ECE 445

Final Report:

CSAS

Cyclist Sensing and Awareness System

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Group 11

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Abstract

This final report denotes an identified and addressable problem, our solution to said problem, and our implementation of our project for ECE 445. Within this document, descriptions of the design, features, cost, and functionality are provided as it pertains to our project.

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1. Introduction

1.1 Problem

Cycling accidents occur all over the world. According to the CDC, there are approximately 130,000 cycling related injuries on U.S. roadways alone. [1] Of these injuries, 1,000 of them are fatal. [1] Many of these injuries and deaths occur in locations that house large populations, cities and college campuses for example. From personal experience, members of our group have collectively seen over 20 near collisions between pedestrians and cyclists and one collision between a cyclist and vehicle. Many of these collisions occur when a cyclist is incoming from the rear of a pedestrian. Despite the implementation of infrastructure such as bike lanes, installed specifically for cyclist and pedestrian safety, these collisions continue to persist and the number of injuries continue to be too high.

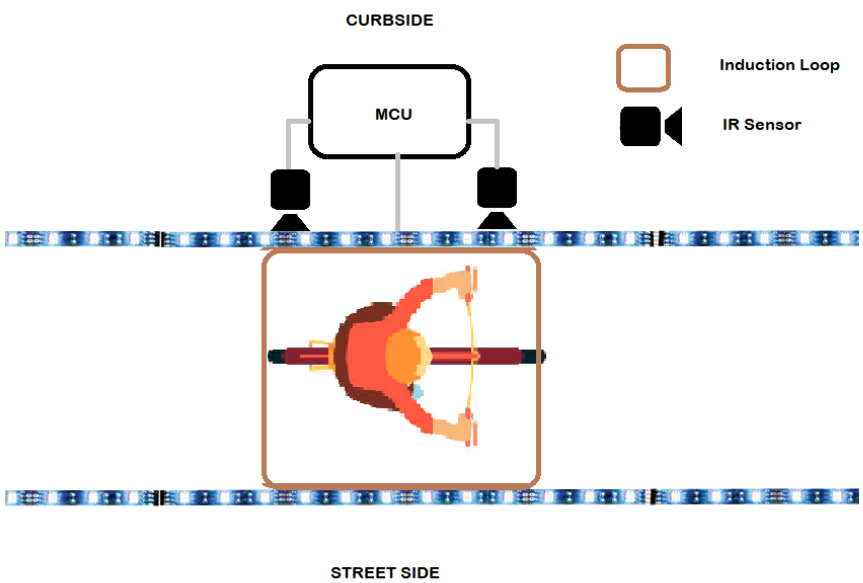
Collisions and near collisions continue to persist despite the best efforts of engineers and city planners. It is for this reason that our group is proposing a new way to combat cycling collisions. We aim to design, build, and present a system that recognizes cyclists then illuminates lights to notify nearby pedestrians and cars that a cyclist is approaching. This will help notify pedestrians and drivers alike of the presence of a cyclist, thereby decreasing the amount of collisions experienced. Our project can also be applied to all major urban centers and campuses to increase overall road safety for cyclists, pedestrians, and drivers.

1.2 Solution

As previously stated, we aim to design, build, and present a system that both recognizes cyclists and notifies pedestrians and drivers of their presence using LED lights. We utilize proximity sensors on each end of our module to detect the presence of a cyclist. In addition to the proximity sensors, we also will utilize an induction loop on the pavement between the sensors to serve as an additional check for a cyclist. Utilizing both the proximity sensors and the induction loop, we aim to minimize misreads of pedestrians, animals, or any forms of noise that may interfere with the sensors. This system will be repeated every five to ten feet. Thus depending on the location of the cyclist, the corresponding lights on the bike lane will light up, signaling pedestrians and drivers that a cyclist is inbound. A very simple visual aid is provided to represent our project in Figure 1 below.

1.3 Visual Aid

In Figure 1, a top-down view on the system is presented. It is important to note that the LEDs will be placed closest to the sidewalk to provide maximum visibility for pedestrians.



(Figure 1: High level Overview of the CSAS)

