# RunCompanion

Team 10

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## 1. Introduction

a. Problem: Many runners struggle to optimize their training because most workout devices on the market only provide static data — like steps, heart rate, and distance—without offering dynamic, real-time feedback based on the actual conditions of their run. Existing fitness devices often fail to guide users during their workout, meaning runners don't receive personalized advice on adjusting their pace or effort in response to changes in their physical state. This lack of adaptive guidance can prevent runners from reaching their full potential, increasing the risk of injury and making it harder to achieve fitness goals. A solution that dynamically integrates multiple sensor inputs to provide real-time, actionable feedback would help runners make informed decisions and optimize their performance during their workout.

b. Solution: Our product is a wearable device designed specifically for runners that provides dynamic, real-time feedback throughout their workout. The device includes buttons for easy input, allowing users to select their run type—whether it's a normal run, HIIT training, or recovery run. Once the workout begins, the device activates multiple sensors to monitor various aspects of the run. The heart rate sensor provides immediate feedback on whether to speed up or slow down based on the selected workout mode. We will combine the IMU data with heart rate data and algorithmically generate feedback displayed via an LED. Post-workout, the device offers comprehensive feedback through data visualization, stored on a phone app. All sensor data is processed by the ESP32 microcontroller, which uses its built-in Bluetooth capability to transmit information to a mobile app, where the user can analyze their performance in detail.

c. Visual Aid:

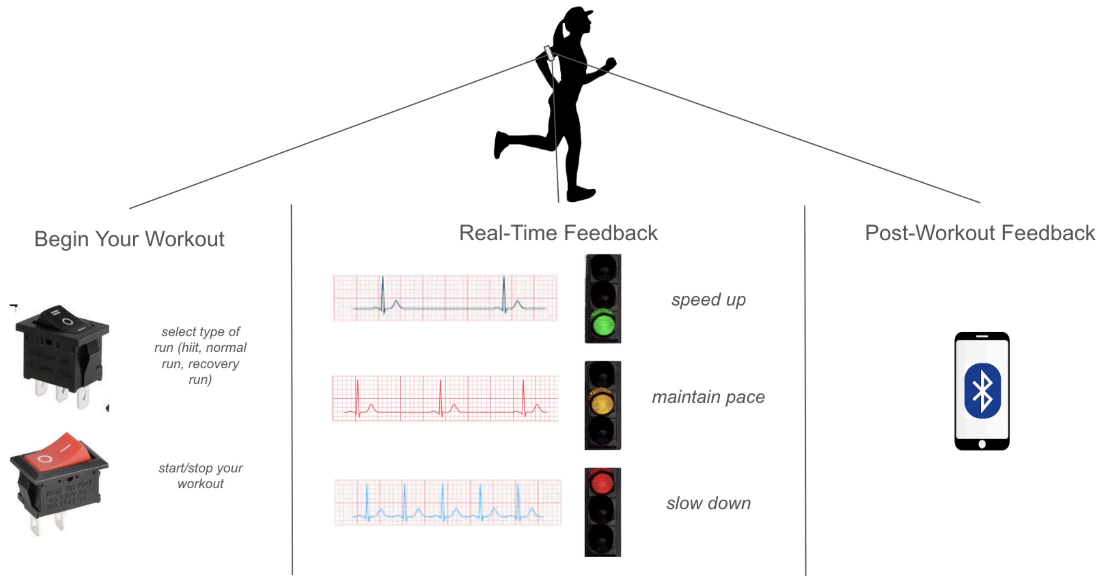


Figure 1: Visual aid of how the overall system works

d. High Level Requirements List:

i. **Requirement 1**: Our device should be able to record the heart-rate signal with an accuracy of ±5 Beats per Minute. The device should also be able to sample and process this data at around a 80 Hz Frequency. Our device's should be able to track angular velocity in both the X, Y, and Z direction with a deviation of ±1°/sec. within +- 0.01g. The device should also be able to sample and process data at a frequency of ideally 80-100Hz. (80-100 Hz range is OK). Our device should be able to filter and process the IMU data with *linear phase* or *little to no phase delay* at all.

ii. **Requirement 2:** The product shall be powered by a rechargeable Lithium-Ion battery, running at normal-performance (3.7V, 400-500mAh) and charge via USB-C. We expect the battery to function at full-performance for approximately 90 minutes.

iii. **Requirement 3:** This product should be about 550 grams, and the dimensions should approximately be within 7.62 cm to 12.7 cm wide, 20.32 cm to 25.4 cm high, and about 2.54 cm to 5.08 cm thick.

