they don't know if they will enjoy listening to it in their current situation. If someone on a treadmill wanted a way to discover new music while they were running, they would most likely have to resort to listening to a specifically-curated, high-energy gym playlist. However, this playlist might not suit the user's tastes after they finish their exercise and might prefer a different type of music to relax to. Currently, Spotify has weekly playlists to discover new music and playlists specifically dedicated to a certain type of mood, but has no functionality to specifically curate a real-time playlist that features unique songs that pertain to a user's physical activity, mood, and surroundings. By considering these factors, the objective of this project is to simplify the seemingly random task of discovering new music for Spotify users.

As mentioned before, there currently exists no technology that can provide song suggestions from the entire Spotify library by keeping track of a person's physical activity levels, environment, and even mood. Our solution is a wearable and interactable wristband that will feature different hardware and software interfaces to accomplish this. By using input buttons to allow the user to signify their mood and using sensors to collect various information including heart rate, acceleration, and background noise, our product will match users to songs that accompany any situation of varying intensity. For example, the wristband would match fast-paced, vibrant songs when the user undergoes strenuous physical activity, or calmer, softer songs to accompany the user doing leisurely activities around the home.

1.2 Background

While there exists no clear-cut method to determine an individual's music preferences, research shows that there are many external influences that may impact one's musical taste. According to a study done at Western Oregon University, one external factor to musical preference is prior exposure due to societal influence [1]. It makes sense that people would prefer music that they are already familiar with, as these are the types of music that society deems popular. However, given the objective of our project, it is impossible to determine whether a user is already familiar with the songs that the product queues up. Thus, we must examine other common factors influencing music preferences. Psychologists recommend activity level, mood, and environmental surrounding context [2] to be powerful indicators of the types of music an individual might prefer. People will want to hear different types of music depending on what situation they are in, which is why our wristband will use the sensors and buttons mentioned above to collect as much information as possible about a person's current surroundings and activity level. Using this information, the product will be able to make an educated guess about the type of genre that one would likely want to listen to in their current situation.

1.3 Visual Aid

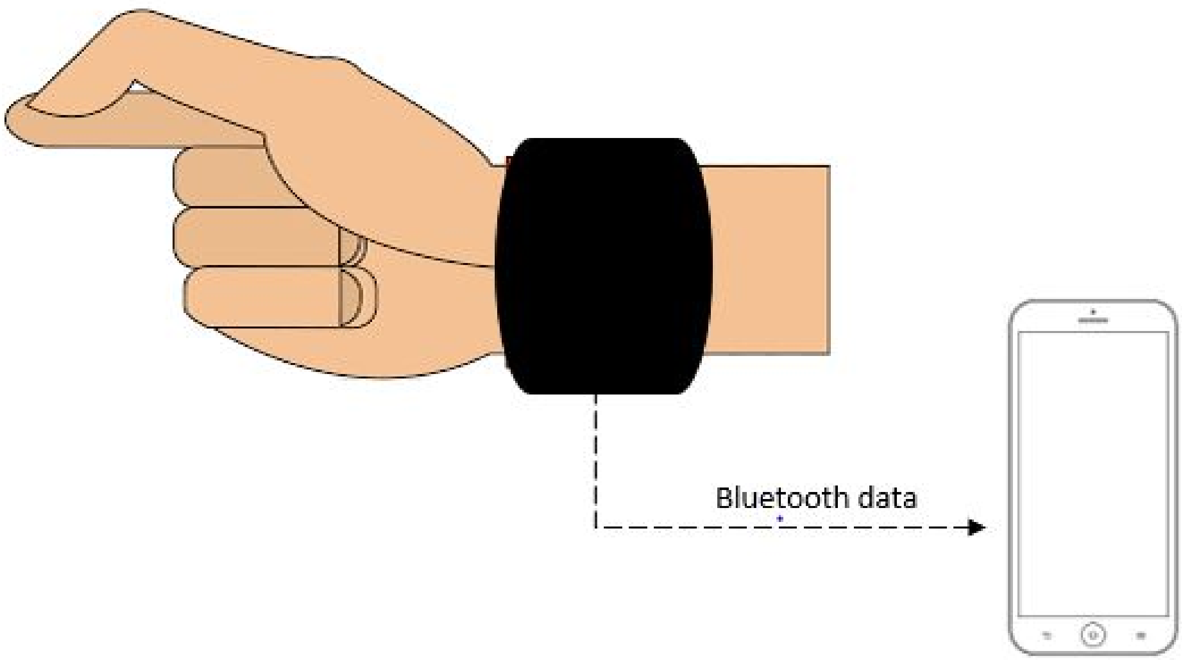

Figure 1. Visual Aid for Scale

The physical implementation of a wristband presented in Figure 1 serves two purposes. The first is that the device will be compact and convenient for the user to fit to their wrist and wear in any environment. The second is that the placement of sensors on the wristband will collect information about a user's activity level, and will utilize Bluetooth connectivity with the user's phone since the phone will often be close to the user. The placement of the wristband on the wrist is essential because of our heart rate sensor, which is designed to capture changes in pulse that flows through the area of the wrist featured in the picture. This sensor will be one of the main components that is used to determine an appropriate song to play for the user.

1.4 High Level Requirements

- A wristband about 5-7 cm in length and 2-4 cm in width that can be adjustable to sit comfortably on the user's wrist.
- Interior design consists of an accelerometer, heart-beat sensor, sound sensor, and button inputs that can accurately track information as it pertains to the user's activity level, surrounding environment, and mood.
- The wristband can transmit the information it collects from its sensors and buttons through a Bluetooth transmitter to the smartphone app, where the app's algorithm must use the information it receives to queue up an "appropriate" song from Spotify's library that matches the user's activity level.