1.4 High-Level Requirements

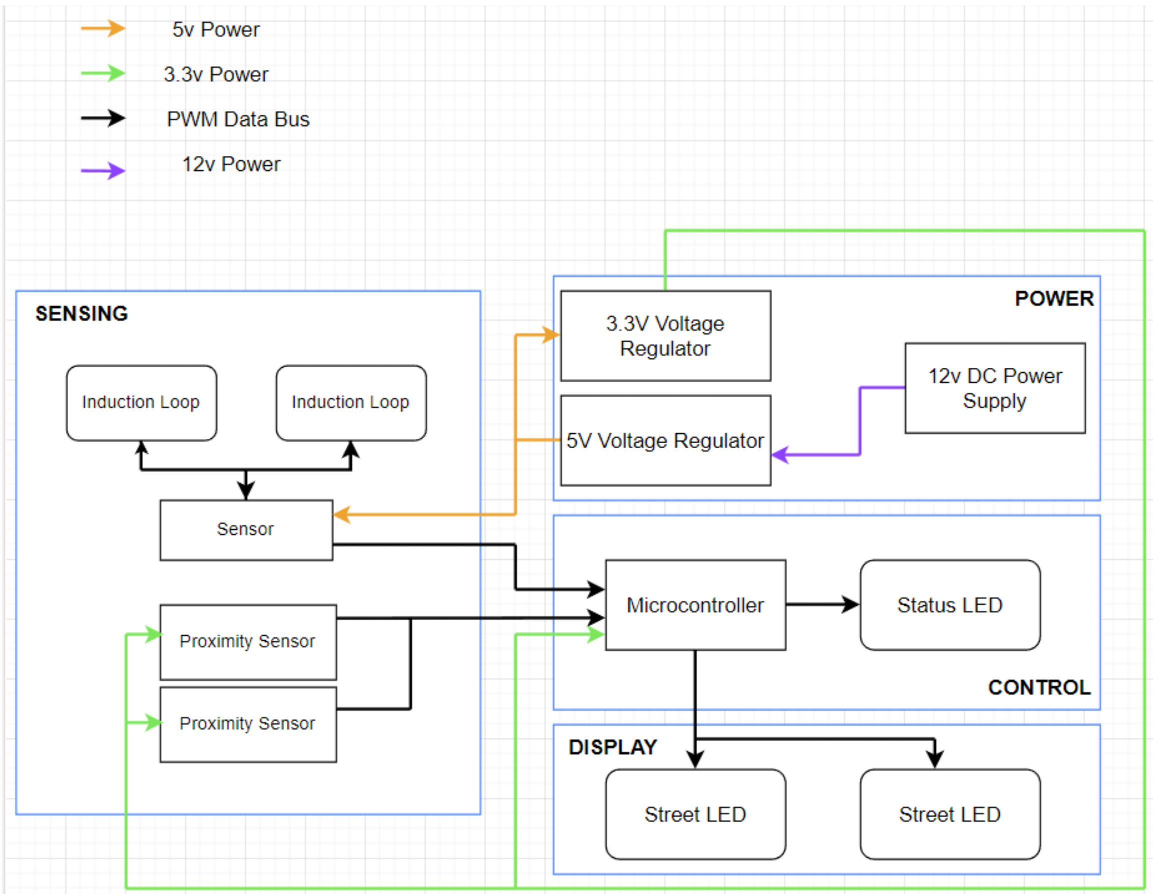
The goals for this project to be considered a success were:

1. The system should be able to output approximately 3000 lumens during the day and 2000 lumens during the night.
2. The system should be able to accurately determine the speed of a cyclist +/- 1 meters per second at any given time.