e. Reasoning for High Level Requirements:

i. *Reasoning for Requirement #1 (i):*

1. The heart's electrical signals typically range between 0.5 to 40 Hz. To capture these signals accurately and avoid any distortion from aliased frequency components, we've chosen a sampling rate of 80 Hz. This ensures that we preserve the integrity of the heart's signal while preventing interference from unwanted frequencies. Studies indicate that most human activity, such as running or general movement, generates frequency components in the 0.5 to 20 Hz range. Although less common, frequencies above 40 Hz can occasionally occur during certain actions. By sampling at 80 Hz, we effectively prevent aliasing of these angular velocity and acceleration signals. For rare, high-frequency events (e.g., a sudden stop followed by rapid leg tapping with a 42 Hz frequency), any resulting aliasing is acceptable since our primary focus is on capturing typical running motions. We want to filter our signals using filters with linear phase or little to no defined phase delay at all so will either not deal with latent signals post-processing or if we do use FIR filters and have a linear phase delay, we will be able to recognize this phase delay when we analyze our filtered signals in a frequency basis and accordingly ***quantitatively*** account for these phase delays when designing the algorithm. We've set strict error tolerances for angular velocity, acceleration, and heart rate measurements to ensure accurate and reliable data collection. However, if testing reveals higher-than-expected noise in sensor data, we are prepared to adjust these tolerances. Any such adjustments will be carefully evaluated to ensure they do not compromise the integrity of the algorithm's output or performance.

ii. *Reasoning for Requirement #2 (ii):*

    1. Reasoning provided in the Tolerance Analysis section.

iii. *Reasoning for Requirement #3 (iii):*

    1. The total weight of the components for your project is around 500 grams, excluding the PCB. Here's the breakdown:
        - MAX30102EFD heart rate sensor: 3g
        - LSM6DS3 accelerometer/gyroscope: 1g
        - R4DBLKBLKBF0 3-position rocker switch: 11g
        - RA1113112R-3457780 2-position rocker switch: 5g
        - ESP32 microcontroller: 10g
        - Six Wurth Elektronik LEDs: 9g
        - 3.7V Li-Po battery: 35g
        - Miscellaneous components (resistors, capacitors, etc.): 10-15g
        - DC-57P Heavy-Duty Electronics Enclosure: 304g
        - Armband: 50g
        - PCB: Estimated 50g

       In addition, the PCB itself should weigh approximately 50 grams itself. This was calculated through LeitOn DE's PCB weight calculator tool [9]. The approximated width and height is 12.7 cm and 25.4 cm respectively. This is based on an ergonomic fit for the user as if it were sized akin to a phone's armband.

## 2. Block Diagram:

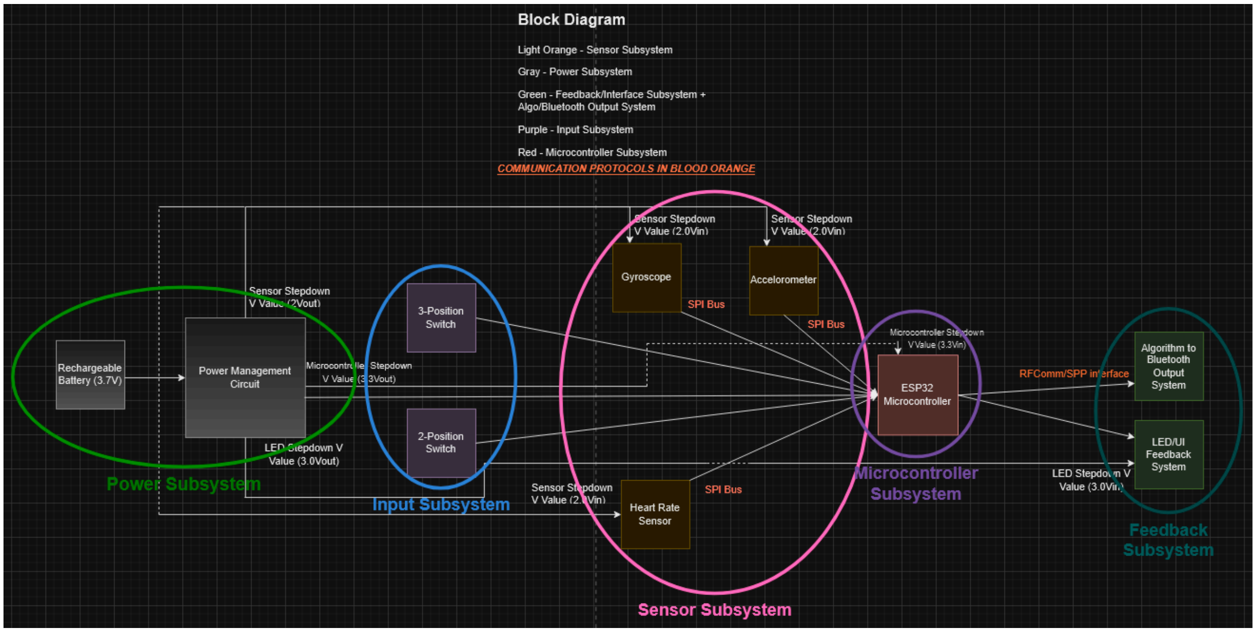


Figure 2: Block Diagram showing the specific details on how all subsystems are connected with each other.