2 Design

2.1 Block Diagram

The five main subsystems presented in Figure 2 each execute individual tasks but feed into the operation of one another to link the system holistically. The power subsystem contains a lithium-ion battery and a voltage regulator which will feed a steady voltage output to the other subsystems to assure they stay on when needed. The sensing subsystem activates the sensors that output readings that can determine the current environment and state of the user. This sensing information is then sent to the control subsystem where a microcontroller with Bluetooth transmitting capabilities processes the information. The data from the microcontroller will be sent to the remaining two subsystems, a hardware user interface and a software user interface. The hardware user interface consists of button inputs for mood, on/off, pause/play, skip song, and turn off device. Status LEDs will show the user that their inputs are accepted and are changing the information processed by the microcontroller. The software user interface is a smartphone application that serves as a basic Spotify music player. It will also display the information coming from the Bluetooth transmitter through the sensors' outputs such as heart rate, current acceleration, and levels of ambiance noise. The user can thus see the information that the backend algorithm is processing to find suitable music.

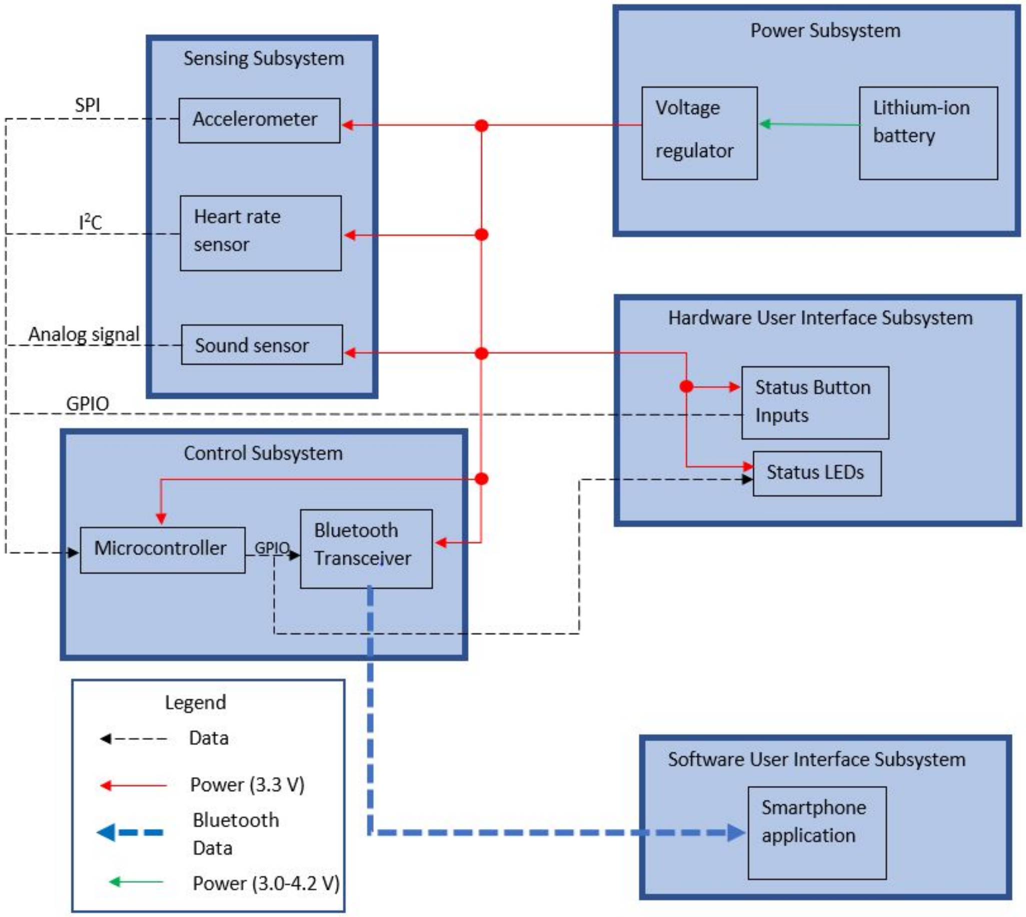

Figure 2. Block Diagram

2.2 Physical Design

Important layout aspects of the various hardware components within the device, illustrated in Figure 3, include the PCB/microcontroller and heart rate sensor on the bottom of the wristband, the sound sensor on the top of the wristband, and the placement of the buttons. The placement of the PCB and microcontroller are important because they will stick out slightly in the wristband and create a flat surface that the user can use to properly orient the wristband. The location of the heart rate sensor allows easy access to the pulse on the bottom of the wrist. The placement of the sound sensor on the top of the wristband is critical as we want to avoid unwanted disruptions such as the sensor bumping or rubbing against objects. Finally, the placement of the input buttons on the outside of the top of the device is also important as they need to be easily accessible to the user and avoid physical interaction, like the ambient noise sensor. These buttons could then also be easily paired with LEDs placed nearby to indicate the change in the user's inputs.

