

Gesture Based Turn Signaling System

ECE 445 Proposal Spring 2024

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1 Introduction

1.1 Problem

Cyclists, skateboarders, and scooter riders often face challenges in signaling their intentions to drivers, especially in low-light conditions. According to the CDC, 1,000 cyclists die and 130,000 are injured every year on the road in the United States [1]. These numbers don't include other riders sharing the road on things like skateboards and scooters. There are many interventions in place to prevent these accidents, such as fluorescent or retro-reflective clothing, or active lighting on the bicycle (required by law in most states) [1], but the traditional method of using hand signals is not always visible or practical, particularly at night or during adverse weather conditions. This lack of clear communication can lead to dangerous situations on the road, as other motorists may fail to recognize the cyclist's intended maneuvers, or if an accident occurs.

1.2 Solution

To address this issue, we propose the development of a gesture recognition-based turn signaling system for cyclists and scooter riders. This system will utilize a combination of sensors, such as accelerometers and gyroscopes, integrated into a wearable like a jacket. Then we process the sensor data to identify specific arm gestures made by the rider and activate corresponding LED signals. For example, if the rider extends their arm straight to the left, the left turn signal is activated, or if the rider indicates a stop, then the brake light is activated, and so on. Additionally, the sensors will be able to detect when the rider has had an accident or a crash, and activate a hazard signal.

We propose placing an IMU above (or below depending on how hard it is to differentiate between movements) the elbow on each arm of the wearable. The microprocessor will then receive and process the data from the IMU, determining what kind of movement has been made. Then, depending on the movement, it will output a specific signal to the LEDs to display on the back and arms of the wearable.

2 Design

2.1 Block Diagram

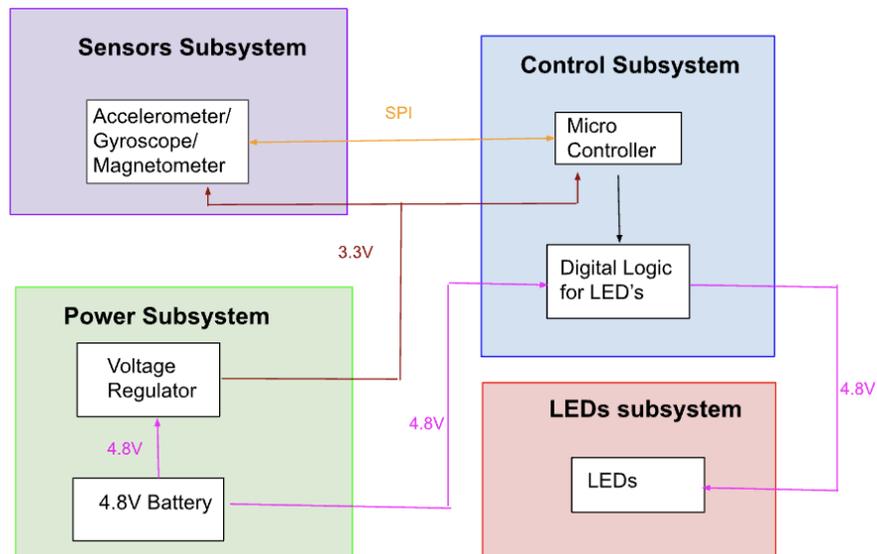


Figure 2: Block Diagram of the system

2.2 Subsystem Overview

2.2.1 Control Unit:

We will design our PCB and microcontroller to be able to receive data through SPI from the sensors, analyze the data, and display the correct signal on the LEDs. The data will consist of acceleration, rotational, and magnetic orientation data from the 9 degrees of freedom (9DoF) IMU. The PCB will contain the microcontroller, power the sensor suite, and contain digital logic to control the LEDs. We will use the ESP32 microcontroller [3] to process the data from the sensors and output the correct signals to the LEDs.

2.2.2 Power Subsystem:

We will use a 4.8V rechargeable battery to power the components, 4.8V for the LEDs, and use a voltage regulator [4] to power the microcontroller and sensors at 3.3V. We can place the battery in an inner pocket of the wearable, making it easy to wire it to all parts.

2.2.3 Sensors Subsystem:

For the sensors, we will use a 3.3V 9dof IMU (accelerometer, gyroscope, magnetometer) [5] for each arm, and use the combined data from both to determine the nature of the motion. In an accident for example, the acceleration will spike, indicating an accident. To distinguish between the other signals, we will use the gyroscope to determine the angle of the gesture. The IMUs will be powered directly by the power subsystem through a voltage regulator to step the voltage down to 3.3V. The sensors will communicate with the ESP32 microcontroller through SPI for data transfer.