## Subsystems:

### Sensor Subsystem

**Overview**:

Overview: The Sensor Subsystem is crucial for collecting workout data. It includes a heart rate sensor and an inertial measurement unit (IMU), consisting of an accelerometer and gyroscope. The heart rate sensor measures the user's heart rate to provide real-time feedback on workout intensity, while the accelerometer and gyroscope monitor movement, contributing to comprehensive data on the user's running performance.

**Requirements & Verification (R&V)**:

- **Heart Rate Sensor (MAX30102EFD [1])**
  - **Requirement**: The heart rate sensor must transmit real-time heart rate data with minimal latency, operating within 1.8V – 2V and drawing 0.6 – 1.1 mA. The sensor should provide accurate heart rate readings with a tolerance of ±5 BPM and a transmission delay of no more than 2 seconds.
  - **Verification**:
    1. Quantify the noise by testing our heart rate data vs an on-the-market heart rate sensor device such as an Apple watch by recording data on the same subject with both methods over time.
    2. Ensure that the current draw accordingly changes based on intensity of usage by using a multimeter across the power pin of the Heart Rate sensor. Verify that VIn stays generally consistent however across the same pin.
    3. Quantify the data latency by measuring the difference in time between when a certain value is read on the SPI data bus connecting the microcontroller to the heart rate sensor to when the same value is read by the microcontroller.
  - **Location:** To specify the heart rate sensor location, it is actually not within the box due to it needing to take a measurement but we will attempt to wire a connection from the PCB to the sensor where it can be snaked to a location of the

users choosing that can be easily accessible by the user onto their arm or neck where it will be easy to take a reading of a heart rate.

- **Accelerometer & Gyroscope (STM LSM6DS3 [2])**
  - **Requirement**: The accelerometer and gyroscope must measure movement and rotation accurately, within ±2% for linear motion and ±2°/sec for rotational motion. They should operate within 1.8V – 3.6V and draw no more than 1.25 mA. Data transmission delay must be <1.5s.
  - **Verification**:
    1. Quantify the noise by testing our accel/gyro data vs an on-the-market accel/gyro sensor device such as an Apple watch or a tablet by recording data on the same subject with both methods over time.
    2. Ensure that the current draw accordingly changes based on intensity of usage by using a multimeter across the power pin of the IMU. Verify that VIn stays generally consistent however across the same pin.
    3. Quantify the data latency by measuring the difference in time between when a certain value is read on the SPI data bus connecting the microcontroller to the IMU to when the same value is read by the microcontroller. On the hardware end, this can be done with an oscilloscope's analog waveform view.

**Connection to Other Units**:

- **Microcontroller**: The sensor data is sent to the microcontroller for processing.
- **Power Subsystem**: The sensors receive power from the main battery via regulated voltage supply to ensure stable operation.

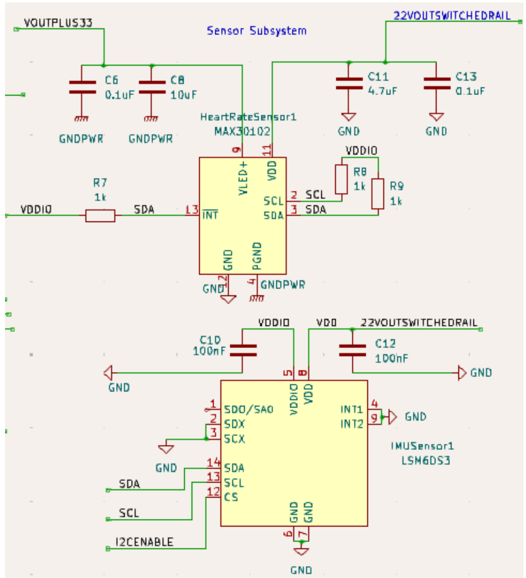


Figure 3: Schematic of Sensors that will be utilized within RunCompanion

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### Input Subsystem (User Interface)

**Overview**:

The Input Subsystem allows the user to control the workout device by selecting the type of run (via a 3-position switch) and starting or stopping the session (via a 2-position switch). These inputs allow the user to interact with the system intuitively during their workout.

**Requirements & Verification (R&V)**:

- **Rocker 3-Position Switch (R4DBLKBLKBF0 [3])**
  - **Requirement**: The switch must allow the user to select their workout mode and transmit signals within 1 second. It should provide clear tactile feedback.
  - **Verification**:
    1. Verify that differing switch positions can be read with an oscilloscope digitally (ideally use digital channels, if not we will manually quantize based on the analog values) to ensure that upon appropriately quantizing our analog signal output of the switch it displays the appropriate value

(000, 001, 010) for the three values so that the signal into the microcontroller is accurate.