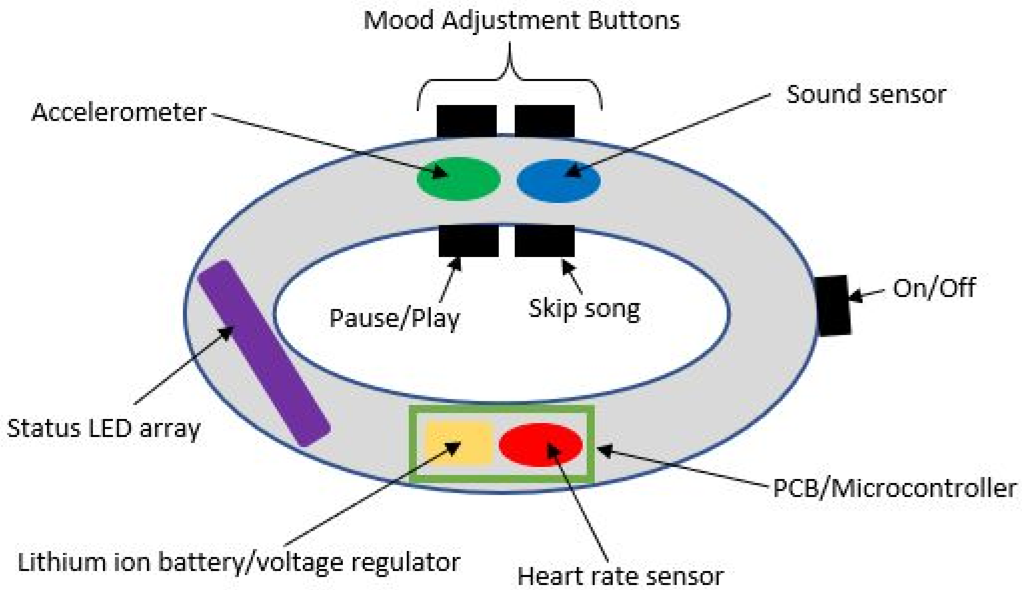

Figure 3. Physical Design

2.3 Power Subsystem

A source of power is necessary to supply the sensing, control, and hardware user interface subsystems. To accomplish this, our design will implement a lithium-ion battery. The voltage provided from the battery must be regulated to 3.3V in order to power the rest of the subsystems of the design.

2.3.1 Lithium-ion battery

The lithium-ion battery will be used as this source of power, providing the wristband with continuous power to allow for uninterrupted use. The power from the lithium-ion battery must power the circuit for an extended period of time. After the battery has run out of power, it should be easy to take out and replace for a new one by the user.

Requirement	**Verification**
Must supply continuous power to design components for 4-6 hours on full charge.	1. Drain battery charge. 2. Provide constant 4.2V to fully charge the battery. 3. During a 4-6 hours time frame, probe voltmeter to ensure there is above 3.0V being outputted.

Must supply between 3.0-4.2 V to the circuit.	1. Measure output at various points in the battery's life using a voltmeter to ensure that the reading is within the required threshold.

2.3.2 Voltage regulator

The voltage regulator will be connected to the lithium-ion battery detailed above. It will accept a range of 3.0-4.2 V from the battery, and will output a constant 3.3 V. This voltage is what is required to maintain the functionality of the rest of the required subsystems.

Requirement	Verification
Keeps the voltage from the battery into the rest of the subsystems near the target 3.3V (±5%).	1. Measure voltage output using a voltmeter to ensure that the reading is within the required threshold.
Supplies ample current for the design components, and operates between 0-300 mA.	1. Use multimeter on output of voltage regulator to check that output is between 0-300 mA.

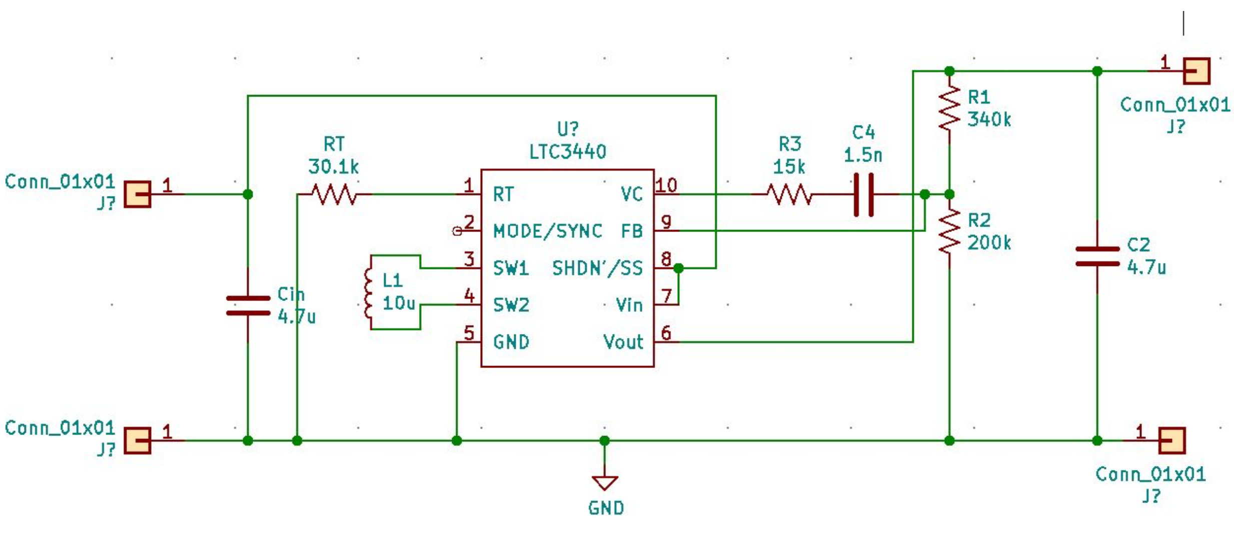

Figure 4. Circuit Schematic of Voltage Regulator

This voltage regulating circuit serves as a buck-boost converter to accomodate for the battery fluctuating from 3.0 to 4.2V. The circuit essentially takes in the input voltage from the battery on the left two pins and sends it through the IC buck-boost to output 3.3V on the right two pins. Important takeaways from the design are the choice of the inductor between SW1 and SW2 which was selected via recommendation from the device datasheet. The input and output capacitors help to maintain a relatively clean DC input and output and serve to stabilize the circuit as much as possible.