3. The system should be able to illuminate LEDs to match the motion of a detected cyclist.

2. Design

2.1 Block Diagram

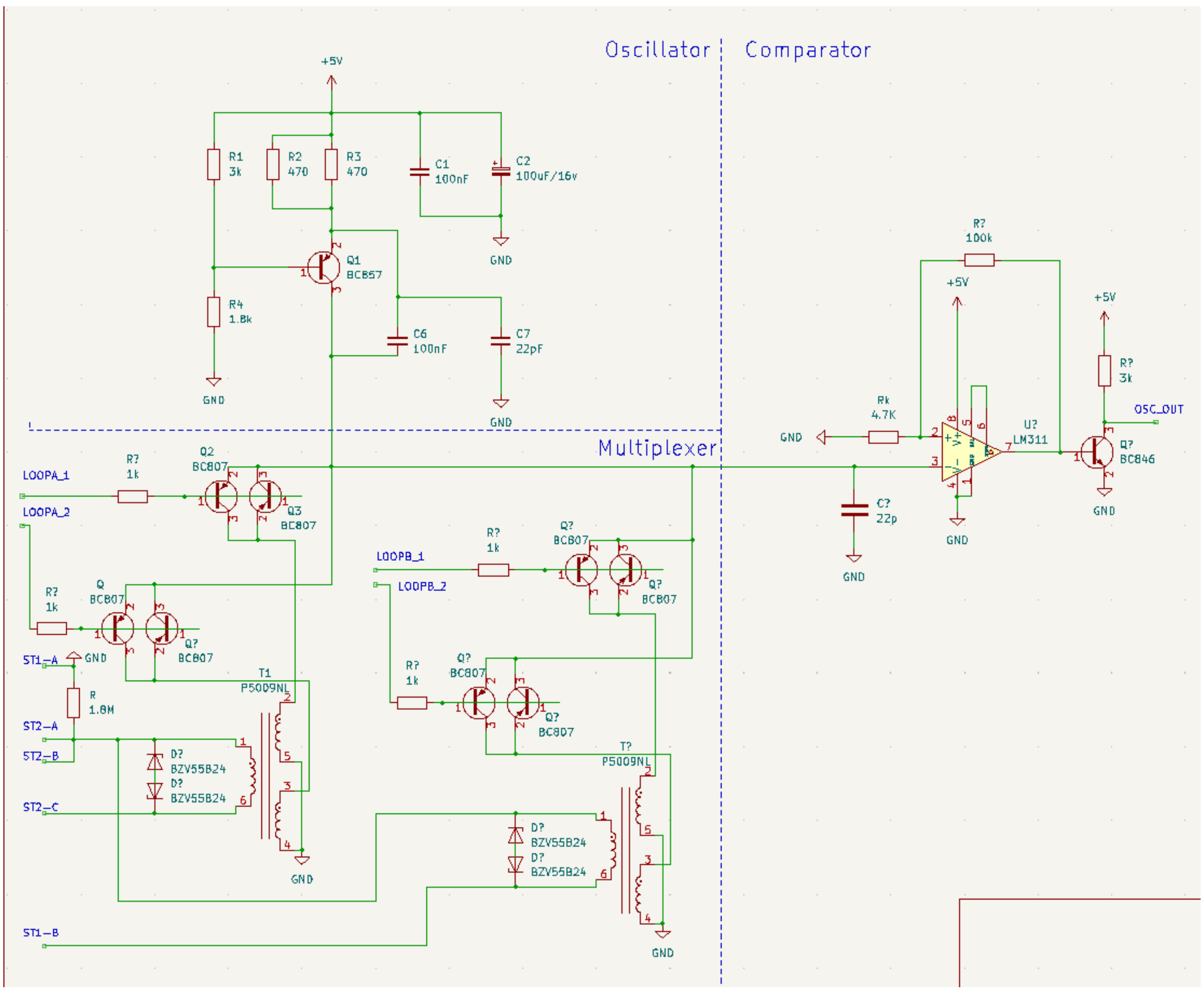


(Figure 2: Block Diagram for our Project)

2.2 Sensing Subsystem

2.2.1 Overview

The Sensing Subsystem manages the sensors that ping when a bicycle is detected. Specifically, it utilizesIR proximity sensors to detect when an object is within range, an induction loop that verifies the detection of a bicycle, and outputs the corresponding data to the MCU to calculate speed and position on said bicycle.



(Figure 3: Schematic for Oscillator, Comparator, and Multiplexer for Induction Sensor)

2.2.2 Interfaces

- Induction Sensor
    - The subsystem receives 5V (+/- .1V).
    - The subsystem generates and monitors a magnetic field.
- Proximity Sensor
    - The system receives 5V.
    - The system outputs varying voltage in the presence of an object.

2.2.3 Requirements

1. The subsystem must be able to supply at least 10mA +/- 5% onto the inductive loop.
2. The subsystem must be able to detect a disruption within its magnetic field within 1 ft. +/- 1in.
3. The subsystem must be able to detect changes in distance when an object enters its field of operation and output it as a voltage value.

Requirements	Verification
The induction subsystem must be able to supply at least 10mA +/- 5% onto the inductive loop.	• Directly measure current by utilizing an ammeter connected to the magnetic wire and ground
The induction subsystem must be able to detect a disruption within its magnetic field within 1 ft +/- 1in.	• Assemble Induction sensor with a complete Microcontroller subsystem. • Apply current to Induction Loop • Place an object with a magnetic field approx. 1 ft above the Induction Loop. • Verify via LED if an object was detected.
The IR subsystem must be able to detect changes in distance within 1 meter when	• Place object in front of IR laser • Verify that microcontroller is able

an object enters its field of operation and output it as a voltage value.	to receive a different voltage value compared to control value