- **Rocker 2-Position Switch (RA1113112R-3457780 [4])**
  - **Requirement**: The 2-position switch must allow the user to start or stop their workout session with a response time of <1 second.
  - **Verification**:
    1. Since the 2-Position Rocker switches are used as power switches (controlling power flow and not signal data, we can simply test the I/O and ensure we receive open/closed circuits on the output end based on different switch positions).

**Connection to Other Units**:

- **Microcontroller**: The switches send workout mode and session control signals to the microcontroller for processing.
- **Power Subsystem**: Although the switches themselves draw no current, they are connected to the microcontroller for signal transmission.

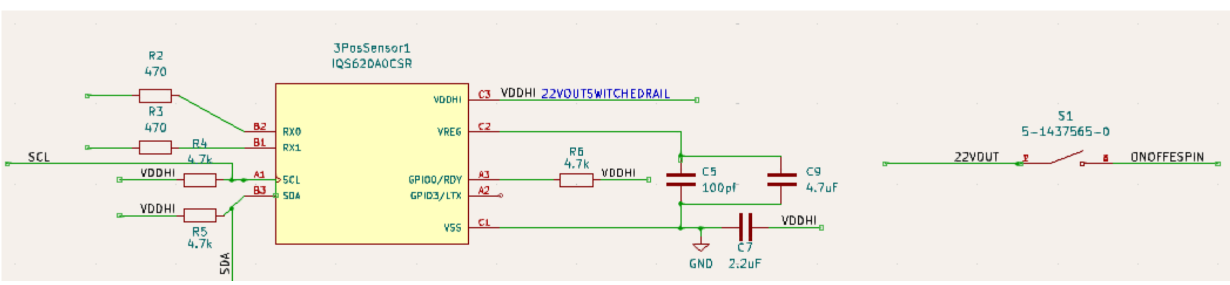


Figure 4: Schematic of Input Systems that will be utilized within RunCompanion

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## Microcontroller Subsystem

**Overview**:

The microcontroller is the central hub of the system, responsible for processing data from the sensors and controlling feedback. It also handles Bluetooth communication with the mobile app for post-workout analysis. The microcontroller ensures the system runs smoothly by executing real-time processing and delivering feedback based on sensor inputs.

**Requirements & Verification (R&V)**:

- **ESP32 Microcontroller (ESP32 [5])**
    - **Requirement**: The microcontroller must ***process*** data from all sensors upon receiving the data with a delay of <1s and transmit data via Bluetooth with a delay of <2 second. It must operate at 3.3V with a current draw of 120mA in active mode and an additional 160mA during Bluetooth transmission.
    - **Verification**:
        1. Test different operating modes for the ESP32 (ie; RF Transmission On/Off etc) and use an oscilloscope/multimeter to measure the current on the Vin port, as well as the current on the SPI pinouts. Likewise, we should be able to verify that the VIn and SPI pinouts also provide voltage stability (ie; measuring around 3.3V on the VIn pin) but have a difference in current draw when we draw differing loads from the GPIO pins.
        2. Ensure the signal integrity of signal pins through multiple means to ensure that the clock signal timing holds consistent. View the jitter from rising edge to rising edge, as well as EMI/RF noise such as crosstalk and RF reflections to ensure that it is as minimal as possible.
        3. Test the ESP32 bluetooth latency by operating the processor at different clock speeds. Calculate the Transmission->Reception time and compare to ensure that even with differing CPU performances the Bluetooth signal is received in a timely fashion.
    - **Bluetooth Specification:** To further specify the bluetooth specification and usage within our project, we will utilize the onboard built-in bluetooth module of the ESP32 to enable us to offload data from the ESP32 to the mobile app we are developing to allow for users to view their data after they complete their runs.

**Connection to Other Units**:

- **Sensors**: The microcontroller processes data from the heart rate sensor, accelerometer, and gyroscope.
- **Feedback Subsystem**: It controls the LEDs for real-time feedback and sends data to the mobile app via Bluetooth.
- **Input Subsystem**: The microcontroller receives user inputs from the 3-position and 2-position switches.
- **Power Subsystem**: It is powered by the main battery and requires voltage regulation to prevent over-voltage issues.

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### Feedback Subsystem (Software)

**Overview**:
The Feedback Subsystem provides the user with real-time workout guidance via LEDs, and post-workout analysis through a mobile app. The LEDs use a traffic-light system to guide the user on pace adjustments, while the mobile app visualizes sensor data to help users improve their performance.