2.4 Control Subsystem

The control unit includes a microcontroller and a transceiver with Bluetooth capabilities. Data recorded from the sensory circuit and user's button inputs will be processed first by the microcontroller. Afterwards, the processed information will be sent to the smartphone application, as well as to the status LEDs located on the wristband in any necessary situation.

2.4.1 Microcontroller

The microcontroller will be programmable with software that will allow it to allocate different memory addresses for the different types of data being received from the various sensors. Upon receiving sensor data, the microcontroller must process this and light up the appropriate status LEDs. At the same time, the microcontroller's Bluetooth capability must send the data to the smartphone application, which will be used to queue up music in the user's playlist.

Requirement	Verification
Must be able to store data from sensors.	1. Connect sensor outputs to different GPIO inputs on the microcontroller. 2. Read information from GPIO ports to ensure there is data being stored. 3. Using sound sensor to test, create noise. 4. Read information from GPIO port sound sensor is connected to and verify that data has changed.
Must be programmable to control status LEDs, and handle button inputs.	1. Connect status LEDs and buttons to microcontroller. 2. Create a test program to light up LEDs and indicate whether a button has been pressed. 3. Use the USB port to program the microcontroller. 4. Run program and record how LEDs

	are lit and how button presses are received to verify functionality.

2.4.2 Bluetooth transceiver

The Bluetooth transceiver on the microcontroller will be used to handle the connection between the wristband and the user's smartphone. The information that is processed by the microcontroller is sent to the Bluetooth transceiver, which can then send the information collected from the sensors and buttons to pick an appropriate song.

Requirement	Verification
Must transmit data within a short range, ideally 5 meters.	1. Connect a button input to a GPIO port on the microcontroller. 2. Program microcontroller using USB to send button toggle data through Bluetooth transceiver. 3. Have smartphone application backend print data it receives through Bluetooth. 4. Keep the smartphone 5 meters away from the wristband and verify that data is received.
Must reliably send data without corruption.	1. Ensure that accelerometer SPI output is connected to a respective GPIO port on the microcontroller. 2. Verify that data from microcontroller is sent through the Bluetooth transceiver. 3. Have smartphone application backend print data it receives through Bluetooth. 4. Record data and verify that it is readable and consistent with accelerometer status.