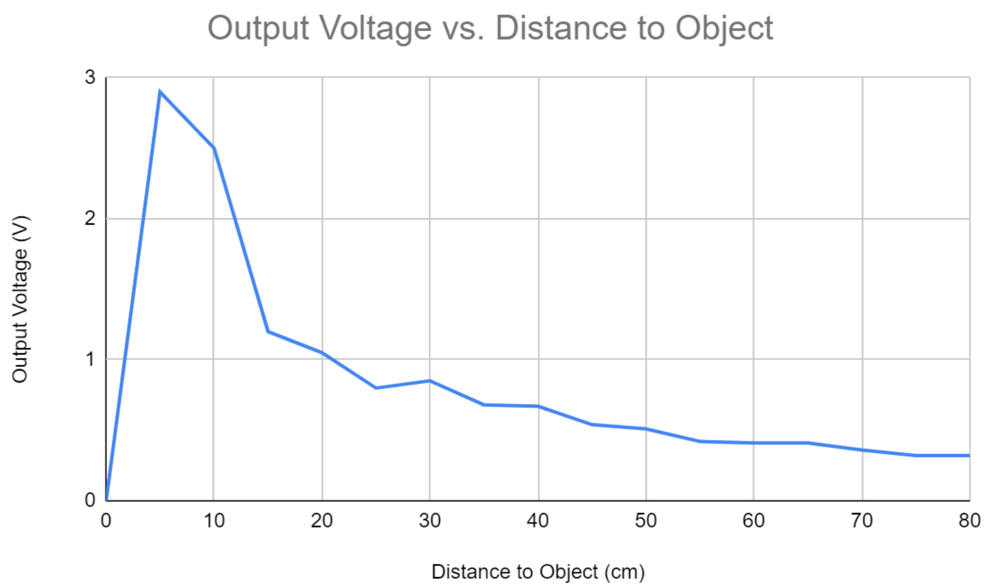
(Table 1: Sensor Subsystem RV Table)

2.2.4 Design Decisions and Changes

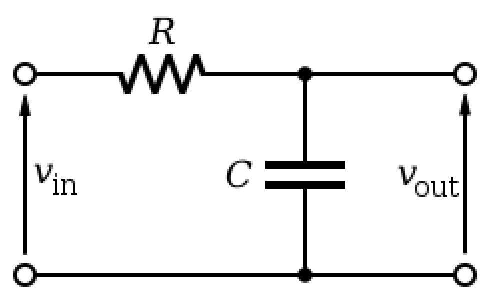
Initially, we utilized NPN transistors to generate the positive and negative edges of the waveform for the induction loop. In testing, we found that the transistors we utilized very often reached saturation, outputting anywhere from 0V to 5V. This caused a number of issues in use. Instead, we utilized a Waveform generator within the lab to generate the waveform for the induction loop.

When utilizing the Waveform generator, we predominantly tested one physical loop which consisted of eight loops and had a surface area of approximately 12.566 in^2. After testing it was found that inputting approximately 150kHz with a measured inductance of 150μH resulted in the most consistent readings of a bicycle. In the presence of a standard bike wheel, we measured anywhere from 50-100 Hz of frequency change in our system.

In regards to the IR sensors, we found that outside of about 4 inches, the voltage output of the sensors when sensing an object steeply dropped. This is represented in Figure 4. In addition to this, we found that both of our IR proximity sensors output around 700-750 mV of noise at any given time. This seemed to be common for the GP2Y0A21YK0F sensors we used. To fix these issues we introduced a simple low pass filter (Figure 5) to the Vout of our IR sensors and encoded out detection to ping very small changes in voltage from the Vout of our IR sensors.



(Figure 4: Output Voltage vs Distance for the IR Sensors)

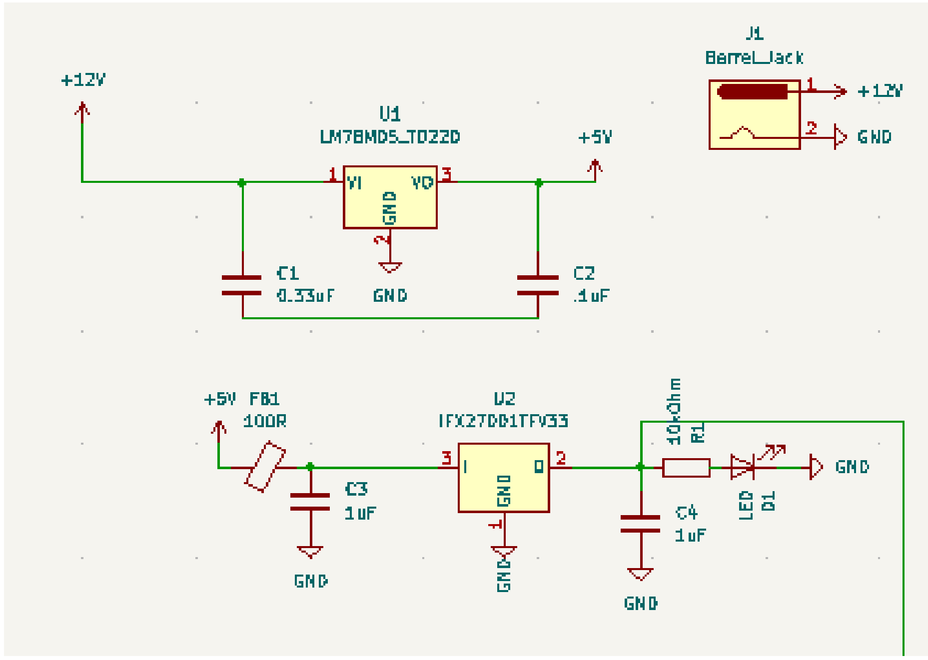


(Figure 5: Low-Pass Filter Schematic)

2.3 Power Subsystem

2.3.1 Overview

The Power Subsystem handles supply and regulation of power for the whole system. Specifically, a 12V DC Power Supply and two linear voltage regulators are utilized to supply 5V and 3.3V to the components. We utilize the LM78 linear voltage regulator chipset as for both our 5V and 3.3V voltage regulators for the system. In Figure 6, we display the schematic for the 12V to 5V voltage regulator, this same schematic will be reflected for the 3.3V regulator with the only difference being that we will step 5V down to 3.3V.