**Requirements & Verification (R&V)**:

- **LED Feedback System (150080BS75000 [6])**
  - **Requirement**: LEDs must provide feedback within 1 second of receiving input from the microcontroller. Each LED operates at 2V – 3V with a current draw of 10 – 20mA.
  - **Verification**:
    1. Ensure that the LEDs only illuminate above a certain threshold (specified operating voltage)
    2. Test LED response time using an oscilloscope to confirm the 1-second requirement is met. This can be done by tracking the time between rising edge of the Microcontroller output (sending power to the LED) going high to the LED subsequently turning on.

    3. Test system response in different scenarios to ensure LEDs display accurate feedback for "Speed Up," "Slow Down," and "Maintain Pace" in real-time.

- **Mobile Application**
    - **Requirement**: The app must provide accurate workout statistics and visualizations, with data transmitted from the microcontroller within 1 minute of workout completion.
    - **Verification**:
        1. Measure Bluetooth transmission time to ensure that all workout data is transmitted to the mobile app within 1 minute.
        2. Compare the sensor data stored in the mobile application with actual values recorded by the heart rate sensor, accelerometer, and gyroscope to verify accuracy.
        3. Test the bluetooth connection in different environments and conditions to ensure that the application will always be updated.

**Connection to Other Units**:

- **Microcontroller**: The microcontroller sends sensor data to both the LEDs and the mobile app for feedback.
- **Power Subsystem**: The LEDs draw power from the main battery, requiring stable voltage for continuous operation.

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## Power Subsystem

**Overview**:
The Power Subsystem provides energy to all other subsystems, ensuring continuous operation throughout a workout session. It consists of a 500mAh rechargeable battery and a power management circuit to regulate voltage and protect against overcurrent.

**Requirements & Verification (R&V)**:

- **Rechargeable Battery**
  - **Requirement**: The battery must provide 3.7V ± 0.1V and supply at least 342mA continuously for 90 minutes of operation.
  - **Verification**:
    1. Run a capacity test by operating the entire device under normal conditions and timing how long it lasts before the battery depletes.
    2. Test the USB-C charging circuit by measuring charging time and ensuring it completes in 1.5 hours or less from an empty state.
- **Power Management Circuit**
  - **Requirement**: The power management circuit must regulate voltage to ±0.1V and include overcurrent protection for currents exceeding 500mA.
  - **Verification**:
    1. Step 1 involves utilizing a multimeter to ensure that upon different voltage division the output voltage is as expected for different branches - ie; sensor power, LED power, switch power.
    2. We will simulate current draws by using a multimeter to test currents on these same branches when different load conditions occur. Example scenarios involve having all sensors operate at high performance, all LEDs being on, and the Microcontroller having RF transmission.
    3. Based on the current values of of power output branches, we will verify that our overcurrent protection circuitry limits the loading to the elements that have potential to draw high current values (the ESP32, the IMU, and the heart-rate sensors if the appropriate power branch that serves the respective unit (IMU/Heart-Rate, Microcontroller) has reached a threshold ampacity we define as a current limit.

**Connection to Other Units**:

- **Sensors, Microcontroller, Feedback Subsystem**: The battery provides power to all other components, while the power management circuit ensures stable operation.

## Tolerance Analysis

The total current draw and weight of the system are critical factors in ensuring that the design will function as expected, without overloading the power supply or causing system instability, while also ensuring that it remains portable and wearable, similar to phones in armbands used by runners.

**Total Current Draw:**

- ESP32 Microcontroller: 280mA (active + Bluetooth)
- Heart Rate Sensor: 1.1mA
- Accelerometer & Gyroscope: 1.25mA
- 3-Position Switch: 0mA
- 2-Position Switch: 0mA
- LED Feedback System (3 LEDs): 60mA

Total Current = 280mA + 1.1mA + 1.25mA + 0mA + 0mA + 60mA = **342.35mA**

**Battery Life Calculation:**

The system uses a **500mAh** battery. Based on the total current draw, the battery life can be calculated as follows:

Battery Life (hours) = 500mAh / 342.35mA ≈ **1.46 hours** ≈ 87.6 minutes

This is sufficient for a typical workout session, as the system will last approximately 87 minutes of operation under full load.

**Voltage Consistency:**

The **3.7V Li-Po battery** is compatible with all components, and voltage regulation will ensure a stable power supply. Components that operate below 3.7V (e.g., the heart rate sensor at **1.8V**) will receive regulated power to prevent over-voltage issues. This ensures smooth operation and reduces the risk of malfunction.

**Size and Weight Considerations:**

In terms of size, the components are carefully selected to ensure the device is compact and portable, fitting comfortably in an armband, much like a phone. Phones like the **iPhone Max** typically weigh **228 grams** without a case, while a phone with an armband and a protective case can weigh **300 grams or more**.