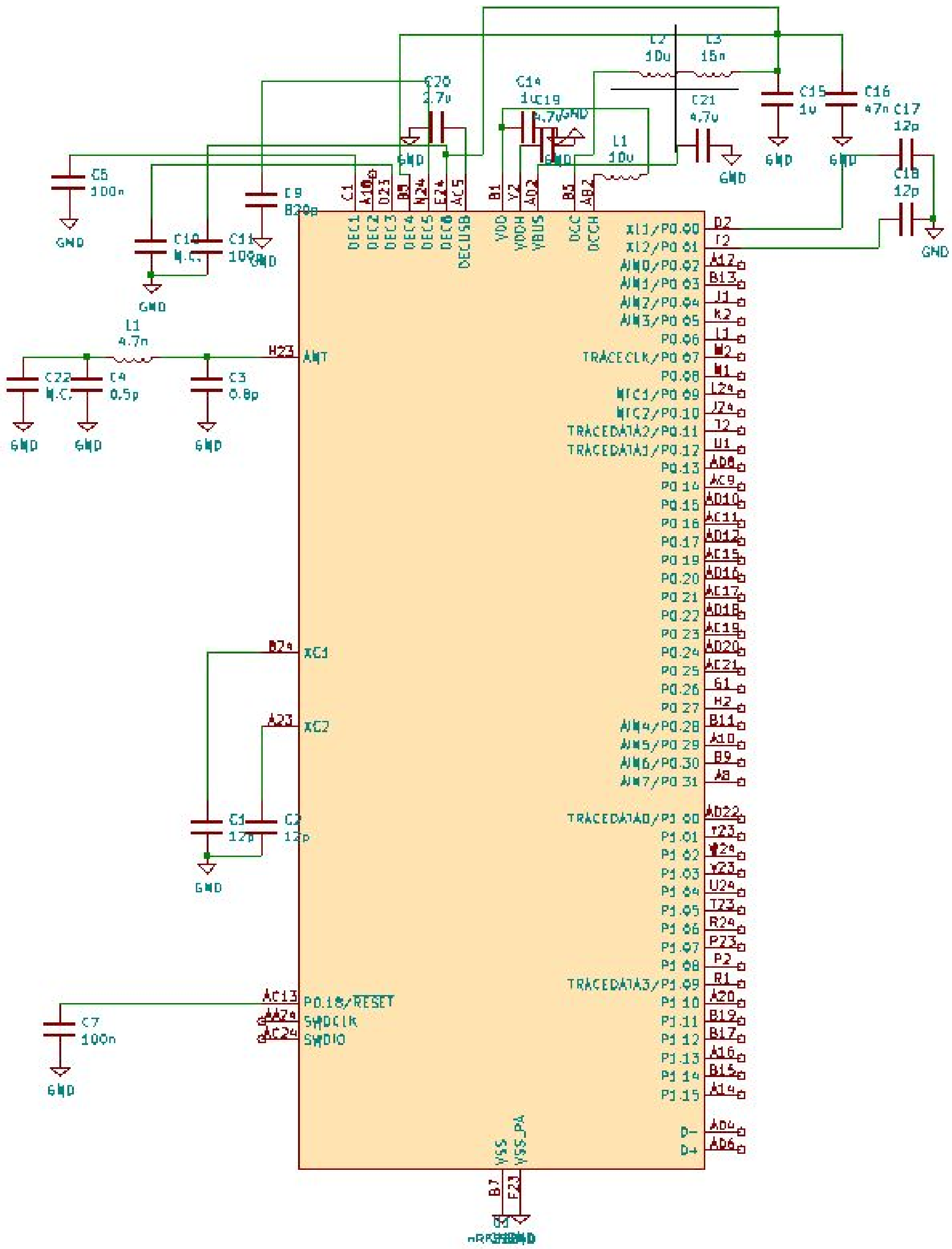

Figure 5. Circuit Schematic of BLE

This BLE schematic in figure 5 serves as a processing unit, bluetooth transmitting device, and as the microprocessor unit for the project. It has compatibility with SPI, I2C, and FIFO inputs via the general I/O pins shown on the right side of the schematic. This is perfect for the design we have in mind as these various pins will accept and process the data from the sensors via the programming we give to it and transmit that data via the development kit within the parts list.

2.5 Sensing Subsystem

The sensing subsystem is arguably the most important subsystem of the entire project, as it is the basis for which the wristband can interact with the users, as well as the smartphone application that is being used to pick music. The wristband will utilize an accelerometer, sound sensor, and heart rate sensor to capture information on the user's activity level and environment. The information collected from these sensors will be processed by the microcontroller, which can then send information about the user's activity to the smartphone application.

2.5.1 Accelerometer

The accelerometer will be used to accurately detect the acceleration of the wristband's user. It will probe for changes in acceleration as well, as these changes can be used to determine the fluctuation of the user's physical activity. For example, if the microcontroller senses that the user's average acceleration is decreasing, it might send a signal to the smartphone application to modify the tempo of the song accordingly.

Requirement	Verification
Must be able to send information to microcontroller to be stored.	1. Connect SPI output of the accelerometer to a GPIO port on the microcontroller. 2. Read information from GPIO port to ensure there is accurate data being stored.
Must accurately gather information of the user's acceleration to determine the amount of physical activity.	1. Verify that with the wristband sitting still, the microcontroller register containing the SPI output indicates that there is no acceleration. 2. Wearing the wristband and running, check the microcontroller register containing the SPI output to verify there is an accurate increase in acceleration.

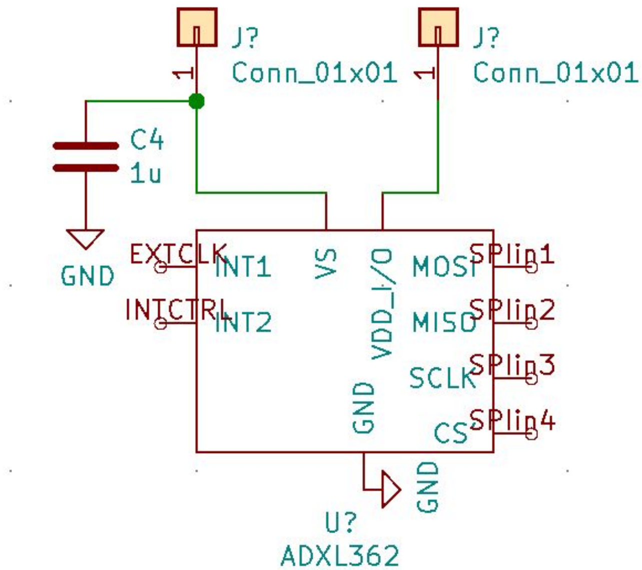

Figure 6. Circuit Schematic of Accelerometer

This accelerometer schematic shown in figure 6 illustrates the taking in of an external clock signal from the microcontroller and returning the internal time measurement for which the accelerometer has detected activity or inactivity. On the right side of the chip there are the various SPI outputs which can be connected directly to the microcontroller due to its compatibility. The inputs on the top of the schematic are DC power sources where the 3.3V from the voltage regulator can be used. The capacitor on the left serves to further stabilize the input voltage to keep the device from having many glitches where it cannot receive power.

2.5.2 Sound sensor

The sound sensor will have the capability to detect ambient noise in the user's surroundings. By measuring the intensity of surrounding noise in the user's environment, the sound sensor can send this information to the microcontroller to analyze whether the user is alone, in a casual social setting, or a busy environment.

Requirement	Verification
Must be resistant to noise disturbance caused by shifting of the wristband.	1. Connect the envelope pin of the sound sensor to the ADC of the microcontroller. 2. Shuffle wristband around wrist. 3. Record output data from microcontroller and verify shifting has minimal impact.

Must accurately collect sound information from sources outside of the wristband and send this information to the microcontroller.	1. Connect the envelope pin of the sound sensor to the ADC of the microcontroller. 2. Test various noises within five meters and confirm output data from microcontroller matches relative noise level.