2.2.4 LEDs Subsystem:

The LED subsystem should be able to turn on the LEDs when powered by a 4.8V input from the control/power subsystems. We will use 2 LED strips with a length of 80 cm each. The strips will start from the upper chest toward the upper back, then it will go towards the wrist, refer to the visual aid for clarifications.

2.3 Subsystem Requirements

2.3.1 Control Unit:

The control unit should be able to receive SPI data from the sensor subsystem and use the ESP32 microcontroller to analyze it in order to route the 4.8V from the battery to power the LEDs. To control the LEDs, we will add transistors [6] to the PCB.

Requirements:

- Must be able to communicate with the sensors and LEDs through the PCB
- Must be able to determine the correct turn signal from the IMU
- Must be able to determine the correct movements/accident from the sensor data

2.3.2 Power Subsystem:

The Power subsystem should be able to output 4.8V through the control unit to power the LEDs, as well as output 3.3V to power the Control and Sensors subsystems. The power to the LEDs should pass through transistors [6] in order for the microcontroller to activate/deactivate the LEDs.

Requirements:

- Must be able to supply $3.3\pm 0.3V$ to the IMUs and the ESP32
- Must be able to supply $4.8\pm 0.3V$ to the LEDs
- The temperature of the battery should stay below 50 C during operation

2.3.3 Sensors Subsystem:

The sensor subsystem should contain an IMU (accelerometer, gyroscope, and magnetometer) for each arm, read and controlled by the ESP32 microcontroller via an SPI signal. The data should contain acceleration, rotational, and cardinal direction data and should be filtered properly so as to not miss vital information and not cause false signals. The IMUs will be powered by a 3.3V input via the Power Subsystem.

Requirements:

- Must be able to constantly communicate with the ESP32 throughout a power cycle (1 hour).
- The accelerometer must be able to detect acceleration within $\pm 1m/s$.
- The magnetometer must be able to detect North.
- The gyroscope must be able to detect angular rate within ± 15 dps.

2.3.4 LEDs Subsystem:

The LED subsystem should be able to turn on the LEDs when powered by a 4.8V input from the control/power subsystems.

Requirement:

- Must be able to turn on and off given a 4.8V input.
- Must be bright enough for drivers to see from 250ft.

2.4 Tolerance Analysis

We will be using several components operating at 3.3V and a 4.8V battery that allows recharging. Therefore we need to use a voltage regulator to step down the voltage for the sensors and the ESP32. Considering that our product is a wearable, it is important that the component, specifically the linear regulator, doesn't get too hot. We can calculate the change in temperature of the linear regulator by first calculating the power dissipated using $I_{out}(V_{in} - V_{out})$ and multiplying it by the thermal resistance of the linear regulator (Θ_{jc}).

ESP32 worst case current draw: 355 mA

2 IMUs, current draw for each: 4.6 mA

Total current draw: 364.2 mA

Assumed ambient temperature: 25°C

$$\Delta T = I_{\text{out}}(V_{\text{in}} - V_{\text{out}})(\Theta_{\text{jc}}) = 0.36 \times (4.8 - 3.3) \times 5 = 2.7^\circ\text{C}$$

$$\text{Final Temperature} = \Delta T + \text{Ambient Temperature} = 27.7^\circ\text{C}$$

The temperature rise is well within the operating range of the voltage regulator as well as not too warm for the user, so we can use it for our design.

3 Ethics and Safety

3.1 Ethical Considerations

The biggest concern as it relates to ethics and safety for this project is with regard to the safety of the user and those on the road around the user. Under the IEEE code of ethics, we are required to prioritize the safety of the safety of the public [7]. If the wearable isn't user friendly enough, or restricts any movements, this can lead to potentially catastrophic accidents. We can solve this by integrating the electronics out of the way of the user, such as in the inner pockets of the jacket (for the PCB and battery), and providing ample slack in the wires throughout. This will allow the user to move more naturally. Another concern might be the privacy of the user [7] because we will be collecting and processing data constantly during a ride/commute. We can limit the data collection to IMU data, so that nothing personally identifiable is collected, as well as deleting any data past a certain period of time.

3.2 Safety Considerations

The IEEE Code of Ethics mentions that it is important to “hold paramount the safety, health, and welfare” of the public”. [7] We have to consider the brightness of the LEDs, and if they can be distracting to other drivers and pedestrians. Having bright LEDs can be beneficial for low light or adverse conditions, but can also be harmful if they dazzle other drivers, impairing their vision. There aren't any safety regulatory requirements for LEDs for bicycles relating to the brightness of the lights, so we make sure we are following the vehicle regulations for turn signals. [8] It is also important to note that wearing a battery is always dangerous. Because of this we will be using the guidelines provided by UIUC [9].

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