Our total device weight is estimated to be approximately **500 grams**, including the enclosure and the armband. However, the actual electronic components contribute just **74 grams**, ensuring the device itself is not heavy. Given that the enclosure and armband add most of the weight, this design is still in a comfortable range for wearables during a workout. Furthermore, we plan to hollow out as much as we can of the enclosure to still allow for the great protection we plan to have, just without the additional weight when using a strong material such as hard plastics that will protect against common day to day impacts. We are also considering different options for enclosures if the weight still ends up being too much such as utilizing an armband of sorts or combining the enclosure with the armband to ensure a secure fit onto the runner to allow for it to seem natural.

| Component | Description | Weight (grams) |
|---|---|---|
| MAX30102EFD Heart Rate Sensor | Monitors heart rate data | 3 |
| LSM6DS3 Accelerometer & Gyroscope | Tracks motion and rotation | 1 |
| R4DBLKBLKBF0 3-Position Rocker Switch | Selects workout mode | 11 |
| RA1113112R-3457780 2-Position Rocker Switch | Controls start/stop functionality | 5 |
| ESP32 Microcontroller | Central processing and Bluetooth communication | 10 |

| | | |
|---|---|---|
| Wurth Elektronik LEDs (3) | Provides visual feedback | 9 |
| 3.7V Li-Po Battery | Powers the entire system | 35 |
| Miscellaneous Components (Resistors, Capacitors, etc.) | Required for device functionality | 10-15 |
| PCB (Printed Circuit Board) | Supports all electronic components | 50 |
| DC-57P Heavy-Duty Electronics Enclosure | Enclosure for housing the device | 304 |
| Target All-In-Motion Armband | Holds the device on the user's arm | 50 |
| Total Weight | | ~500 grams |

Figure 5: Table displaying the component, description, and weight of all the components utilized in the system.

Compared to carrying a phone in an armband, which can weigh around **300-350 grams** with accessories, the **RunCompanion** device is slightly heavier but offers more robust functionality for runners. The design remains portable, ergonomic, and secure for extended workouts.

**Overcurrent Protection:**

The power management system includes overcurrent protection, which will prevent any component from drawing excessive current and will protect the system from potential damage or instability. This is crucial for the long-term durability of the product, ensuring that even in peak usage scenarios, the device remains functional and reliable.

**Component Variability and Environmental Factors:**

Each component in the design is selected with a tolerance to handle slight variances in operating conditions. For instance, the heart rate sensor operates between **1.8V and 2V**, and the accelerometer operates between **1.8V and 3.6V**, ensuring stable performance despite fluctuations in battery voltage. Additionally, the power system ensures these components receive the right voltage.

The design is also built to withstand environmental variability. Runners may use the device in both hot and cold environments, so all components are chosen for their ability to perform under a wide temperature range. The enclosure will protect sensitive electronics from sweat, dust, and temperature fluctuations during runs.

### Noise Reduction (FIR Filtering/Stochastic Filtering):

To ensure accurate sensor readings, especially from the accelerometer and gyroscope, **FIR filtering or Stochastic Filtering** will be applied to reduce noise. This will prevent false readings and improve the accuracy of real-time feedback to users, even during rapid movement or changes in environment.

### Component Aging and Degradation:

Battery performance typically degrades over time, which will affect the overall battery life. However, with a starting life of **87 minutes**, the device will still perform within acceptable limits for over a year of regular use. Additionally, the sensors and microcontroller are chosen for their durability, ensuring that they continue to perform accurately even after extended periods of use.

## Risk Analysis

The wearable device designed for runners relies on various hardware components such as the MAX30102EFD heart rate sensor, the STM LSM6DS3 accelerometer and gyroscope, and a 3.7V 500mAh Li-Po rechargeable battery. Each of these components plays a critical role in delivering accurate, real-time feedback to users, but their failure or improper functioning presents potential risks to both the user and the device's overall performance.

1. Sensor Accuracy Risks
    a. Heart Rate Sensor (MAX30102EFD): If the heart rate sensor provides inaccurate or delayed readings, it may suggest an incorrect workout intensity. This could lead to overexertion or underperformance, potentially causing fatigue or injury due to improper workout guidance.
        i. Mitigation: We will use FIR filtering to minimize noise in the sensor signals without introducing phase delays. The device will undergo extensive testing in different environmental conditions to ensure the heart rate readings remain accurate in real-world running scenarios.
    b. Accelerometer and Gyroscope (STM LSM6DS3): If the motion sensors fail to track the user's movement accurately, the feedback on running form, pace, or effort could be misleading. This could lead to improper adjustments to running posture or speed, increasing the risk of injury.
        i. Mitigation: The sensors will be calibrated in diverse running environments, and secured wiring will be used to prevent disconnections or signal degradation due to movement or vibration.