2.5.3 Heart rate sensor

The heart rate sensor will monitor the user's heart rate to keep track of the intensity of the activity the user is doing. Using LEDs to detect blood flow, the heart sensor's data will be sent to the microcontroller along with the other sensors' data. The information from the heart sensor will go hand-in-hand with the accelerometer's data, as an elevated heart rate would correspond with high levels of acceleration, and vice versa. This information could be used to make a more holistic judgment of the user's situation and what song to select.

Requirement	Verification
Placement of the sensor on PCB should be in the interior of the bottom side of the wrist.	1. Have tester's hand wear the wristband and report that the heart rate sensor can be felt on the bottom side of their wrist.
Must accurately monitor the user's heart rate and send this information to the microcontroller.	1. Connect FIFO output to a GPIO port on the microcontroller. 2. Have a tester wear the wristband with the heart rate sensor resting on the bottom of their wrist. 3. Record data stored in microcontroller to determine if heart rate information is accurate.

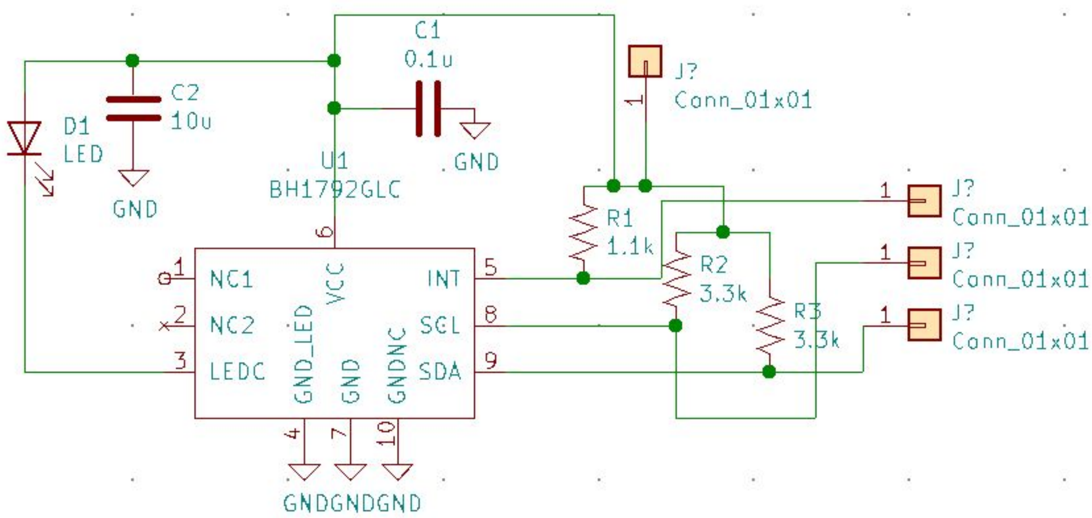

Figure 7. Circuit Schematic of Heart Rate Sensor

This schematic shows the power and FIFO connections from the BH1792GLC heart rate sensor. The LED on the left shows the functionality of the heartbeat sensor which feeds into the 3.3V supply on the top of the chip. The three connectors on the right show the FIFO outputs that will go directly to the general I/O pins of the microcontroller.

2.6 Hardware User Interface Subsystem

The hardware user interface subsystem will contain various button inputs and status LEDs that the user can interact with. The buttons will allow for music playback accessibility, as well as two mood buttons that the user can use to signify how their mood might shift. The status LEDs will then flash to signal to the user that the wristband has accepted its input and has relayed the information to the smartphone application to control the playing of songs.

2.6.1 Status button inputs

The wristband will include buttons to pause/play a song, skip a song, and indicate mood level. Mood will be represented as a numeric range of values, and the user can adjust their mood in a positive or negative direction using the buttons, and this will reflect on the type of music that is played subsequently. The range of moods that will be available will extend from sad to excited.

Requirement	Verification
Must be easily accessible and clickable by the user.	1. Have a tester wear the wristband and check that the buttons are accessible with their other hand. 2. Press each button and visually determine if buttons are being fully clicked.
Placement must ensue accidental button activation is minimal.	1. Bump the wristband on the tester's body and common objects such as a table or a wall. 2. Record buttons that are seen to be activated from the status LEDs. 3. Use data to ensure that accidental button activation was minimal.

2.6.2 Status LEDs

Along the wristband, there will be an array of LEDs that will be easily visible to the user. Based on the information that the microcontroller receives from the sensors and input buttons, LEDs of different colors will light up. These will indicate the status of the user's defined mood, playback state, and whether the device is on or off. These must not break otherwise the user will have no visual indication that the device has processed the information that it is collecting from the user.

Requirement	Verification
Must be easily visible from the user's perspective.	1. Visually verify that LEDs can be seen from a couple meters away when wristband is being worn.
Must be durable and resistant to damage via outside contact.	1. Bump the wristband on the tester's body and common objects such as a table or a wall. 2. Press button inputs and see if the corresponding LEDs light up.

2.7 Software User Interface Subsystem

The software user interface subsystem encompasses the smartphone application that will receive the data from the wristband to determine a suitable song to be played through the user's Spotify account.

2.7.1 Smartphone application

The smartphone application is what will be used to control what songs are being played to the user. Through the wristband's Bluetooth capability, the application will receive the necessary data from the sensors and mood buttons to filter through the Spotify library and queue songs that match what the user's situation is according to the data from the wristband.

Requirement	Verification
Application must be Bluetooth compatible to receive wristband data.	1. Verify that Bluetooth capability is turned on in the smartphone. 2. Have tester wear wristband and examine application backend to verify that data is being recorded.
User interface must be simple and resemble a standard music player.	1. Visually compare user interface of application with Spotfy, Apple Music interfaces and record differences. 2. Analyze differences and verify that application interface is simple and resembles a standard interface.
Backend of the application must choose a song that is appropriate according to the transmitted information.	1. Given application algorithm, hard code data that would imply a calmer song and verify that song output matches this description. 2. Use different data that implies a faster, energetic song and verify that song output matches this description.