(Figure 6: Voltage Regulator Schematic)

2.3.2 Interfaces

- Voltage Regulator
  - The subsystem takes a 12v input and supplies 5v and 3.3v respectively to the rest of the circuit.

2.3.3 Requirements

1. This subsystem must be able to supply 5v +/- 0.1v and 3.3v +/- 01.v of to their respective components.

Requirements	Verification
This subsystem must be able to supply 5v +/- 0.1v and 3.3v +/- 01.v of to their respective components.	- Assemble complete voltage regulator circuit - Measure Voltage with a voltmeter by connecting one probe to the output of the lm78 chipset and one

	probe directly to ground - Verify for that each voltage regulator outputs the desired voltage

(Table 2: Power Subsystem RV Table)

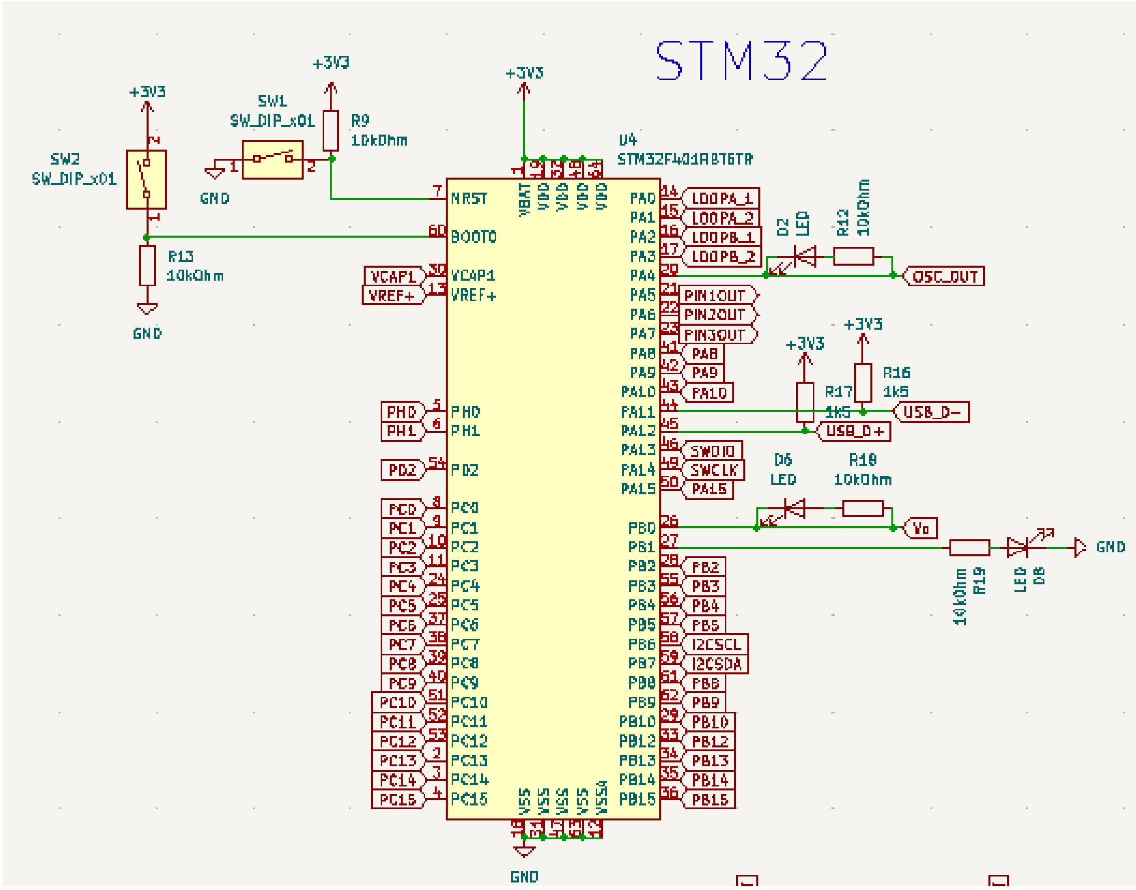
2.3.4 Design Decisions and Changes

We utilized linear voltage regulators over other alternatives such as buck converters as linear voltage regulators generally produce voltages with minimal to no noise at the output more consistently than buck converters. This was very important for our system as we utilized the 5V output from our first voltage regulator as a reference voltage for our Induction Loop sensor. As such, introducing noise to the reference voltage would produce inconsistent behavior from our project as a whole. Linear voltage regulators generally utilize more power than their counterparts. This, however, was not a concern as in testing our voltage regulators never reached temperatures out of spec and in real world implementation, our system would be connected to the grid.