2. Battery and Power Supply Risks
    a. Overheating or Short Circuiting: The Li-Po rechargeable battery is susceptible to overheating, short circuiting, or fire if improperly handled or exposed to environmental factors like sweat, dust, or impact during a run.
        i. Mitigation: The battery will be housed in a robust, non-conductive, and water-resistant enclosure to protect it from external damage, sweat, and

moisture. Regular inspection and maintenance guidelines will be provided to users to ensure safe battery use.

b. Battery Life: A depleted or malfunctioning battery could result in the device shutting down mid-run, preventing the user from receiving real-time feedback.
    i. Mitigation: Battery level indicators will notify the user of low battery, and the device will be designed to function efficiently within the battery's capacity for extended use during workouts.

3. Wiring and Connections Risks
    a. Loose or Frayed Wires: The wiring connecting the sensors and microcontroller could loosen or become frayed due to repetitive motion during running. This could lead to sensor failures or inaccurate readings, potentially affecting feedback accuracy and leading to inappropriate workout intensity.
        i. Mitigation: The wiring will be secured and insulated to prevent disconnection or short-circuiting. Vibration-resistant designs will be incorporated, ensuring the connections remain intact throughout the workout.

4. Environmental and Usage Risks
    a. Moisture and Sweat Exposure: As a wearable device, exposure to sweat and environmental moisture could cause malfunction or damage to the internal electronics, affecting sensor accuracy or device operation.
        i. Mitigation: All components, including the battery and wiring, will be housed in water-resistant enclosures, protecting them from moisture intrusion. The device will be rated for sweat and environmental exposure to ensure reliability during exercise.

5. User Safety Risks
    a. Incorrect Feedback Leading to Injury: Inaccurate or delayed feedback could prompt users to push beyond safe limits or perform exercises with improper form, increasing the risk of injuries such as muscle strain or overexertion.

i. Mitigation: Redundant signal filtering and calibration will ensure that feedback is consistently reliable. The device will also incorporate safeguards to alert the user if sensor accuracy drops below acceptable levels during use.

## Cost Analysis

| Description | Part Number | Cost of Part | Total Cost (cost of part + tax + shipping) | Link |
|---|---|---|---|---|
| Heart Rate Sensor | MAX30102EFD+TCT-ND | $14.19 | $22.32 | Link https://tinyurl.com/445heartsensor |
| IMU Sensor | LSM6DS3 | $6.74 | $13.27 | Link https://tinyurl.com/IMUsensor |
| 2 Position Switch | SW-SPDT-OO | $1.50 | $6.62 | Link https://tinyurl.com/2positionswitch |
| 3 Position Switch | R4DBLKBLKBF0 | $1.91 | $10.05 | Link https://tinyurl.com/3posswitch |
| Microcontroller | ESP32-S3 | $28.07 | $28.06 | Link https://tinyurl.com/s3neopart |
| LED | CLS6B-FKW | $0.38 | $8.40 | Link https://tinyurl.com/creedled |
| Battery | TURN1000-1S | $1.69 | $14.11 | Link https://tinyurl.com/battery445 |
| Enclosure | DC-57PMBYT | $13.07 | $23.03 | Link https://www.polycase.com/dc-57p |
| PCB Cost | N/A | $30 | $30 + shipping + tax | N/A |
| Arm Sleeve | Item Number: 082-02-2568 | $10.99 | $18.51 | Link https://tinyurl.com/armband445 |
| Screws for PCB Mounting | SCREWS-MBR-100 | $4.22 | $13.47 | Link https://www.polycase.com/screws-mbr-100 |

Figure 6: Parts and the costs associated with procuring them

The total cost for the parts as listed in the table of figure 4 is: $187.84 with shipping and tax included. Assuming a compensation of around $45/hour, and utilizing the equation of $45 * 2.5 * 60, we can assume a total compensation per person of $6750. Including the two others in the group the total compensation will be $20,250 in terms of labor cost. This brings the total cost to $20437.84 which includes parts, shipping, tax and labor costs.

## Schedule

| Week | Task(s) | Who? |
|---|---|---|
| 10/07/2024 | Attend design review with professor and finalize overall design | Everyone |
| | Finalize PCB design and submit for first-round audit | Rohan, Advaith |
| | Order necessary components for PCB and sensors | Everyone |
| | Initial design for LED flashing algorithm | Arnav |
| | Start mobile app framework development | Arnav |
| 10/14/2024 | Begin PCB assembly and wiring for sensor connections | Rohan, Advaith |
| | Develop basic ESP32 firmware for sensor data collection | Arnav |
| | Debug first PCB iteration on Kicad | Everyone |
| | - Draft mobile app interface design | Arnav |
| 10/21/2024 | Test LED flashing algorithm with real-time sensor data | Arnav, Advaith |
| | Refine and re-order PCB if needed (second round audit) | Rohan, Advaith |
| | Continue ESP32 and Bluetooth integration | Arnav, Rohan |
| 10/28/2024 | Test PCB connections with power system and sensors | Rohan |
| | Test Bluetooth communication from ESP32 to mobile app | Arnav |