2.8 Tolerance Analysis

The block within our design that poses the greatest risk to the failure of this project is the sensing block as each of the sensors must work with reliable and consistent outputs. This can be an issue due to excessive movement from the user while using the device for activities such as running that may create unreliable outputs in the sound sensor device. These unreliable outputs might then interfere with the algorithm's process of correctly identifying suitable music.

A critical component of this project is to detect a user's surroundings and activity level using various sensors, meaning that the sensor's sensitivities and information response time must be carefully considered. The accelerometer and pulse sensors will mainly be used to determine the user's activity level. Activity can be detected by the accelerometer when samples from the sensor are a certain, user-defined amount above the sensor's reference value for a period of time that is also defined by the user, as seen in equation 1.

$$\text{ABS}(\text{Acceleration} - \text{Reference}) > \text{Threshold} \qquad \text{Eq. 1 [4]}$$

Taking this into consideration, we can expect our design to have two main modes as they relate to physical activity: "active" mode when the left hand value is greater than the threshold, and "chill" mode when it is less than the threshold. We can tell when the accelerometer gives active measures with equation 2.

$$\text{Time} = \text{TIME\_ACT/ODR} \qquad \text{Eq. 2 [4]}$$

This gives us an output of the time that has passed since detection of the first occurence of an activity. We will be able to measure this time as long as there is a sustained activity level. The heart rate sensor will also be used to detect the level of activity and it is important that this sensor can accurately determine the user's heart rate.

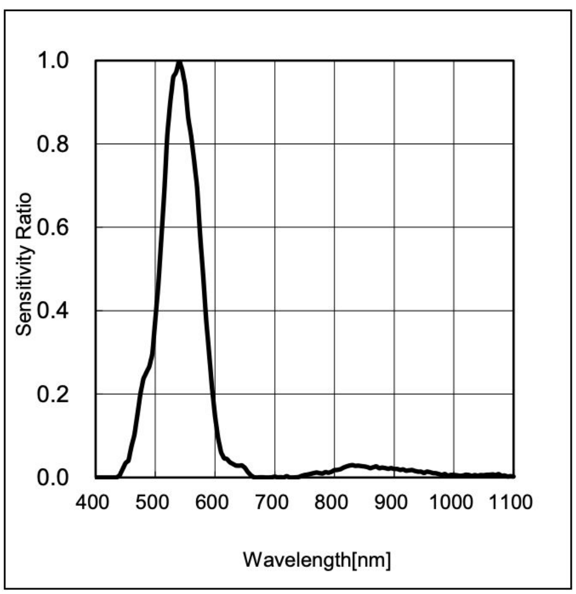

Figure 8. Sensitivity Ratio vs Wavelength for Heart Rate Sensor [5]

From figure 8, we can see that the photodiode's high sensitivity to wavelengths around 500nm to 600nm long means that the green light of the sensor will result in highly accurate pulse wave readings [5]. Other light wavelengths will minimally affect the pulse wave detection so we can ensure that our heart rate sensor will detect accurate information.

The sound sensor will be used to detect the user's environment so it is crucial that it gives reliable data and minimizes the amount of unwanted noise. To combat this issue, we are choosing the placement of the sound sensor on top of the wristband opposite of the PCB and heartbeat sensor. We believe that this placement will help in negating some unwanted noise in the ambient sensor from either bumping into objects or the user themselves. We can also control the gain of the sensor to find the right level needed for our wristband.

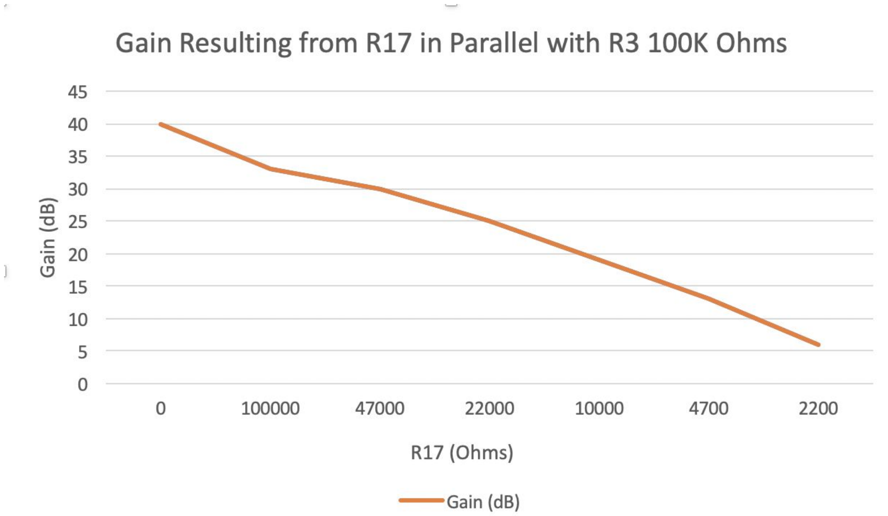

Figure 9. Gain Resulting from R17 in Parallel with R3 100K Ohms [6]

$$Gain(dB) = -5.4643(R17(Ohms)) + 45.571 \quad \text{Eq. 3}$$

By populating R17 in parallel with R3 in the sound sensor, we can reduce the amount of gain from our sensor and test at various values of R17 to find one that results in reliable information [6]. Using this equation we can easily quantify different gain levels before testing our sensor with different R17 values.