2.4 Control Subsystem

2.4.1 Overview

The control subsystem consists mainly of our MCU, which in this project is the STM32, along with the necessary connectors that will enable our MCU to communicate with the other components of our project. This includes pullup resistors, debugging LEDs, and Reset and Boot switches. This subsystem will communicate with the induction loop sensors, proximity sensors, and the LEDs to calculate the presence of a cyclist. Using the proximity sensors, the control subsystem will also calculate the speed of any given cyclist using the distance and time between “checkpoints”.



(Figure 7: STM32 Schematic)

2.4.2 Interface

- STM32
    - Receives power from power source (wall)
    - Outputs power signal to LED strips
    - Receives voltage signal from induction system
    - Reads proximity sensor data through I2C

2.4.3 Requirements

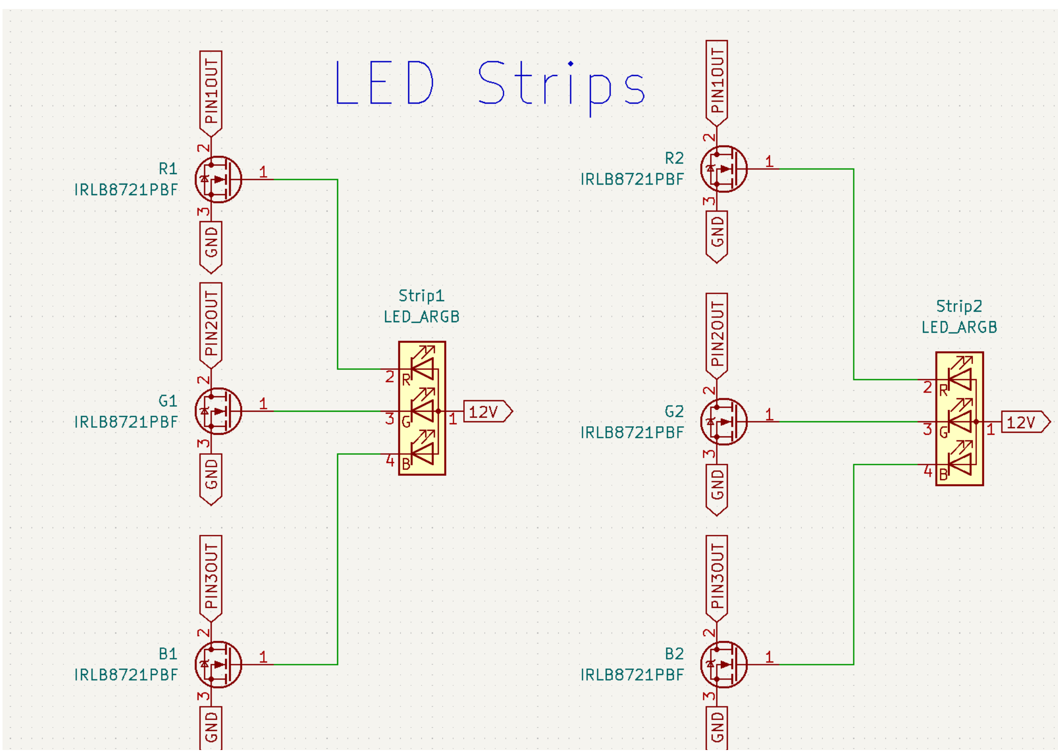
Requirements	Verification
This subsystem must be able to supply 3.3 V power to all subsystems	All other subsystems have power. This will be checked by measuring voltage on a voltmeter for 3.3V.

Must be able to communicate with PWM to other subsystems	Outputs desired PWM waveform on oscilloscope.
Must be able to determine speed of bicycle with information from the sensing subsystems	Calculations matches a speedometer (i.e phone etc.)

2.5 Display Subsystem

2.5.1 Overview

The display subsystem is responsible for the visual aspect of our project. It will be how the pedestrians on the street receive the appropriate information about incoming cyclists. It consists of two LED strips, with 3 MOSFET transistors each, all of whom are connected to three outputs from the control subsystem.



(Figure 8: LED Schematic)

2.5.2 Interfaces

- LEDs
    - Must be able to receive 5V to Vin.
    - Must be able to receive RGB input values
- Transistors
    - Must be able to receive RGB PWM data from the microcontroller.
    - Must send that data to LED strips.