| | | |
|---|---|---|
| | Finalize LED feedback logic and integrate with sensors | Everyone |
| | Submit for third-round PCB audit if needed | Everyone |
| 11/04/2024 | Integrate mobile app with Bluetooth and display sensor data | Arnav, Advaith |
| | Optimize PCB design and wiring for final iteration (if needed) | Rohan |
| | Debug and refine algorithm and firmware for sensor and LED control | Arnav, Advaith |
| 11/11/2024 | Conduct full system tests: hardware and software integration | Everyone |
| | Conduct full system tests: hardware and software integration | Arnav |
| | Finalize mobile app data export and visualization | Arnav |
| 11/18/2024 | Perform endurance and stability tests (battery life, long sessions) | Rohan, Advaith |
| | Conduct mock demo with TA and gather feedback | Everyone |
| | Make adjustments based on mock demo feedback | Everyone |
| 11/25/2024 | Refine project for final demo and fix any remaining bugs | Everyone |
| | Prepare final presentation materials | Everyone |
| 12/02/2024 | Final demo and system presentation | Everyone |

Figure 7: Planned schedule for who will complete what tasks leading up to the deadlines

## Ethics & Safety

Taking a look at the "IEEE Code of Ethics" [7] and the "ACM Code of Ethics and Professional Conduct" [8], there are some guidelines this project must follow to adhere to them to be beneficial towards society. This project is in guidelines with with specifically I.1 within the IEEE Code of Ethics as it states, "to hold paramount the safety, health, and welfare of the public, to strive to comply with ethical design and sustainable development practices, to protect the privacy of others, and to disclose promptly factors that might endanger the public or the environment" [7] and this project successfully satisfies those conditions [7]. Furthermore, this project also satisfies the ACM Code of Ethics where it states, "Contribute to society and to human well-being, acknowledging that all people are stakeholders in computing." in section 1.1 [8].

This wearable device made for runners is focused on only monitoring and improving their running performance through real-time feedback based on heart rate and respective movement data. It is made to enhance the user's running experience and to optimize their workouts, hence it is a positive tool. The data collected is utilized to improve the runner's experience/workout by guiding improvements on their pace, form, and effort. Beyond the information regarding running performance, the system does not collect any unique identifier information. This reduces the risk of this product for being used unethically.

In addition, by helping runners with optimizing their workouts, the device will be able to help with reducing the risk of injury, which is commonly seen in poorly planned/followed workout routines. The ethical positivity of this project is the fact that it is promoting health and fitness, to aid in the end user to achieve their workout goals safely. The ACM Code of Ethics encourages the development of technologies that benefit human well-being [8]. As this product is directly aimed towards benefitting humans this project satisfies that requirement. The device also utilizes data-based scientific feedback to users, hence it does not mislead the user. This also supports the positive morality about the project. Due to all of these reasons, this project aligns with ethical standards and has a clear societal benefit.

There are some safety issues to consider when sensors such as the MAX30102EFD [1] heart rate sensor and the STM LSM6DS3 [2] accelerometer and gyroscope are being used. The accuracy of the heart rate sensor must be accurate as any improper readings can alter the output of the real-time dynamic feedback provided by the algorithm hence causing improper and even dangerous workout intensities. To mitigate this issue, we will use redundant signal filtering using FIR/Kalman/Stochastic filtering to minimize noise without introducing any phase delays. This will ensure that the feedback will be reliable and correct. To further test the various scenarios, we will test in various environments to calibrate and test sensor accuracy in a wide variety of real-world scenarios.

The safety of the 3.7V 500mAh Li-Po rechargeable battery is also a concern of this developed device. Possible issues could be overheating, short circuiting, and even fire, and to mitigate all of these scenarios, the battery will be housed in an enclosure to protect it from sweat, dust, impact, and even possible punctures. This enclosure to satisfy all of these conditions will be made out of a non-conductive hard material such as plastic. This battery enclosure will also have to be water resistant to prevent any moisture from infiltrating the battery enclosure causing issues.

Additionally, the wiring of this device must be secured and insulating to prevent any short circuits and interference with the sensor readings. The wires connecting the heart rate sensor, accelerometer, and gyroscope will be secured to prevent them from becoming loose or frayed due to the vibration during running. If they were to come loose, the accuracy of the sensors will drop very drastically. Overall, by ensuring that the battery and the wired connections are durable and secured, the accuracy of the overall system can be assured. As stated earlier, it was stated that this project will satisfy both the IEEE Code of Ethics and the ACM Code of Ethics, and through the later detailed paragraphs it has been shown that it is in fact true. This project will be transparent so the end users will always be informed about their rights and safety in regards to the use of this product.

## References


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[7] IEEE - IEEE Code of Ethics. (n.d.-b). https://www.ieee.org/about/corporate/governance/p7-8.html

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