3 Cost and Schedule

3.1 Cost Analysis

3.1.1 Labor

Assuming a ten hour work week, where each member of the group works at a $50 hourly rate, and accounting for a multiplier of 2.5 for overhead costs, our total cost of labor is:

$$3\ members \cdot \frac{\$40}{hour} \cdot \frac{10\ hours}{week} \cdot 10\ weeks \cdot 2.5 = \$30{,}000 \qquad \text{Eq. 4}$$

We conclude that the total labor cost of our design process over the next 10 weeks will amount to $30,000.

3.1.2 Parts

Part	Quantity	Cost
NRF52840-DK Microcontroller and Bluetooth Transceiver	1	$49
ADXL362BCCZ-RL Accelerometer	1	$10.39
BH1792GLC-E2 Heart rate sensor	1	$10.91
SEN-14262 Sound sensor	1	$11.95
3898 Lithium Ion battery	1	$6.95
LTC3440EMS#TRPBF Buck-Boost Voltage Regulator	1	$6.99
Schurter 1301.9314 Push Button Switch	5	$1.25
COM-11120 RGB LEDs	3	$3.15

Total	**14**	**$100.59**

3.1.3 Total Cost

Concluding our analysis, we find that the total costs of our project will be the sum of labor costs found in 3.1.1 and the total of the parts cost calculated in 3.1.2. The grand total of the project cost comes out to be $30,100.59.

3.2 Schedule

Week	Nitin	Vignesh	Michael
3/2	Organize parts needed to discuss with machine shop	Organize parts needed to discuss with machine shop	Organize parts needed to discuss with machine shop
3/9	Design initial PCB	Design initial PCB	Design initial PCB
3/16			
3/23	Design song choosing algorithm for smartphone application	Design song choosing algorithm for smartphone application	Implement necessary changes to initial PCB design to include sensors
3/30	Layout initial circuit design using PCB and microcontroller	Start developing application to get and request songs from Spotify library	Layout initial circuit design using PCB and microcontroller
4/6	Continue developing application to include Bluetooth functionality	Work on sensing system for wristband	Work on power and control systems for wristband
4/13	Debug sensors and control system	Finish application user interface and test backend	Work on hardware user interface system
4/20	Test Bluetooth capability of application and	Test and debug hardware user interface system	Test and debug power system and overall circuit

	wristband		
4/27	Final demo and paper	Final demo and paper	Final demo and paper
5/4	Final presentation	Final presentation	Final presentation

4 Ethics and Safety

There is a potential ethical issue that our wristband might discriminate against users that are not able to fit the product around their wrists. To avoid violating code #8 of the IEEE Code of Ethics, our design will be adjustable to fit any size of wrist in order to "treat fairly all persons and to not engage in acts of discrimination" [3].

Another potential ethical issue is that of the durability of the wristband in situations that involve contact with objects or liquids which may damage or destroy the integrity of the circuit. Code #1 of the IEEE Code of Ethics states that our product should "hold paramount the safety, health, and welfare of the public, ... strive to comply with ethical design and sustainable development practices, … [and] disclose promptly factors that might endanger the public or the environment" [3]. To combat this ethical concern the device will be as water resistant as possible to avoid shocking the user or shorting the circuit in accordance with IP66 guidelines. Durability will also be compromised if wires connecting the components in our wristband become exposed. To ensure that this is not an issue, our wristband's exterior will consist of a durable and shock absorbent material, perhaps rubber or plastic, to nullify minor physical collisions that may damage the internal circuit or expose wires within the design.

A safety concern that arises with our project is the risk of overcharging the lithium ion battery that is used to power the voltage regulator that sends power to the rest of the subsystems in the circuit. Despite being smaller and lighter than other lead acid batteries, the inherent danger with lithium ion batteries are that they are highly flammable [7]. Due to the severe risks that are associated with a lithium battery catching on fire if it becomes overcharged , excessively discharged, or exposed to extreme temperatures, the course staff recommends additional fire extinguisher and safety training. It is recommended that an additional circuit is incorporated in our design to ensure that the battery cell voltage does not stray from the threshold of 3.0-4.2V. Our design will address this problem with its voltage regulator circuit, and all of the testing with charging and discharging the battery will specifically be performed when the battery is inside a lithium safety bag and after two TAs have approved the design of our charging circuit [7].

Our wristband will constantly gather information about the user's activity level, environment, and mood. This can lead to an ethical concern over how someone's data is used and where this information goes. According to the IEEE Code of Ethics #5, "to improve the understanding by individuals and society of the capabilities and societal implications of conventional and emerging technologies, including intelligent systems" [3], it should be clear how the application handles the user's data and what it is capable of. We ensure that the application on the user's smartphone is the sole owner of the user's data and that we do not send or own this information in any capacity. Data that is being collected from the sensors and stored in memory in the microcontroller is strictly sent through Bluetooth from the wristband to the phone to be used in an algorithm to pick out a song.

To avoid misleading the user about the product's ability to connect with music services apart from Spotify, the wristband and phone app must clearly reference connection with a Spotify account and various existing songs within Spotify. To avoid confusion, this can be clearly labelled on the wristband as well as within the phone app. By code #8 from the IEEE Code of Ethics, communication of this is key to both Spotify as well as the user "to avoid real or perceived conflicts of interest whenever possible, and to disclose them to affected parties when they do exist" [3].

References

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