2.5.3 Requirements

- The LED strip lighting must be able to be controlled. Ex. turned on/off by the microcontroller

Requirements	Verification
- Sections of varying distance of the LED strips must be able to be turned on/off.	Manually program sections and distances through code in the STM32 board

2.4.4 Design Decisions and Changes

Our final product utilizes non-addressable RGB LED strips. We utilize MOFSETs to program the RGB data onto the LED Strip. We did some tests with a WS2812b addressable RGB LED light strip, however found the performance to not match our intention. Mainly, the LEDs would only light approximately 50% of the desired time. In addition to this, we could not light the entire LED strip to the max luminosity of 3000 lumens all at once. We determined that this was due to lack of current supplied to the strip, especially in regards to LEDs further down the strip. Because of these issues, we reverted back to our original non-addressable LED strips.

2.6 Tolerance Analysis

The sensitivity for our Induction Sensor will be tested between 10kHz and 200kHz. Additionally we will test multiple orientations for our magnetic loop. The majority of the documentation regarding induction loops are based on detecting vehicles. Vehicles induce larger magnetic fields onto the induction loop than bicycles, because of this a wide range of testing is required to test with both the frequency and loops in the sensor. As shown in Figure 5, the inductance generated can greatly increase based on the frequency generated based on the amount of loops utilized. [2] This can be calculated using Equation 1:

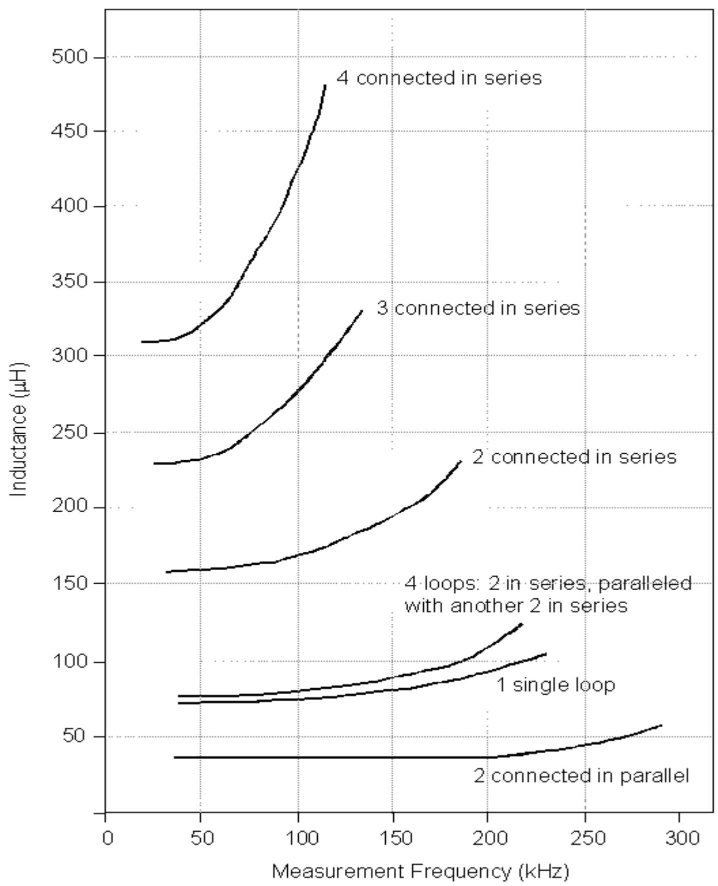
$$L = \frac{N\mu_r \mu_0 HA}{I} = \frac{\mu_r \mu_0 N^2 A}{\ell} \tag{1}$$

Where μ_r is the relative permeability of material, μ_0 is the permeability constant of the vacuum in the magnetic field, N is the number of loops, l is the length of the magnetic field. wire, and A is the area of the loop.

Using this, we can calculate the sensitivity of the induction loop using Equation 2:

$$S_L = 100 \times \frac{L_{NV} - L_V}{L_{NV}} = 100 \times \frac{\Delta L}{L} \tag{2}$$

Where delta L is the change in inductance when a vehicle is present in the system and L is the inductance without a vehicle introduced into the system. Using Figure 5, and assuming a one loop system at approximately 225 kHz, we expect to see approximately 100μH of inductance in the system. Small motorcycles generally equate to approximately .13 percent sensitivity using a similar system [2] at roughly the same inductance. Using this we expect to measure .10 +/- .02 percent sensitivity rating from a bicycle. As such the expected inductance change is approximately 10 μH.



(Figure 8: Loop Inductance vs Measuring Frequencies based on Inductive Loops)

3. Cost and Schedule

3.1 Cost Analysis

3.1.1 Part and Materials

Quantity	Unit Price	Part Number	Description
1	0.67	LM311	Differential Comparator
1	0.71	L78M05CDT-TR	5v Linear Voltage Regulator
1	10.99	ABLEGRID 12 V PSU	12 V AC Power Adaptor
1	0.16	BC846BLT3G	NPN BJT Transistor
1	1.05	Screw Terminal	2-pin Screw Terminal
1	1.05	Screw Terminal	3-pin Screw Terminal
2	3.84	P5009NL	Pulse Transformer
4	0.33	BZX884B24L-G3-08	Zenner Diodes
4	0.21	BC807-16LT3G	PNP BJT Transistor
4	0.29	ESK107M016AE3KA	Polarized Capacitor
1	0.9	BU33JA2DG-CTR	3v Linear Voltage Regulator
1	6.59	STM32F401RBT6TR	STM32 MCU
6	1	IRLB8721PbF	MOSFET Transistor
2	15	GP2Y0A21YK0F	IR sensor
2	35	https://www.amazon.com/HitLights-Warm-White-Light-Strip/dp/B01LBDM2XM	LED strip

3.1.2 Estimated Hours to Develop

Category	Estimated Hours	
	Hann	Jeremy
Circuit Design	15	15
Board Layout and Component Check	10	10
Soldering	15	15
Induction Sensor Development	10	30
Proximity Sensor Development	30	10
Integration	30	30
Prototype and Debub	40	40
Documentation and Logistic	20	20
Total Hours	170	170

Both members of our group are Electrical Engineering students. According to the Grainger College of Engineering website, the average starting salary for an Electrical Engineering graduate from the University of Illinois is $80,296 per year. [3] This equates to approximately $38.60 per hour.

$38.60(Hourly Rate) *340 (Total Estimated Hours) = $13,124

Total Cost: $13,124 + $204.12 = $13328.10

3.2 Schedule

Week of 2/20

Design Document, Schematic Feedback, Design PCB

Week of 2/27

Finalize PCB Design, Order PCB, Order PCB parts

Week of 3/6

Induction Sensor Development, Proximity Sensor Development

Week of 3/13

Spring Break

Week 3/20

Induction Sensor Development, Proximity Sensor Development

Week 3/27

Induction Sensor Development, Proximity Sensor Development

Week 4/3

Integration, Testing and Debug

Week 4/10

Integration, Testing and Debug

Week 4/17

Mock Demo, review, prepare for presentation and paper

Week 4/24

Final Demo, debug, review, prepare for presentation and paper

Week 5/1

Final Presentation, Final Paper

4. Ethics and Safety

4.1 Ethics

CSAS operates accordingly based on the IEEE Code of Ethics established by the IEEE Board of Directors. Our project aims to help prevent the injury of cyclists and pedestrians while trying to minimize the impact on their daily lives. We aim to accomplish our project with the highest quality and standards possible through continuous teamwork and mentorship, accountability for our team at every step, and respect and kindness for our teammates and end users. [4]

Our team's skill set is diverse and varying. Despite this, there are holes in our experiences. Constant peer to peer and peer to mentor (through course staff and TAs) is vital and essential for our group to succeed and maintain a high standard for our project. We accomplish this by following the schedule we set as a group and fully utilizing our weekly meetings with the course staff.

In order for our project to be successful, accountability for all of our members at all times is necessary. As stated before, following our schedule is the standard our group aims to meet. Continuous checks over work being done and tasks accomplished maintains the standard we set for our project.

Respect and kindness for our peers is also vital for a functioning project. Being respectful of our team member's time and efforts will keep morale high and keep the group as a whole on task to get our jobs done. Doing this through the utilization of Discord, Google Apps, and constant and clear communication has worked and will continue to be the standard for our team. Additionally, being wary and respectful of the intended end users is essential to remain within the IEEE Code of Ethics. Catering changes based on end user safety will always take precedence over easier options. CSAS directly influences the safety of cyclists, pedestrians, and drivers, and as such, we aim to produce the best possible product we can.

4.2 Safety

In this section we explore the safety hazards relevant to the end users of the CSAS. Because the real world implementation of our system is subject to outdoor conditions year round, operation and reliability may be hindered. As such, end users may experience misreads or lack of reads from the circuit, resulting in potential collisions between pedestrians and cyclists due to a lack of bicycle recognition. For example, in the presence of precipitation such as snow, the proximity sensors. The solution for this comes down to proactive city services clearing the roads. Our current iteration cannot proactively address issues pertaining to precipitation or foliage. Just as when driving a car, cyclist consideration is necessary for our system in the event of poor weather conditions.

In addition to this, for higher end bicycles that are made of materials such as fiberglass and carbon fiber won't necessarily be detected by our system. As such, reliance on our system for these riders poses a safety threat. This is a design flaw that, at this time, we are choosing to overlook. This is to focus development on a system that applies to masses, hoping to narrow in on more niche cases in further iterations of our system.

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